# A Study on Energy use in the Water Supply and Treatment in Dehradun, India

**Medha, Development Alternatives**

**Abstract:** Water is a necessary element for maintenance of life on earth and is indispensable for the economy. The rivers, lakes and groundwater are the main source of freshwater for purpose of irrigation in agriculture and drinking and sanