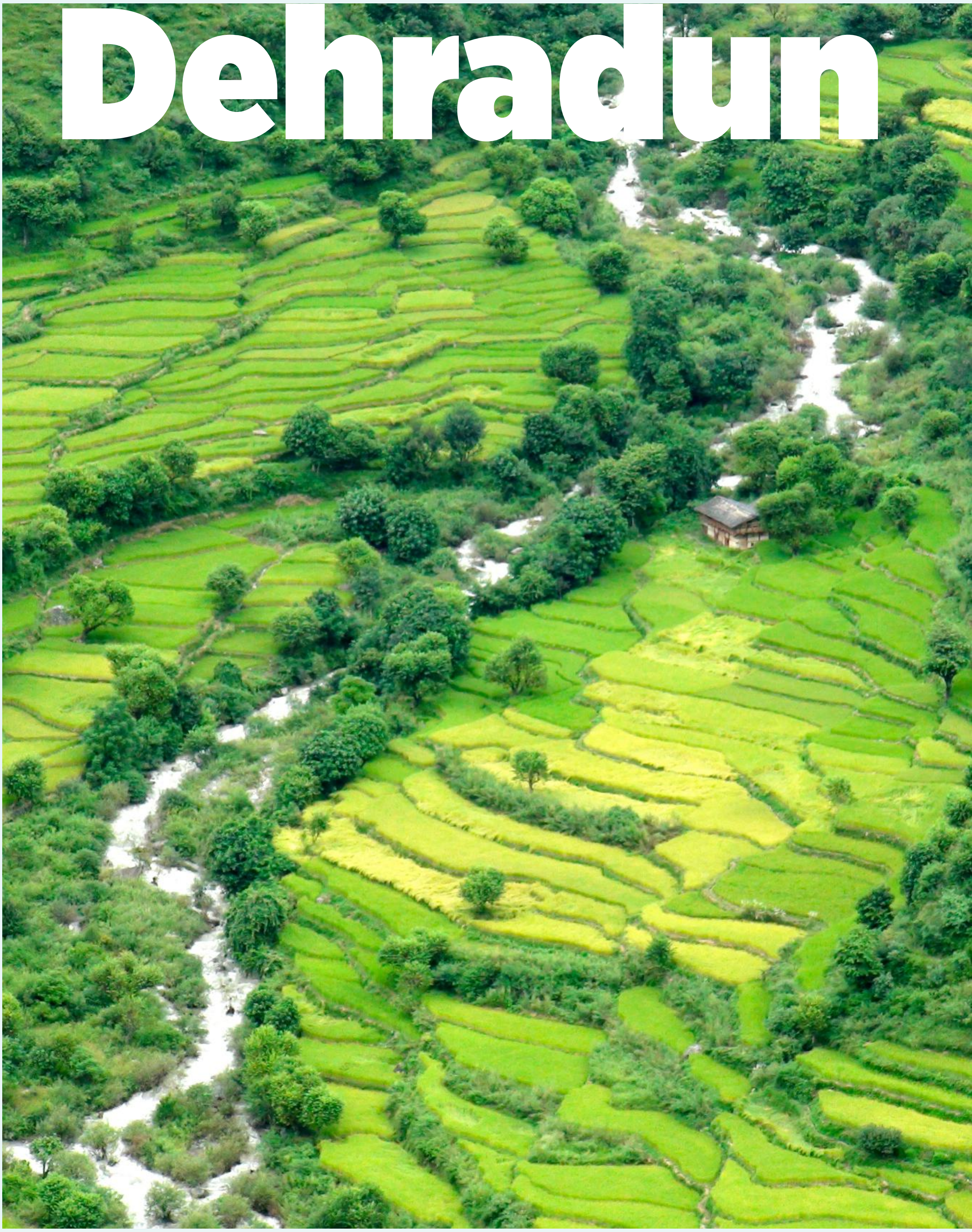
WATER-ENERGY NEXUS

Dehradun



Development Alternatives

HEINRICH BÖLL STIFTUNG
INDIA

The **Water Energy Nexus in Dehradun** Report jointly published by the Heinrich Böll Stiftung Germany and Development Alternatives New Delhi, December 2020

About Heinrich Böll Stiftung

HEINRICH BÖLL STIFTUNG
INDIA

The Heinrich Böll Stiftung is a German foundation and part of the Green movement that has developed worldwide as a response to the traditional politics of socialism, liberalism, and conservatism. We are a green think-tank and an international policy network, our main tenets are ecology and sustainability, democracy and human rights, self-determination and justice. We place particular emphasis on gender democracy, meaning social emancipation and equal rights for women and men. We are also committed to equal rights for cultural and ethnic minorities. Finally, we promote non-violence and proactive peace policies. To achieve our goals, we seek strategic partnerships with others who share our values.

Our eponymous, Heinrich Böll, personifies the values we stand for: protection of freedom, civic courage, tolerance, open debate, and the valuation of art and culture as independent spheres of thought and action.

Our India Liaison Office was established in 2002 in New Delhi.
For more information visit: www.in.boell.org

Heinrich Böll Stiftung/Foundation, India Office
C-20, 1st floor, Qutub Institutional Area, New Delhi 110016, India

About Development Alternatives

Development Alternatives

Development Alternatives (DA) is a premier social enterprise with a global presence in the fields of green economic development, social empowerment and environmental management. It is one of the leading Think Tanks in the field of Sustainable Development. DA is credited with numerous innovations in clean technology and delivery systems that help create sustainable livelihoods in the developing world. DA focuses on empowering communities through strengthening people's institutions and facilitating their access to basic needs. It enables economic opportunities through skill development for green jobs and enterprise creation and promotes greener pathways for development through natural resource management models and clean technology solutions. DA delivers environment friendly and economically viable eco-solutions to communities, entrepreneurs, government and corporate agencies through measures that foster the creation of sustainable livelihoods in large numbers.

Development Alternatives drives strategic change through Innovation of eco-solutions, Incubation of enterprise based business approaches, demonstration and capacity building for Implementation of solutions at scale and the Influence of policies for sustainable development.

This publication is not for sale.
"Water Energy Nexus in Dehradun"

Authors:

Core Team:
Medha, Fellow
Aishwarya Varadharajan, Deputy Manager
Siddharth Deputy Manager

Advisory Panel:
Zeenat Niazi, Vice President
Gitika Goswami, Senior Programme Director

Designed by: Pritam Poddar

Cover Photo by: Dr Lokesh Ohri

Funded by: Heinrich Böll Stiftung

ACKNOWLEDGEMENTS

PROJECT FUNDER

HEINRICH BÖLL STIFTUNG

EXPERT CONTRIBUTORS

Our special thanks go to the many experts from academia, government, non- profits, and research organisations who provided invaluable perspectives and expertise throughout the project.

Uttarakhand Pey Jal Nigam

V C Purohit, Chief Engineer
Y K Mishra, Chief Engineer Gharwal
Narendra Bisht, Chief General Manager, Construction Wing
S C Pant, Superintendent Engineer
L M Karnatak, Superintendent Engineer
G P Singh, AMRUT Nodal Officer (Drainage a& Sewerage), Central Store Division
Meenakshi Mittal, Assistant Engineer, (Doon Division –Dehradun)
Jaspreet Singh, Executive Engineer, Mechanical Division
Namita Tripathi, Executive Engineer

Uttarakhand Jal Sansthan

S K Sharma, Chief General Manager
Neelima Garg, General Manager
L K Adlakha, Officer Special Duty
Subodh Kumar, Superintendent Engineer
Manish Semwal, Executive Engineer–Water works (South division)
Yashbir Mall, Executive Engineer–Water works (North division)

Dehradun Nagar Nigam

Rachna Payal, Executive Engineer
Ashish Kathait, Nodal Officer- AMRUT
Dinesh Khanna

Uttarakhand Environmental Protection & Pollution Control Board

S P Subudhi, Member Secretary

Department of Irrigation, Uttarakhand

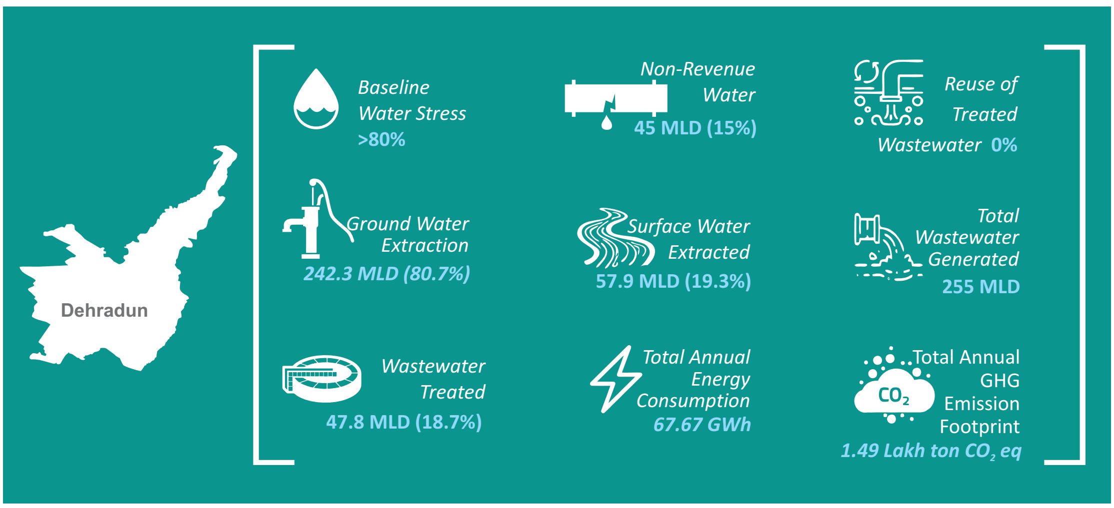
Subhash Chandra Pandey, Superintendent Engineer

Dehradun Institute of Technology

EXECUTIVE SUMMARY

Water is a necessary element for maintenance of life on earth and it is also indispensable for the economy. The rivers, lakes and groundwater are the main sources of freshwater for the purpose of irrigation in agriculture and drinking and sanitation in the cities. The water sector is one of the most energy-intensive sectors. The water system efficiencies can be understood from the energy use in water systems in conjunction with the management of extraction, treatment, storage and consumption across the flows of the resource. This problem calls for an integrated approach such as the study of water-energy nexus to provide effective strategies to address the gaps in the urban water systems. Water-energy nexus approach highlights the interdependencies between water resource and energy security for economic development and well-being of humans simultaneously ensuring sustainability of global natural resources without harming the natural ecosystem.

This study focuses on finding the energy consumption and associated environmental footprint of the urban water system of the city of Dehradun. Mapping the flow of water, calculation of power consumption across each stage of the urban water system starting from water extraction to final disposal and calculation of carbon emission at each stage is the approach adopted in this study. The study conducted in 2019 finds that the city extracted approximately 80% (242MLD) of its total supplied water from the ground making water extraction highly energy intensive. The exact data of per capita consumption is not known due to non-availability of metered data because households do not have water meters. Only 47.8 MLD (18.74% of total 255 MLD sewage generated) post consumption wastewater is treated, and rest of the wastewater is directly disposed-off into drains. The total annual energy consumption of the total water supply system based on data collected in 2019 is 67.67 GWh and total GHG emission of total water supply system including all four zones is 1.49 lakh tonnes CO_2 eq which is 14.1 x 10-4 kg CO_2-eq per litre of water. It is found that city needs to increase energy efficiency by revamping the infrastructure of the urban water system which will reduce total energy consumption and in turn will reduce carbon footprint. Further, reduction in non-revenue water is required which can be done by mending leakages in the system, arresting unauthorized connections and smart metering of water connections. Wide spread of sewerage network along with functional STPs for increasing the treatment of wastewater will ensure tapping huge potential for reuse of treated wastewater. This will also reduce load on drains and the emissions released by untreated water. Diversifying to water sources other than groundwater and building a resilient system will be a long term solution. Such comprehensive analysis of the system provides scientific basis to city managers in making balanced decisions. The study also delved into understanding the experiences, aspirations, and consumption behaviours of citizens of the city of Dehradun through a household survey conducted in five wards under smart city area. The findings of the survey revealed that there is a need for increase in awareness among people about the water stress Indian cities are facing, importance of metering the water consumption, reuse of treated wastewater and valuing the water. It was also found that there is inequality in distribution among various wards and zones. With increased awareness among the local communities and institutions about micro-level measures for water conservation, reuse and rainwater harvesting, and collaborative participation of all stakeholders in the city, the water resource- efficiency, conservation, distribution equity and long term sustainability of the ecosystem can be achieved.



contents

LIST OF ACRONYMS

AMRUT	Atal Mission for Rejuvenation and Urban Transformation
BPL	Below Poverty Line
BWS	Baseline Water Stress
DoDW	Department of Drinking Water
GHG	Green House Gases
GWh	Giga Watt per hour
HH	Household
kWh	Kilo Watt per hour
LPCD	Litres per Capita Day
MDDA	Mussoorie Dehradun Development Authority
MLD	Million litres per Day
NBA	Nirmal Bharat Abhiyan
NRDWP	National Rural Drinking Water Programme
NRW	Non-Revenue Water
PMU	Project Management Unit
STP	Sewerage Treatment Plant
UJN	Uttarakhand Peyjal Nigam
UJS	Uttarakhand Jal Sansthan
URWSSP	Uttarakhand Rural Water Supply & Sanitation Project
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant
APL	Above Poverty Line
BPL	Below Poverty Line
AAY	Antyodaya Anna Yojana

LIST OF FIGURES

LIST OF TABLES

LIST OF PICTURE

LIST OF GRAPHS

LIST OF ANNEXURE

INTRODUCTION AND BACKGROUND

Water and energy in the urban environments are managed in isolation; in India the respective ministries work in silos too. This creates hindrance for effective management of the urban water systems and such problems call for comprehensive solutions, such as an integrated system. Hence, there is a need to analyse the urban water-energy nexus and provide effective strategies to address the gaps in the systems. Water-energy nexus is typically characterised in resource use efficiency terms such as energy intensity and the environmental impacts in terms of energy consumption of water systems within the urban water cycles. Understanding the nexus of energy and water will help in achieving reduction in energy consumption and greenhouse gas emissions by adopting efficient systems.

Energy is currently derived from non-renewable resources and the percentage of renewable in total energy is projected to grow significantly. Water sector is one of the most energy intensive sectors. Energy consumption in water sector depends upon factors such as topography, climate, seasonal temperature, average rainfall, demand of water and the technologies used (Wakeel Rana, Chen, Hayat, & Ahmad, 2016). Energy is consumed for extraction of water, treatment, distribution, wastewater collection treatment and reuse. Groundwater is more energy intensive as compared to surface water. At times 40% of total energy of certain countries is used up for pumping groundwater. Pumping from greater depths increases the energy demand of the water sector (Hoff, 2011).

In Indian cities, on aggregate basis major portion of energy is consumed for water supply than for wastewater treatment because the quantity of water supplied is far more than the wastewater treated in the WWTPs or STPs. In Dehradun, the total energy consumption for water supply is almost 16 times of that consumed for wastewater treatment. The electricity related emissions from the municipal water supply and wastewater infrastructures as a percentage of the electricity related emissions of total community wide use in residential, commercial, industrial, transportation and waste etc, is just 6% for most of the Indian cities (Miller, Ramaswami, & Ranjan, 2013).

The study conducted in 2019 finds that in 2018 Dehradun extracted 80% (242MLD) of its total supplied water from the ground, making water extraction highly energy intensive. The rest 20% of water is sourced from surface water which flows majorly through gravity. Only surface water undergoes primary treatment hence the energy intensity of treatment is low. The extracted water is conveyed to the storage tanks, and from here water flows through gravity due to the natural gradient of the city. Although, in some areas the water needs boosting, however, due to lower volumes, the total energy consumed for distribution is low in comparison to energy consumed in ground and surface water extraction and treatment. After consumption major portion of the wastewater is directly disposed off into drains. Only 47.8 MLD (18.74% of total 255 MLD sewage generated) post consumption wastewater is treated, and rest of the wastewater is directly disposed-off into drains. As per the data of 2018 collected in 2019, total GHG emission of total water supply system including all four zones is 1.49 lakh tonnes CO_2 eq which is 14.1 x 10-4 kg CO_2 eq per litre of water. The electricity consumption for water production and wastewater treatment and that for final disposal accounts for 71.12% and 28.88% of the total GHG emissions, respectively.

During this study, an attempt has been made to map the energy and GHG footprint of the water supply system along the life cycle of water. The primary and secondary data collected from the public sector sources[1] and simulations are run for the model on the material flow analysis tool. During this study a household survey was also conducted among wards under Dehradun Smart City area, to get primary information from the citizens of the city about the quantity and quality of water supply they get, the duration of supply, and their monthly energy and water consumption.

This water energy nexus study is an approach to look at the water supply system in a holistic way, wherein, environmental implications and social equity aspects of the whole system can be understood better and possible areas of intervention for increasing efficiency and circularity in the most cost-effective and socially relevant ways can be explored. This approach needs to be implemented by both supply and demand side of the value chain, to achieve long term self-sustaining relation between the natural ecosystem and anthropological activities for development.

[1]Data of 2018 was collected from Jal Sansthan and Pey Jal Nigam of Dehradun in 2019

The study also delved into understanding the experiences, aspirations, consumption behaviours of citizens of the city of Dehradun through a household survey conducted in five wards under smart city area. The findings of the survey revealed that there is need of awareness among people about the water stress Indian cities are facing, importance of metering the water consumption, reuse of treated wastewater and valuing the water. With increased awareness among the local communities and institutions about need for metering their connections, micro-level measures for water conservation, re-use and rainwater harvesting; and collaborative participation of all stakeholders in the city, the water resource- efficiency, conservation, distribution equity and long term sustainability of the ecosystem can be achieved.

STUDY OBJECTIVES

This study builds upon a volumetric analysis of water flows across the whole urban water supply system of Dehradun, that was conducted in 2018 to understand total flows, leakages and unaccounted for water, access of water to all citizens of the city, wastewater and sewage network, sewage treatment infrastructure and functional capacity, and the status of post-consumer water. Through this study it was found that there is tremendous scope of revamping the supply and treatment infrastructure and this led to the idea of analysing the energy consumption and associated GHG emissions of the system and the untreated wastewater. So, in the current phase the study focused on analyzing and identifying the opportunities of enhancing the system efficiencies. From the consumer end, since the public agencies had inadequate primary data at household level, so it was thought to conduct a household survey in selected wards under Smart City area.

The objectives of the study are:

1. To assess the energy consumed by the urban water system starting from the raw water extraction till the final wastewater disposal.
2. To assess the environmental impact of the urban water systems by estimating the GHG emissions.
3. To assess the water distribution and energy and water consumption at household level.

STUDY AREA

The city of Dehradun is the capital of the state of Uttarakhand in India. It lies in the Terai region of the Himalaya, situated on the flatland called the Dun. Dehradun was chosen as one of the study areas because the city has high baseline water stress of greater than 80% (WRI, India water Tool, 2018) and a high reported NRW according to the Smart City proposal. There are 100 wards in the city which are considered for this study. The city has been divided into 4 water supply zones- namely North, South, Raipur and Pithuwala. The operation and maintenance of these water supply zones is done by the Jal Sansthan. The map 1 shows surface and groundwater fed zones in Dehradun.

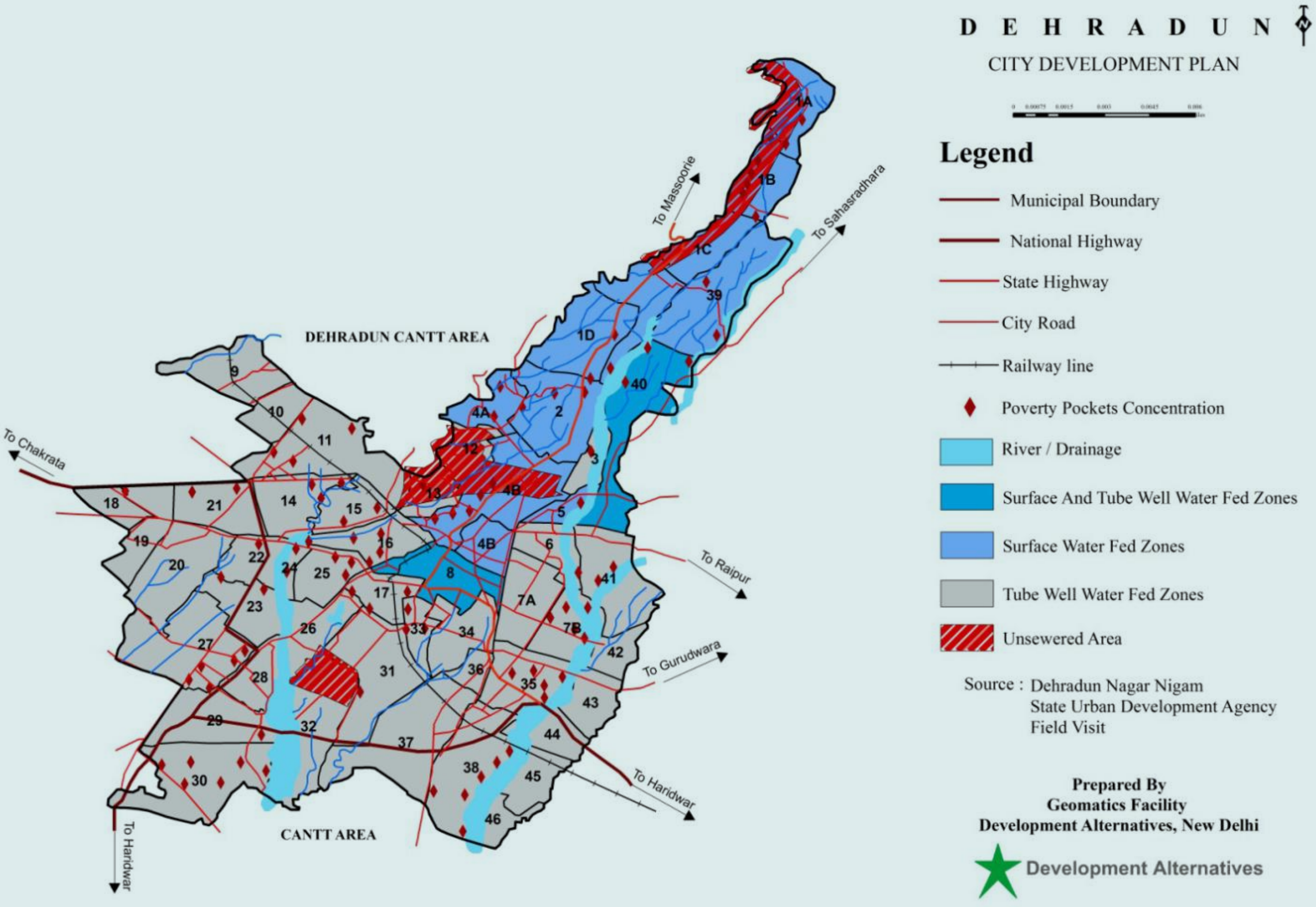


Figure 1: Map of Surface and Groundwater fed zones in Dehradun

Source: MDDA

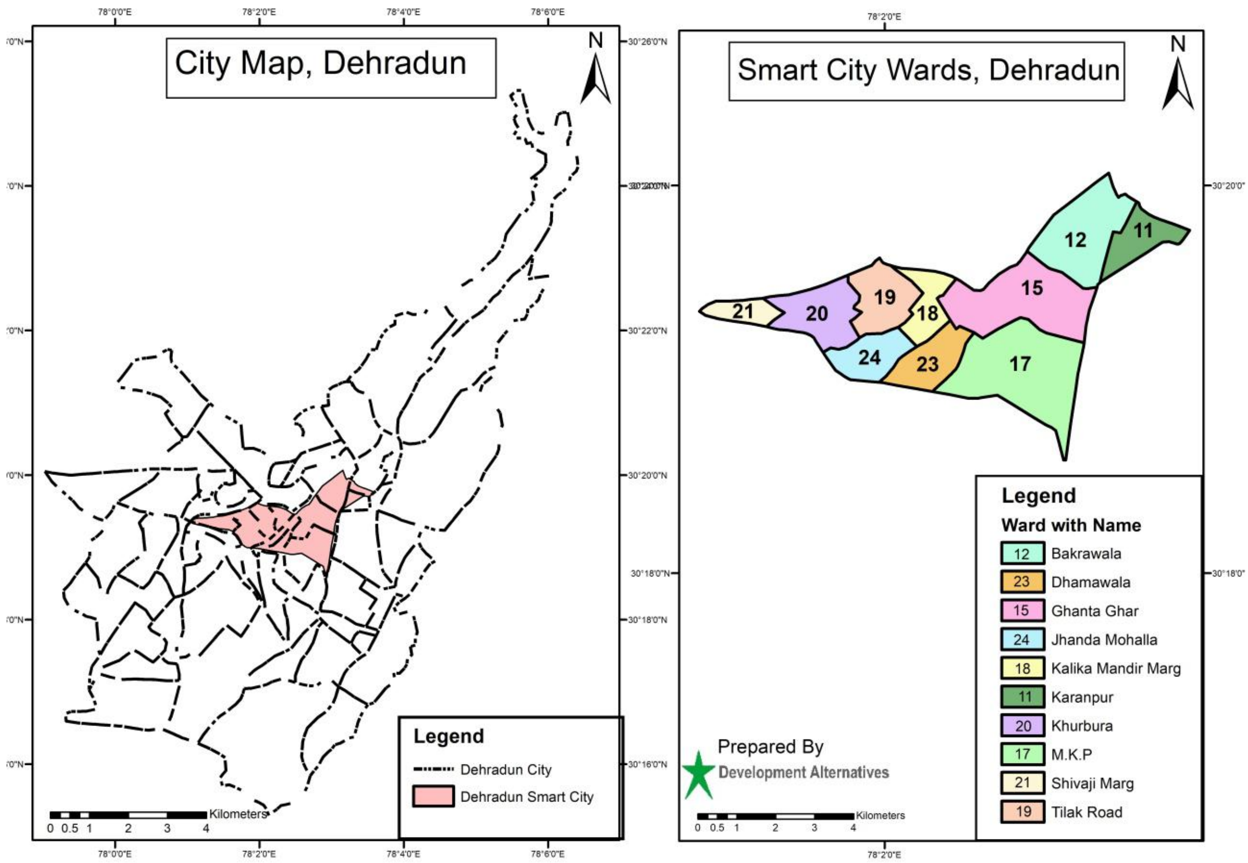


Figure 2: Map of Wards in Dehradun

ANALYSIS FRAME

During the study conducted in 2018 for mapping urban water flow in Dehradun, it was found that the city lacks the real time data on non-revenue water and how much water is consumed by households, the base line water stress was more than 80%, the non-revenue water was 48% due to leakages and unaccounted for water consumption, and inadequate sewer connections and treatment of sewage. So, for an effective sustainable urban water system, the natural and anthropological parts of the urban water system have been analyzed from the lens of resource sufficiency, efficiency & equity, and operational performance of the infrastructure.

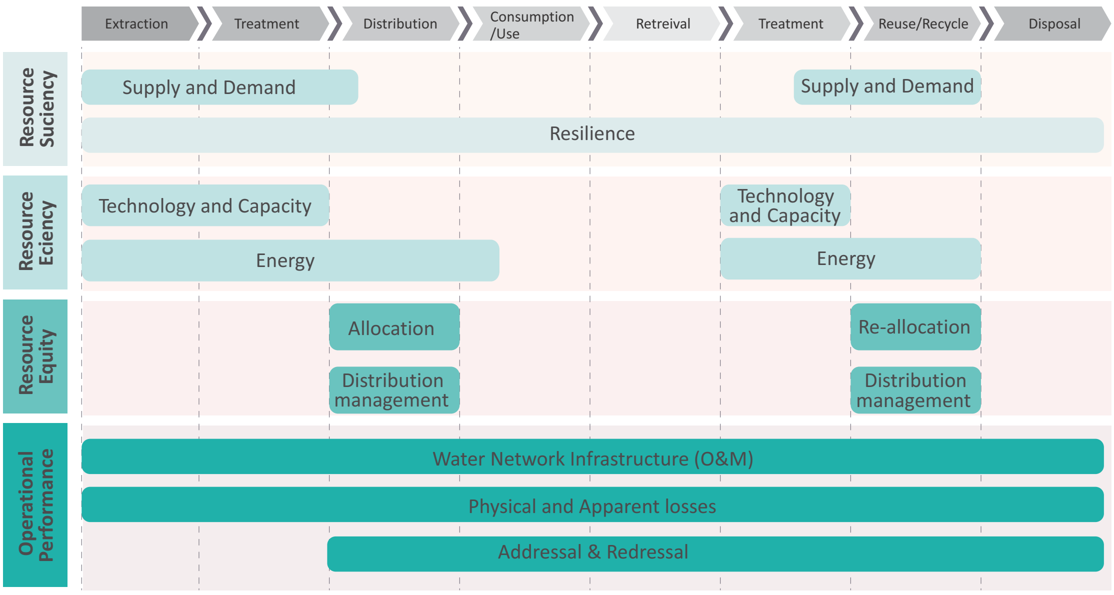


Figure 3: Analysis Frame

The four lenses through which the water flows in the Dehradun city is analysed are:

Resource Sufficiency: This refers to the ability of ensuring continuity in consumption without constraints on the supply. The main drivers of increased self-sufficiency are identified as shortage of available water, constrained infrastructure, high quality water demands and commercial and institutional pressures. Research studies have demonstrated that increase in self-sufficiency ratios can be achieved up to 80% with contributions from recycled water, sea water desalination and rainwater collection.

Resource Efficiency: Resource efficiency is defined as the ratio of outputs (in terms of economic, social & environmental benefits) and resource inputs. It is an innovative approach to resource consumption by reducing the total environmental impact of the production and consumption from raw material extraction to final use and disposal. It plays a pivotal role in introducing sustainable production and consumption patterns to residents of the city as well as municipal governments on the opportunity to improve resource efficiency, decrease CO_2 emissions, reduce environmental risks and safeguard ecosystems. In this report we explore the energy use and the environmental impacts of the urban water systems in the city of Dehradun.

Resource Equity: This refers to ensuring equitable access to water and the benefits from water use, to women and men, rich and poor, across diverse social and economic groups which involves issues of entitlement, access, and control.

Operational performance: This refers to the performance of the urban water system which is measured against standard or prescribed indicators of effectiveness, efficiency, and environmental responsibility such as cycle time, productivity, waste reduction and regulatory compliance.

METHODOLOGY

1. ESTIMATION OF ENERGY CONSUMPTION OF URBAN WATER SYSTEM

The study of water-energy nexus is accomplished through data available from public records and confirmed through interviews and discussions with concerned municipal officials. A primary study in one area of Dehradun was used to fill in some key gaps and validate secondary information. Initially a literature search was conducted to develop an understanding on water-energy nexus and energy use in the urban water systems in different countries. This study derives the framework of analysis from the reviewed studies, which helped in identifying the data points required to be collected from the officials of government water departments and agencies. The data was collected by stakeholder interviews with officials of Jal Sansthan and Peyjal Nigam responsible for the operation and maintenance of the urban water systems and construction of urban water schemes, respectively. The details of the pump (pump-wise rated capacity (HP), hours of pumping, MLD water for pumped) installed for water extraction and distribution in four zones North, South, Raipur and Pithuwala and the data of energy consumption by water treatment plants was collected from energy bills of the plant from executive engineer and assistant of Jal Sansthan and Peyjal Nigam. Details of the installed capacity and energy consumption of the sewerage treatment plant at Kargi were collected from Jal Sansthan-South Zone and for other plants from Peyjal Nigam.

The pump-wise total energy consumption for water extraction is calculated as the power (kW) times the number of hours a pump is run in a day and accounted for the 70% efficiency based on information given by the officials. This gives daily pump-wise energy consumption and annual energy consumption is calculated using the daily data. The data of discharge per minute is collected from the four zones of Jal Sansthan and is used to calculate the annual discharge based on the number of hours and days pump is running. 30% of extracted groundwater is conveyed for direct pumping, while 70% is conveyed through the storage tanks.

Through monthly energy bills of water treatment plant collected from the north, south and Raipur zone of Jal Sansthan annual energy consumption is calculated. Most of the extracted surface water goes for water treatment, except for 15 MLD which is directly pumped in the North Zone of Jal Sansthan. Similarly, the annual energy consumption by a particular wastewater treatment plant was calculated by using monthly data collected from South Zone, Jal Sansthan and Peyjal Nigam. The total water treated is equal to the total reported working capacity of the wastewater treatment plant.

2. PRIMARY SURVEY OF HOUSEHOLDS IN FIVE WARDS UNDER SMART CITY AREA:

Water and Energy Consumption in Smart City Area: To find the water and energy consumption at household level a primary survey was conducted in the five wards under Smart City area of Dehradun. The survey was done using a questionnaire which collected data on demographics, quality and quantity of

Table 1: Population and Sample size of Five Wards Surveyed under Smart City area

Ward name	Households[2]	Population	Sample Size
Bakralwala	669	2933	83
Ghantaghar	920	3962	114
Kalika Mandir Marg	1190	5326	147
Khurbura	1612	7374	199
Shivaji Marg	2044	10237	252
Total	6435	29832	795

[2]Source of number of households in each ward is Nagar Nigam.
https://nagarnigamdehradun.com/images/tendernotice/revised_eoi_for_hfa.pdf

the water supplied and the energy consumption (household survey questionnaire annexed). The energy and water consumption by households in different income classes in five wards is shown in graphical form in findings section.

As some of the wards are covered in the smart city area, the total population and number of households are adjusted according to the area of the ward covered under Smart city. From each of the 10 wards a sample of 12.3% was selected out of the total households reported according to the 2011-12 census in the Smart city area. From each ward the households were selected using simple random sampling. The survey was conducted in the months of November and December hence the average consumption of water in a year would be more than the reported numbers. Due to absence of water meters the households were not able to report the exact water or energy consumption. The energy consumption is calculated as the product of rated power of the pumps, its efficiency, and the average running hours of pump. Further, water consumption is calculated based on the size of water storage and number of hours this water lasts. In absence of any comprehensive study, this survey serves as the starting point of the data collection at the consumption level. This survey only covers five wards of the smart city area, providing comprehensive analysis on sufficiency, efficiency, and equity.

3. ESTIMATION OF GHG EMISSION OF URBAN WATER SYSTEM:

The GHG emission of the urban water system in each of the four zones is estimated by using a material flow analysis software UMBERTO tool. This tool uses the Ecoinvent 3.5 data base which provides well documented process data for thousands of products to account for the environmental impacts. The database gives the emissions according to the Indian scenario. The emissions are accounted according to per unit of input energy and volume of the water in the system at each stage from groundwater and surface water extraction to consumption. The figure 4 shows a picture of user interface of UMBERTO tool.

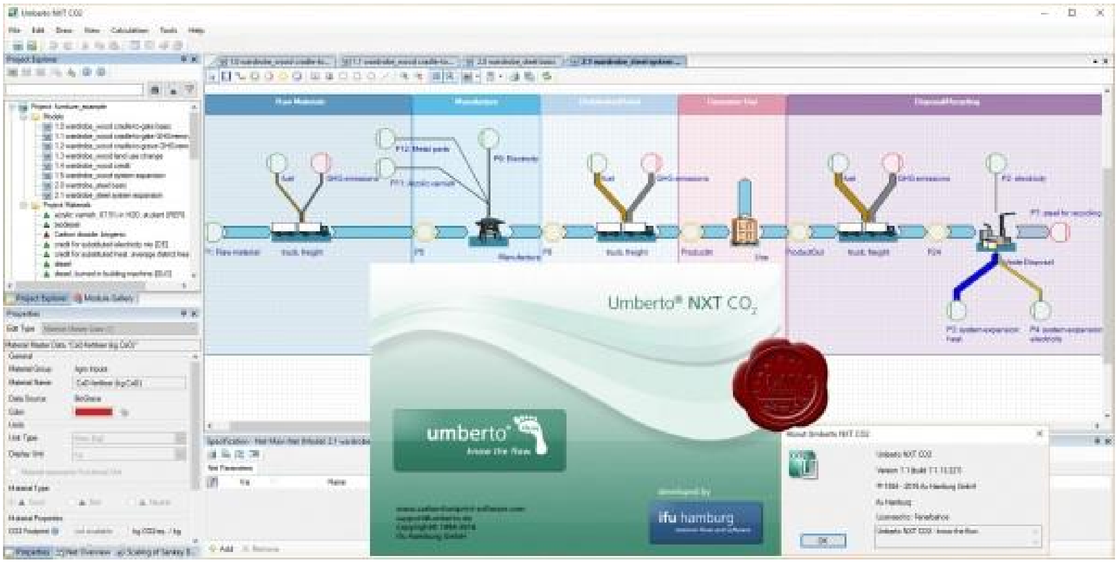


Figure 4: User Interface of UMBERTO tool

The Umberto® solution is used for modelling and assessment of all types of material and energy flow systems, to identify improvement potentials, conduct scenario analysis and to develop models for alternative processes. This tool ensures robust data collection and analysis, it is credible MFA tool for expert validity, provides visual representation of data and helps to identify specific pain points in the urban water management system. The processes starting from water extraction till the consumption of water is depicted using boxes. The intermediate output from each process is shown using yellow circles. While the red circle shows the output of the system. In the model the grey arrows are proportional to the water flow and pink arrows are proportional to the energy input in the system.

FINDINGS OF THE STUDY OF URBAN WATER SUPPLY SYSTEM

I. WATER SOURCES AND FLOW

Dehradun extracts around 80.7% of its water from groundwater, while 19.3% is extracted from surface water and this amounts to a total of 300 MLD (based on total pump-wise extraction). Out of the 242 MLD ground water extracted, 70% is conveyed to the storage, while 30% is sent for direct distribution. Out of 58 MLD surface water extracted 75% is conveyed to water treatment plant from where it is transferred to storage, while 25% of the surface water is send for direct distribution in the North Zone of Dehradun. The total consumption of revenue water is 255 MLD as 15% is the standard NRW losses[3] . Of this 255 MLD, 47.8 MLD (18.7%) wastewater is currently being treated and then disposed of, while 81% of the wastewater is untreated and disposed of directly in the nearby nalas. 43.27 MLD surface water is sourced from Bandal river, Bijapur Canal (tons river), Massi fall and Sikharfall, Galogi and Kalanga. Other than these major sources, 15 MLD of surface water is being directly supplied in the north water supply zone. The Sankey diagram below shows the flow of water through the supply system.

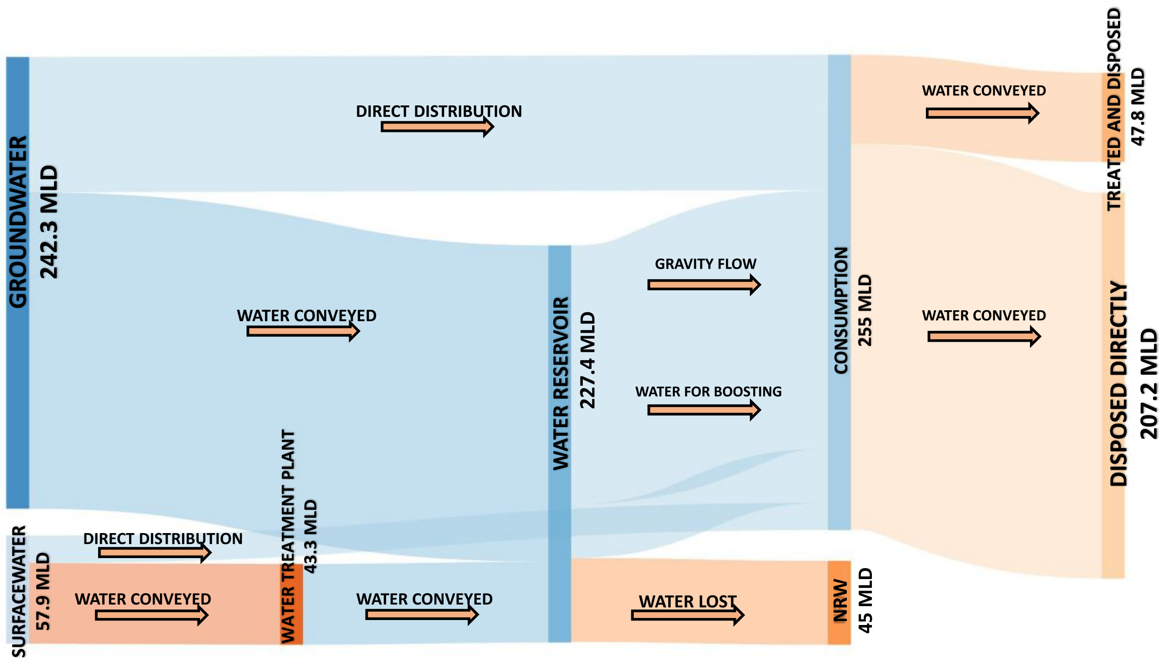


Figure 5: Sankey Diagram of water flow through the Urban Water Supply System in Dehradun

[3]Standard loses of the system as mentioned in the documents collected from Jal Sansthan.

Table 2: Findings of urban water supply system in Dehradun

Parameters	Quantum	
Baseline water stress	>80%	
Total water extracted	300MLD	
Ground water extraction	80.7% (242.3MLD)	
	70% (169.6MLD) conveyed to storage and later distribution	30% (72.69MLD) sent for direct distribution
Surface water extraction	19.3%(57.9MLD)	
	75%(43.4MLD) sent to WTP and later for storage and later distribution	25%(14.475MLD) sent for direct distribution
Non-revenue water	15%(45MLD)	
Revenue water	255MLD	
Wastewater	255MLD	
	18.7% (47.8MLD) treated and disposed in water bodies	81.3% (207.2MLD) non-treated disposed in water bodies
Reuse of treated water	0%	

Source: Data collected in 2019 from Jal Sansthan and PeyJal Nigam

The data (table 3 below) of the design and functional capacity of water treatment plants in Dehradun, collected from government water agencies indicate that the WTPs are running at 71% of their total capacity because limited water which is extracted from surface sources is treated. There is potential to treat more water and this can be achieved if a shift from groundwater to surface water is made, hence reducing ground water stress.

Table 3: The capacity and total annual energy consumption of water treatment plants

Water Treatment Plants	**Design Capacity (MLD)**	**Functional Capacity (MLD)**	**Water Distribution Locations**	**Total Annual Energy Consumption (kWh)**
Dilaram Bazaar (South)	27.50	14.83	*Rajpur Road, Ambedkar Colony, D.L. Road, Old survey road, Karan Road, Anand Chowk, Krishi Road, Vijay Colony, Kalidas*	18,52,844.00
Shahanshahi water works (North)	14.00	11.30	*Kathbangla, western canal road, DoonVihar, Rajpur road, Dhakpatti and Kishanpur*	15,86,280.00
Purukul Gram (North)	15.00	13.54	*Chalroti, Purukul, Ginial, Jakhan, Anarwala, Naiwala, Johdi, Guchupani, Chidowali, Hathibarkala, Arjangarh, Kandoli*	34,944.00
Kesharwala (Raipur)	4.20	3.60	*Raipur, Nehru Gram, Nathanpur*. Water from Kesharwala is boosted in south zone.	2,06,928.00
Total	**60.70**	**43.27**		**36,80,996.04**

Source: Data collected in 2019 from Jal Sansthan and PeyJal Nigam

II. TOTAL ANNUAL ENERGY CONSUMPTION OF THE URBAN WATER SYSTEM

The total annual energy consumption for the water supply system accounting for water extraction, conveyance, treatment, distribution, and wastewater treatment is 67.67 GWh. Groundwater extraction consumes highest energy at 83% of total energy consumption, followed by fresh water-treatment at 6%. Most of the distribution in Dehradun is by gravity hence energy consumption is only 4% and least energy consumption at 2% by surface water extraction. The wastewater treatment plants are not working at their designed capacity due to lack of sewerage lines and connections to feed the plant.

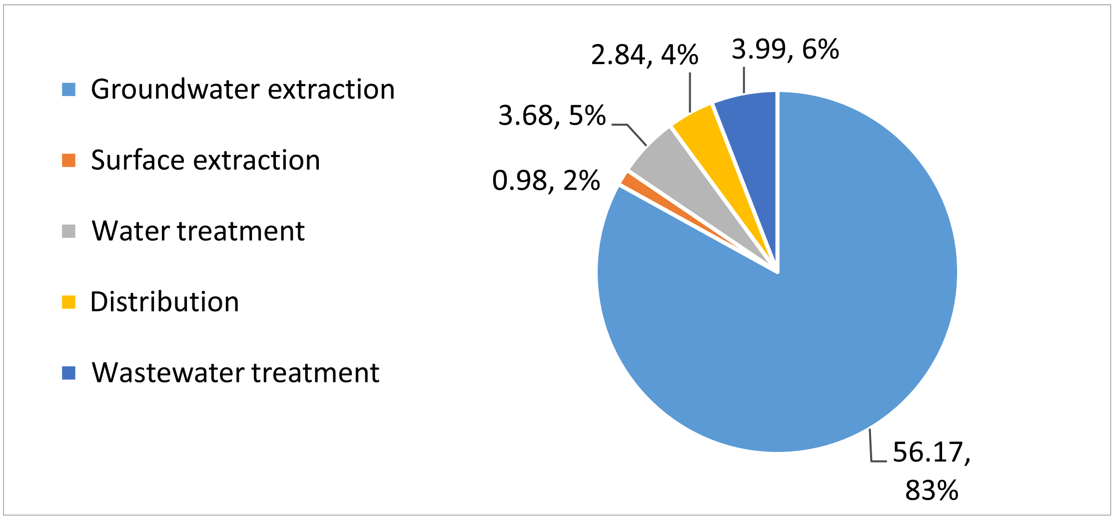


Figure 6: Proportion of Total Annual Energy Consumption at different stages of Urban Water System (GWh)

Table 4: Total Annual Energy Consumption of different stages of Urban Water System

Urban Water System Stages	Total Annual Energy consumption (kWh)
Groundwater extraction	56,174,448.45
Surface extraction	9,79,849.80
Water treatment	3,680,996.04
Distribution(boosting)	2,836,201.81
Wastewater treatment	3,999,765.00
Total	**67,671,261.10**

Source: Data collected in 2019 from Jal Sansthan and PeyJal Nigam

III. ZONE WISE ENERGY CONSUMPTION OF THE URBAN WATER SYSTEM

When comparing the total annual energy consumption across the four water supply zones in Dehradun, it is found that the energy consumption of the South zone is the highest because it extracts, treats and distributes highest amount of water as compared to the other zones. In the South zone, the highest energy consumption is for groundwater extraction followed by the energy consumption for distribution, treatment, and surface water extraction. There is negligible surface water extraction in the North zone, Raipur and Pithuwala hence the energy consumption is minimal.

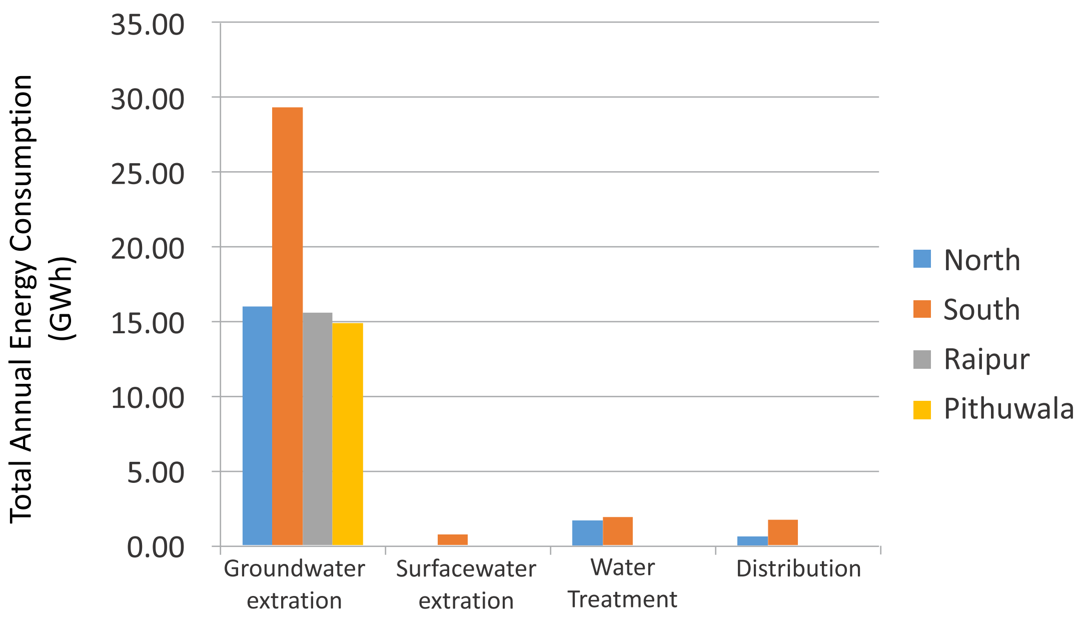


Figure 7: Total annual energy consumption (GWh) by different stages of water supply system across the four zones

Source: Data collected in 2019 from Jal Sansthan and PeyJal Nigam

IV. WATER DISTRIBUTION NETWORK

The total length of distribution network in the town is 1,964.35 km in addition to 119.65 km of rising mains from tube wells (ADB town report, 2010). In several cases the distribution lines are buried under the middle of the road. The old and dilapidated pipelines in the old city area also give rise to frequent problems in service. The total number of household water connections are detailed in table 5 below.

Table 5: Number of connections in the four water supply zones

	North	South	Raipur	Pithuwala
Domestic	32,011	48,046	38,615	43,419
Non-domestic	1,800	3,330	478	2,130
Total Connections	**33,811**	**51,376**	**39,093**	**45,549**

Source: Data collected in 2019 from Jal Sansthan and PeyJal Nigam

GROUNDWATER

30% of the groundwater amounting to 73MLD is distributed directly to the households and rest 70% of groundwater is distributed to households through storage tanks, according to Jal Sansthan. The energy consumption has been accounted for in the section on groundwater extraction. There is no additional input of energy to distribute the water.

SURFACE WATER

According to the information and data shared by Jal Sansthan, in the North zone, 15 MLD of water is transferred directly to households and no energy input is required for this. The rest of the surface water is treated, stored in clean water reservoirs, and distributed from here. In Dehradun, most of the distribution is through gravity. Water is supplied to the households through the overhead tanks. The rest 29 MLD of water is boosted from the storage and in the distribution line by the centrifugal pumps in the North and

South Zone. The total number of connections are 1,62,091 and accordingly the total water reaching each domestic connection is 1,573 litres per day. The average household size is 4.58 people, so water supplied per capita is 343 litres per day. Considering a standard design figure of 15% loss due to NRW and not the actual 40% NRW, the total water reaching for consumption is 255 MLD.

V. SEWAGE TREATMENT PLANTS

There are total 8 STPs in the city of Dehradun according to the data shared by Jal Sansthan and Peyjal Nigam. The total installed capacity of all the sewage treatment plant is 94.13 MLD. The STP at Kargi has been constructed by Asian Development Bank and is being run by Jal Sansthan. The rest of the STPs are constructed under JNNURM and currently run by Peyjal Nigam. A total 32.72 MLD of sewage is being treated in these wastewater treatment plants using the SBR technology. The total annual energy consumption for treating the sewage is approximately 3.99 GWh. The total number of sewer connection for North, South, Pithuwala and Raipur are 5,273; 26,687; 7,937; and 5,481, respectively. There are total 45,378 individual sewer connections, amounting to 31.5% of the 1,44,112 households in Dehradun (Census 2011) having sewer connection. The data indicates that there is inadequate sewer connections leading to running of STPs at under capacity. There is potential to treat more sewage and if treated water is reused according to the quality achieved either for potable or non-potable consumption, then the stress on the fresh water sources will be reduced.

Table 6: Annual energy consumption by Sewage Treatment Plants

STP location	Installed capacity (MLD)	Working capacity (MLD)	Technology	Energy consumed per day (kWh)	Annual Energy consumed (kWh)
Indira Nagar	5.00	2.50	SBR	1772.10	646816.50
Mothorowala	20.00	15.00	SBR	6023.30	2198504.50
Vijay Colony	0.42	0.42	SBR	70.00	25550.00
Salawala	0.71	0.30	SBR	447.60	163374.00
Kargi	68.00	14.50	SBR	2682.00	965520.00
Total	**94.13**	**32.72**		10995.00	**3,999,765.00**

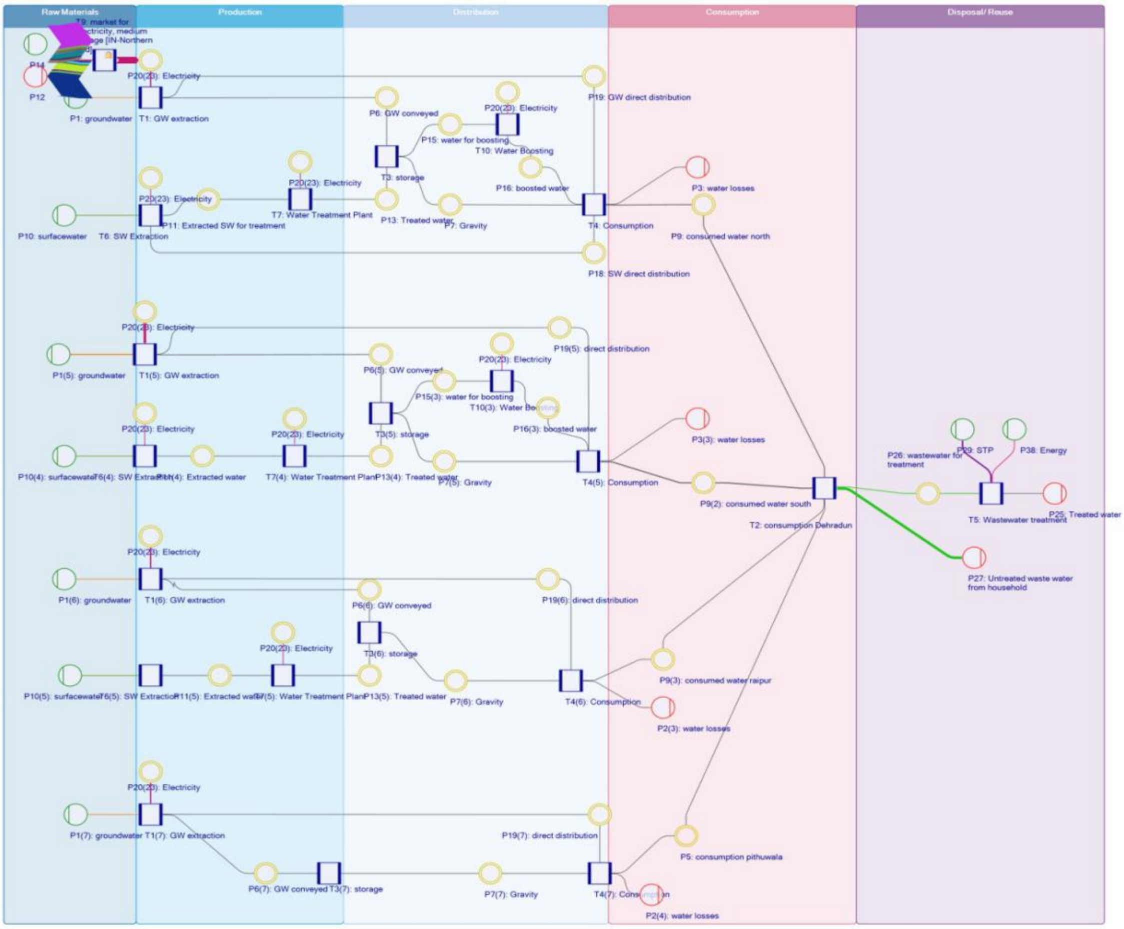
Source: Data collected in 2019 from Jal Sansthan and PeyJal Nigam

VI. FINAL DISPOSAL OF WATER

Only 47.82 MLD wastewater is treated in the sewage treatment plants which is disposed of directly in the nearby water bodies like rivers or nalas. There is a filling station at the Kargi water treatment plant, this water is used for horticultural purposes in the nearby areas. 207.2 MLD wastewater is untreated and directly disposed of in water bodies, as per the information and data shared by Jal Sansthan.

VII. ZONE WISE TOTAL ANNUAL GHG EMISSION OF URBAN WATER SYSTEM

The GHG emission of the urban water system in each of the four zones is estimated by using a material flow analysis software UMBERTO tool. This tool uses the Ecoinvent 3.5 data base which provides well documented process data for thousands of products to account for the environmental impacts. The database gives the emissions according to Indian scenario. The emissions are accounted according to per unit of input energy and volume of the water in the system at each stage from groundwater and surface water extraction to consumption. Total annual GHG emission of urban water system in each of the four zones have been calculated using the UMBERTO tool wherein water and energy are input materials into the system. The processes covered are starting from water extraction till the consumption of water. The total annual carbon footprint of the urban water system of Dehradun (including GHG emission of disposal 43,086,827.04 kg CO2 eq.) is 1.49 lakh tonne CO_2 eq. The picture 1 shows the Umberto model of total urban water supply system of Dehradun and Table 7 shows the zone wise total annual GHG emissions in four zones of urban water system.



Picture 1: Umberto Model of Total Water Supply System including all zones

Table 7: Zone Wise Total Annual GHG Emissions in four zones of Urban Water System

Zones	Total Annual GHG Emission (kg CO_2 eq.)
North	23,233,352.30
South	42,705,439.26
Raipur	20,063,494.48
Pithuwala	18,951,075.54

FINDINGS OF SURVEY OF FIVE WARDS IN SMART CITY AREA

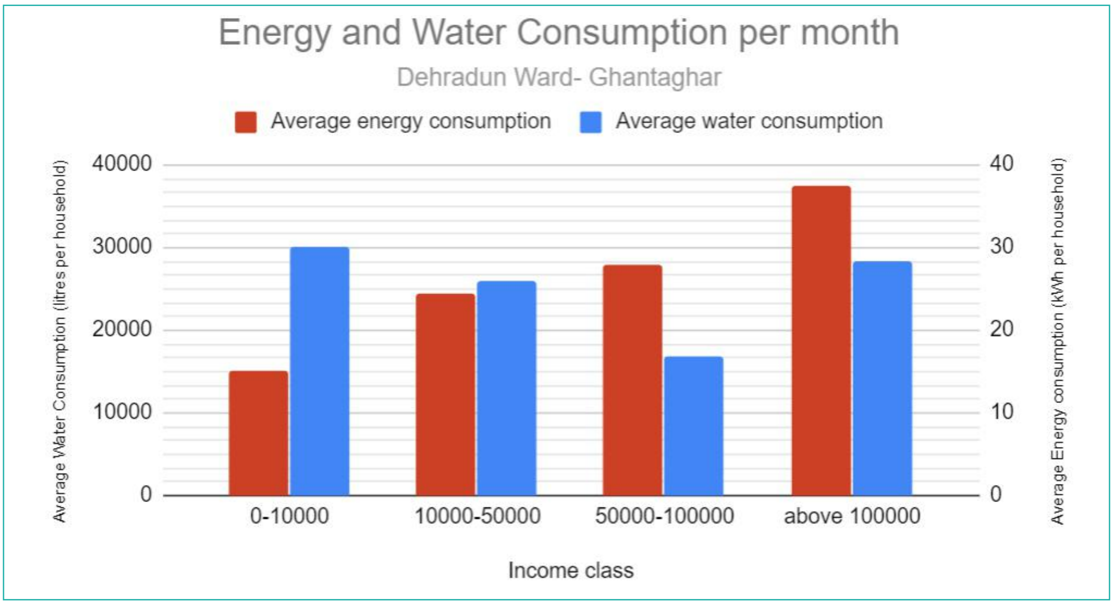
This analysis is limited by its small sample size. The survey was conducted in the months of November and December 2019 and hence the average consumption of water in a year would be more than the reported numbers. Due to absence of water meters the households were not able to report the exact water or energy consumption. The energy consumption is calculated as the product of power of the pumps and the average hour this pump is used. Further, water consumption is calculated based on the size of water storage and number of hours this water lasts. In absence of any comprehensive study, this survey serves as the starting point of the data collection at the consumption level. This survey only covers five wards of the smart city area, providing comprehensive analysis on sufficiency, efficiency, equity and operation and maintenance.

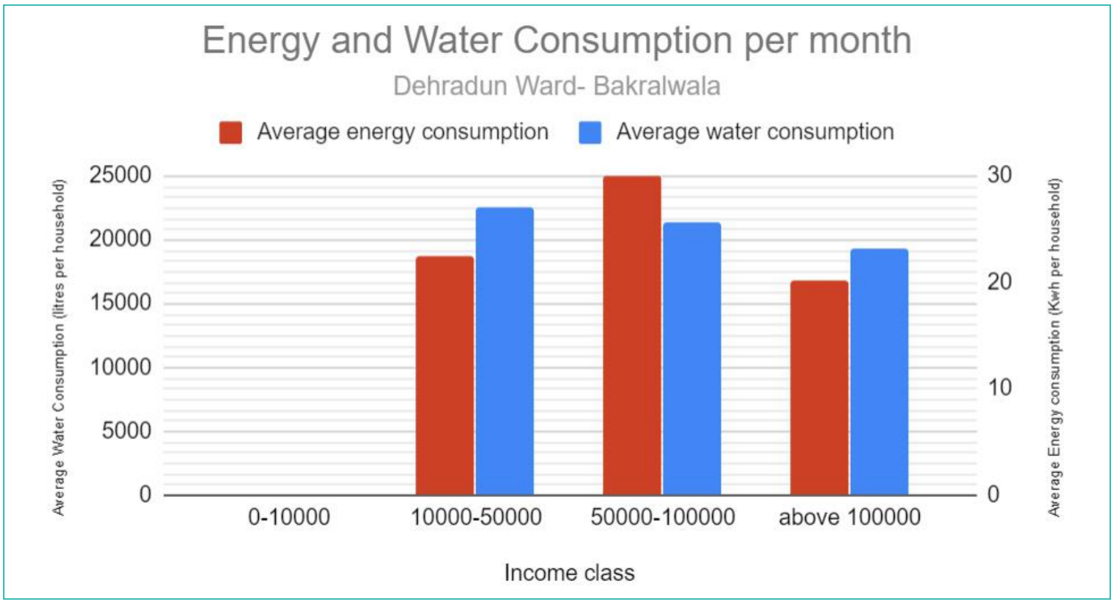
As per perception of citizens in these wards, all the wards face water supply issues such as limited hours of water supply and inadequate amount of water due to lack of pressure in the pipeline. The lack of pressure in the pipelines leads to longer running hours of the pumps, leading to high power consumption. In almost all the wards, people have directly connected their pumps to the main lines, which affect the pressure in pipelines, as well as the supply. This is one of the reasons why the pipes frequently burst and leak.

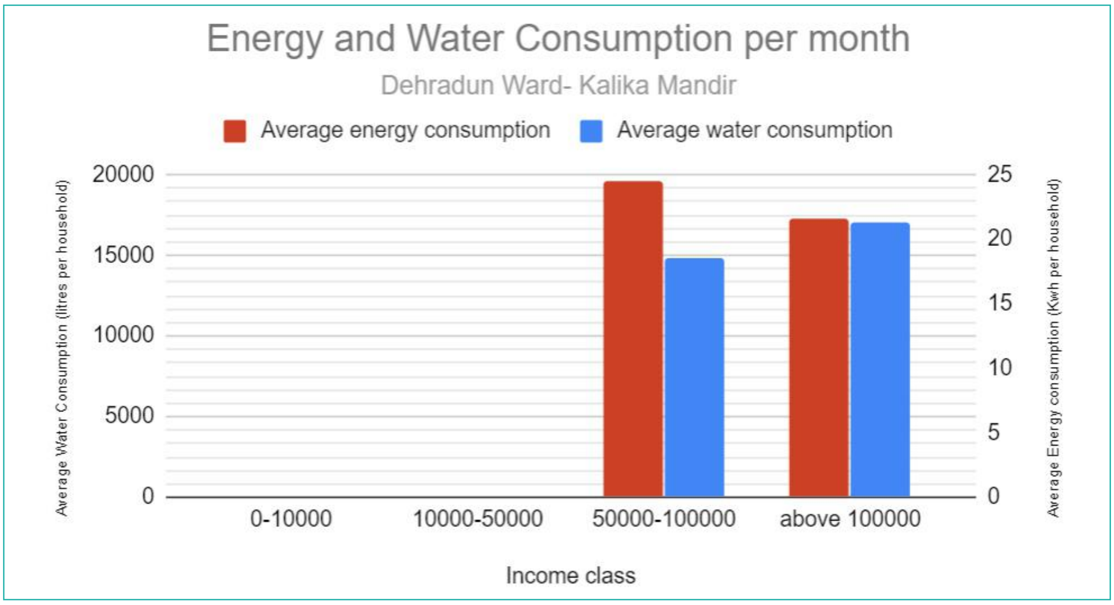
There is a perception among the citizens that the supplied water is salty with smell of chlorine or dirt, and brown or black colour. In certain areas such as Chaat wali gali, Mannuganj and Hakikatrai Nagar, the supply system is made of old plastic pipes which are dirty and in turn make the whole supply impure. None of the households have water meter and hence they don't know how much water they are consuming and how much they can save.

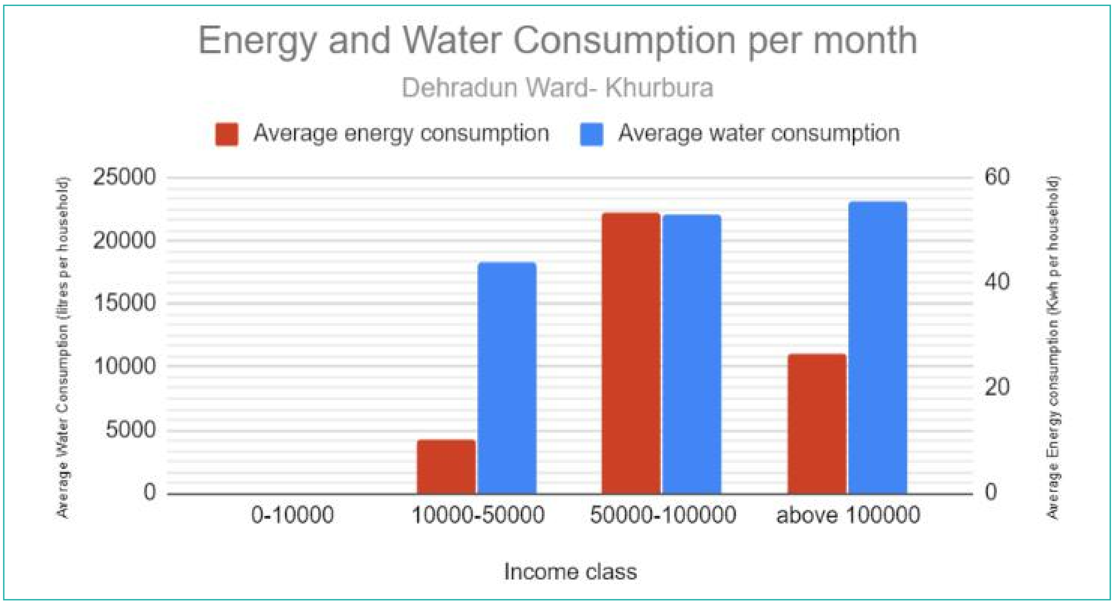
No rainwater harvesting was observed in any of the colonies. However, the areas experiencing shortage, practice re-use of water at micro-level such as using the leftover water after washing, for flushing or storing the AC water. People are un-aware of the water recycling techniques, and are not willing to take initiatives themselves, unless the measures are implemented by the government authorities. The graph 1 below has been plotted based on primary household survey data, of the average monthly water and energy consumption by households, according to the four income classes in five wards.

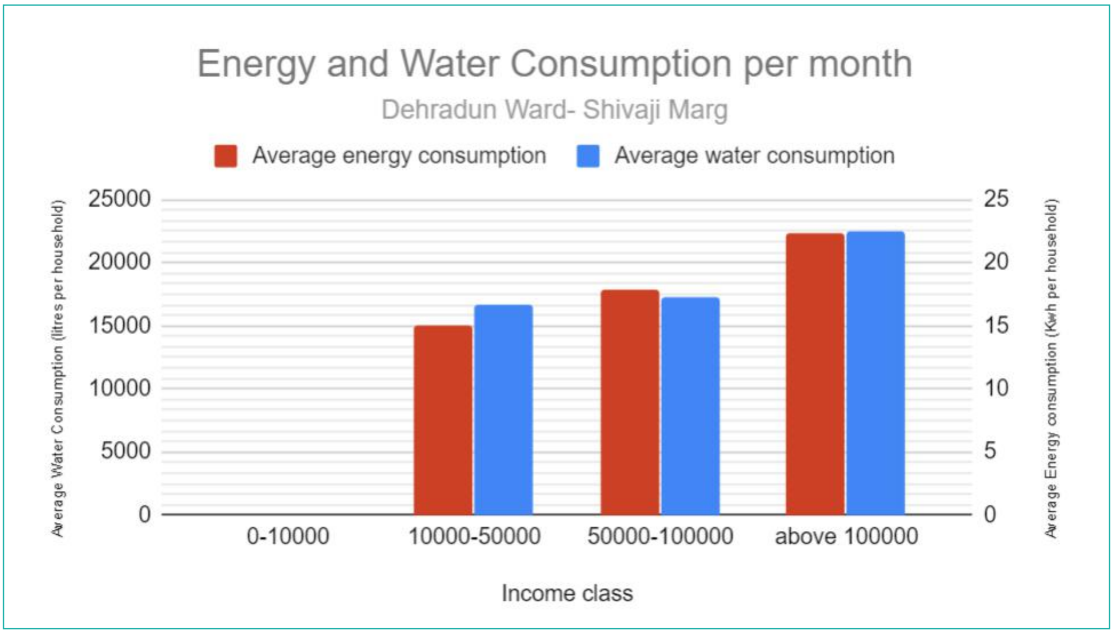
Graph 1: Average monthly consumption of energy and water across income classes in five wards




Energy and Water Consumption per month
Dehradun Ward- Bakralwala
Average energy consumption
Average water consumption
Average Water Consumption (litres per household)
Average Energy consumption (Kwh per household)
25000
20000
15000
10000
5000
0
30
20
10
0
0-10000
10000-50000
50000-100000
above 100000
Income class


Energy and Water Consumption per month
Dehradun Ward- Kalika Mandir
Average energy consumption
Average water consumption
Average Water Consumption (litres per household)
Average Energy consumption (Kwh per household)
20000
15000
10000
5000
0
25
20
15
10
5
0
0-10000
10000-50000
50000-100000
above 100000
Income class


Energy and Water Consumption per month
Dehradun Ward- Khurbura
Average energy consumption
Average water consumption
Average Water Consumption (litres per household)
Average Energy consumption (Kwh per household)
25000
20000
15000
10000
5000
0
60
40
20
0
0-10000
10000-50000
50000-100000
above 100000
Income class



The above graphs indicate that there is no correlation among the amount of consumption of water and energy and the income size in the five wards surveyed. In wards Ghantaghar and Shivaji Marg, the energy consumption is increasing with increase in income class size. But similar trend is not visible in rest of the three wards.

The table below is the summary of information collected from the lens of resource sufficiency and equity and the operational efficiency of pumping system from the households in five wards.

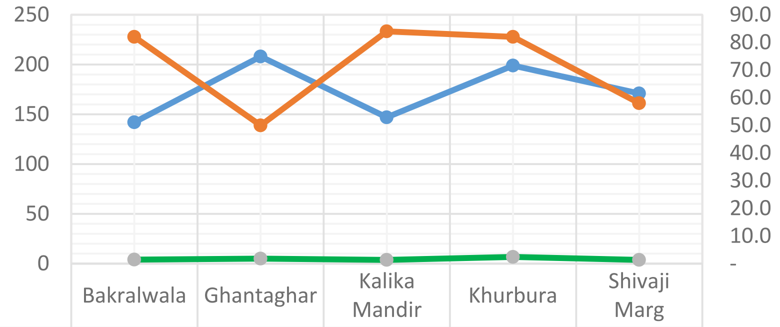
Table 8: Primary information collected in household survey in five wards

WARD NAME	DEMOGRAPHICS	SUFFICIENCY	EFFICIENCY	EQUITY
GHANTAGHAR	• 57% HH[4] >1lakh income • HH Size- 5	• Water supply per day- 5 hours • Water shortage- ½ HH during summers	• Average energy consumption 35.5 kWh per month/HH • Average water consumption 26,004 litres per month/HH • Energy intensity 0.00165kWh/l	• Average per capita consumption-208 (highest for income range 0-10k) • Water Quality-88% normal (maximum bad reported in income class >1 lakhs)
BAKRALWALA	• 89% HH >1lakh income • HH Size- 4	• Water supply per day- 4.2 hours • Water shortage- 82% HH during summers	• Average energy consumption 20 kWh per month/HH • Average water consumption 19,330 litres per month/HH • Energy intensity 0.0013 kWh/l	• Average per capita consumption-142 lpcd (highest for income range 10k-50k) • Water Quality-97% normal (maximum bad reported in income class >1 lakhs)
KALIKA MANDIR	• 61% HH >1lakh income • HH Size- 4	• Water supply per day- 3.7 hours • Water shortage- 84% HH during summers	• Average energy consumption 22.8 kWh per month/HH • Average water consumption 16,204 litres per month/HH • Energy intensity 0.0016 kWh/l	• Average per capita consumption-147 lpcd (highest for income range> 1 lakhs) • Water Quality-76% normal
KHURBURA	• 72% HH >1lakh income • HH Size- 4	• Water supply per day- 6.7 hours • Water shortage- 82% HH during summers	• Average energy consumption 31.3 kWh per month/HH • Average water consumption 22,693 litres per month/HH • Energy intensity 0.00153 kWh/l	• Average per capita consumption-199 lpcd (highest for income range 10k-50k) • Water Quality-88% normal
SHIVAJI MARG	• 79% HH >1lakh income • HH Size- 4	• Water supply per day- 3.7 hours • Water shortage- 58% HH during summers	• Average energy consumption 21.9 kWh per month/HH • Average water consumption 21,315 litres per month/HH • Energy intensity 0.00124 kWh/l	• Average per capita consumption-171 lpcd (highest for income range> 1 lakhs) • Water Quality-89% normal (maximum bad reported in income class 50k-1lakhs)

The findings of the household survey are summarized in the graphical form in the two graphs below.

The graph 2 below, shows the water supply and per capita consumption by households in five wards. The smart city proposal of city of Dehradun states that the water supply in the city is 155 lpcd. The survey informs us that citizens of Dehradun are getting more water supply than the prescribed standards of Public Health and Engineering Department (PHED) and the per capita consumption is even more than the supplied quantity. The per capita consumption at 208 lpcd of households in the Ghantaghar ward is highest among households of other wards and only 50% households in this ward reported shortage during summers. This indicates that households are stocking the water during the limited supply duration of five hours because of which the water agencies are then not able to provide continuous supply for longer duration and citizens experience water shortage. It was also found that there is inequality in distribution among various wards and zones as some wards get supply for more duration because the duration of supply for those connections which have new pipelines is more than for those where pipelines are old.

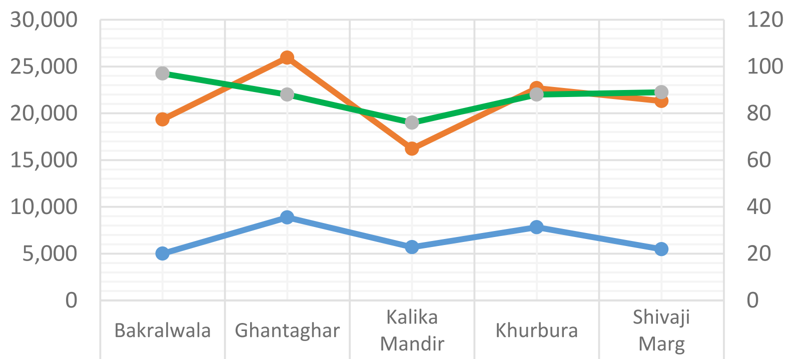
[4]HH- Household; HH size- Household size; >1 Lakhs is greater than 1 Lakhs;10k - 10,000



	Bakralwala	Ghantaghar	Kalika Mandir	Khurbura	Shivaji Marg
Avg. per capita water consumption (lpcd)	142	208	147	199	171
Supply Duration (Hrs/day)	4	5	3.7	6.7	3.7
Reported shortage in summer (%)	82.0	50.0	84.0	82.0	58.0

Graph 2: Water supply and per capita consumption by households in five wards

The graph 3 below, shows the monthly average water consumption and hence monthly average energy consumption by households of Ghantaghar ward are the highest at 25,948 ltrs/month and 35.5 kWh/month respectively, as compared to that by households in other wards. The water quality is reported to be normal by maximum number of households in Bakralwala and lowest by that of Kalika mandir ward as compared to the rest of the wards.



	Bakralwala	Ghantaghar	Kalika Mandir	Khurbura	Shivaji Marg
Avg. Water Consumption (ltrs/month)	19,330	25,948	16,204	22,693	21315
Avg. Energy Consumption (kWh/month)	20	35.5	22.8	31.3	21.9
Water Quality-Normal, clear & no smell (%)	97	88	76	88	89

Graph 3: Monthly average water and energy consumption and water quality in five wards

CITY WORKSHOP

As a part of our project initiative, a city level stakeholder workshop was held on 26 November 2019 in Dehradun. It provided a platform for multiple stakeholders from both government and private sector to come together and deliberate over the most prominent water issues faced by city of Dehradun. Officials from all the zones of Uttarakhand Jal Sansthan and PeyJal Nigam participated and shared their views over the initiatives currently undertaken within the system and some future plans on water management. The primary subject of discussion was how water and energy are interrelated and assessment of the non-revenue water of the city. During discussion, the need to moving towards a sustainable water infrastructural system which includes energy efficiency across the overall water infrastructure, reuse of water fostering water circularity and water conservation practices were identified. The reuse of treated wastewater is inadequate in the city as compared to its potential within the city or outside. On the technological front there is a need of exploring avenues for reuse of treated wastewater by collaborations between the city water departments and solution providers. Whereas, on social front, there is need to engage citizens for active participation through awareness campaigns by which importance of judicious use of water and significance of reusing treated wastewater will be promoted. Many conservation practices are followed in the city, and they need to be accepted at domestic and institutional level such as rainwater harvesting and ground water recharge and storage.

Picture 2: Photos of Dehradun City Workshop held on 26th November 2019 at The Red Fox Hotel

WAY FORWARD

The analysis of findings of the study indicate that the city's urban water supply system has tremendous scope for improving the services efficiency and resource-sufficiency, equity and resilience being four components of systems on it's end and citizen's active and collaborative participation with ownership on the consumer end. Citizens are both demand side and generators of post-consumption wastewater, so their role even becomes more significant as they can sustainably consume water at their houses, provide feedback, and opinions to city government water agencies.

Integrated Systemic Approach- An integrated systemic approach and inclusion of all city stakeholders and actors is thus required to achieve sustainable and healthy water for all, giving an equal importance and attention to all the components of urban water system. The institutional and individual capacity building is required for upgrading the knowledge, skills and management of the systems and for self-sustaining.

Capacity Building- The line department officers should be oriented towards the integrated systemic approach and trained on new age IT systems and tools like material flow analysis software. These tools help in digital drawing and visualizing the entire life cycle of water flow along with the mapping the resource, energy and emission footprints at each node of the network. This enables departments in decision making for planning and executing periodic monitoring and system upgradation.

Non-Revenue Water- Methodologically addressing the issue of non-revenue water including maintaining a real time data on physical losses and illegal tapping into the supply water, mending leakages in the system would ensure no losses. This would have an added benefit for improving the water quality which is affected due to old pipelines. Learning from city of Surat can be adopted which has a non-revenue water cell and adopted a systemic approach of leakage mapping and leak repairs in the system along with a city-wide water audit. As a part of the action plan, Surat Municipal Corporation (SMC) initiated two major activities, a) water audit of core city area and b) initial leakage mapping exercise. These initiatives have led to a reduction of leakages over a period of seven years.

Energy Efficiency- The total energy consumption of the urban water systems is high. So, the energy efficiency needs to be improved which in turn will reduce carbon footprint. In the long term there is a need to diversify to water source other than groundwater. In the short term there is an urgent need to revamp the infrastructure of urban water system. With real time periodic mapping of leakages the energy saving can be achieved by preventing idle running of pumps and motors. There are opportunities for achieving energy efficiency in the water supply infrastructure through installation of efficient pumps and motors adjustable to varying loads, helping in supplying continuous water at adequate pressure and hence reduce the energy consumption and associated emissions, and maintenance cost. The case of Watergy project implemented in Pune by the Pune Municipal Corporation (PMC) which achieved savings of water, energy and cost, is one of the cases that can be referred to. Apart from this, an additional 10% of water was delivered to communities without adding any new capacity.

Wastewater Treatment and Reuse- The municipalities, government water agencies and private players must collaborate and collectively plan, design and integrate decentralized wastewater and sewage treatment systems so that the wastewater management of the city becomes more convenient, circular, less costly, and covers 100% households. This approach will help in preventing any leakage to the natural ecosystems thereby reducing the GHG emissions released by untreated water. Also, measures to encourage the reuse of treated wastewater should be undertaken. The real time periodic mapping of the flow system along with energy efficient pumping system will increase the efficiency of wastewater treatment system. Best practices from both domestic and international cases can be learnt. The Michelson Water Reclamation Plant (WRP) in USA is one such case that was built to supply treated water to the community. To increase its capacity IRWD merged with the Los Alisos Water District and maximized the supply of drinking water. The total capacity of two plants is 20.5 million gallons per day with 12 storage reservoirs and 15 pumping stations to supply recycled water by 300 miles of pipelines to entire community. This treated water caters to the need of population of 3.16 lakhs in the area. Irrigation of residential property, landscape & food crop irrigation, toilet & urinal and cooling towers are few non-potable applications of this treated water. This treated water caters to the need of population of 3.16 lakhs in the area. At macro level, the benefits achieved were reduction in the need to source the water from Colorado River and Northern California, making IRWD drought resilient.

Citizen Awareness Generation- There is a need for including citizens of city with more ownership and collaborative participation. Citizens are both demand side and generators of post-consumption wastewater, so their role even becomes more significant as the households are not connected to the sewer system may be because of technical and financial constraints. They can sustainably consume water, adopt water conservation and harvesting practices in their houses, and provide feedback and opinions to city government water agencies. These campaigns would help in reaching out to various set of stakeholders, academic, research, implementing & decision making institutions, associations, think tanks, activists, women groups, about rainwater harvesting or other conservation technique as an alternate source of water, water conservation, sustainable consumption, wastewater treatment and reuse, need of metering, aimed at behavioral change amongst the citizens.

Integration of New Age Packaged and Cost-effective Solutions- The new age packaged and cost-effective solutions having low resource and emission footprints are to be integrated in the areas of revamping infrastructure (energy efficient pumping system), digitalization of mapping & monitoring of water and wastewater and sewage flow, reliable data collection and analysis, and harvesting solutions for building resilience. A detailed research needs to be conducted to find the best practices around the world which has been implemented to address the identified problems of the urban water system. The research would require exploring key players (government and other organizations) involved in the management of systems and new generation solution providers.

REFERENCES

- Association, W. (2004). Innovative Applications in Water Reuse- Ten Case Studies.
- Energy Efficiency Services Limited. (2018). Investment Grade Energy Audit Report. Jal Sansthan, Dehradun, Uttarakhand.
- GEF. (2015, August 31). The Importance of Water Sustainability. Global Environment Facility: Investing in our planet.
- Hoff, H. (2011). Understanding the Nexus. Background Paper for the Bonn 2011 Conference: The Water, Energy and Food Security Nexus. Stockholm: Stockholm Environment Institute.
- Lee, M., Keller, A. A., Den, W., & Wang, H. (2017). Water-energy nexus for urban water systems: A comparative review on energy intensity and environmental impacts in relation to global water risks. Applied Energy, Elsevier, 589-601.
- Liu, F., Ouedraogo, A., Manghee, S., & Danilenko, A. (2012). A PRIMER ON ENERGY EFFICIENCY FOR MUNICIPAL WATER AND WASTEWATER UTILITIES. Washington DC: The International Bank for Reconstruction And Development .
- Miller, L. A., Ramaswami, A., & Ranjan, R. (2013). Contribution of Water and Wastewater Infrastructures to Urban Energy Metabolism and Greenhouse Gas Emissions in Cities in India. Journal of Environmnetal Engineering, Research Gate.
- PWC; Jalakam Solutions. (2018). Assessment of NRW and developing strategy and implementation action plan for reducation of NRW in Bhubaneswar. Bhubaneswar: PWC.
- (n.d.). SONG_WS.
- UN WATER. (2019). World Water Developmenmt Report 2019. UN-WATER PUBLICATIONS.
- Wakeel Rana, M., Chen, B., Hayat, T., & Ahmad, B. (2016). Energy consumption for water use cycles in different countries: A Review. Elsevier.

ANNEXURE

Questionnaire of household survey

Q.No.	Question	Response Options
1	Annual income (INR)	0-10,000
		10,000- 50,000
		50,000-1,00,000
		above 1,00,000
2	Type of ration Card	APL
		BPL
		AAY
3	Do you have a government water supply connection?	Yes
		No
4	How do you fetch water?	Private borewell
		Private tanker
		Other
5	Where do you store water?	Overhead tanks
		Other
6	If no connection, are you willing to pay for a piped water connection?	Yes
		No
7	If yes, what type of connection?	Piped water
		Public tap
8	Do you face shortage of water in summers?	Yes
		No
9	When you receive water, where do you store the water?	Ground level reservoir
		Other
10	Do you use pumps to convey water to the overhead storage?	Yes
		No
11	Is there a water meter installed at your house?	Yes
		No
12	Do you pay for the water connection?	Yes
		No
13	Is the water supplied sufficient for your needs?	Yes
		No
14	If water not sufficient for the needs, what are the other source from which you extract water?	Private borewell
		Private tankers
		Public tankers
		Hand pump

		Other
15	How frequently do you fetch water?	Twice in a day
		Once in a day
		Once in two days
		Once in three days
16	Do you use washing machine?	Yes
		No
17	How frequently do you use the washing machine?	Once everyday
		Every alternate day
		Twice a week
		Once a week
		Once in 15 days
18	Do you use water for gardening?	Yes
		No
19	Do you use a water purifier?	RO
		Aquaguard
		Other
20	What kind of toilet do you have?	Western
		Indian
		Both
21	If Indian toilet, what type?	Cistern flush
		Pour flush
22	Do you practice rainwater harvesting or any other groundwater recharge practice?	Yes
		No
23	Do you re-use water?	Yes
		No
24	In the last one year, did anyone in the household suffer from	Cholera
		Diarrhoea
		Typhoid
25	Have you seen water leakages near your house?	Yes
		No
26	Did you report it?	Yes
		No

B-32, Tara Crescent,
Qutub Institutional Area,
New Delhi 110016.
India.
Email: mail@devalt.org
Website: www.devalt.org
Tel: +91-11-2654-4100, 2654-4200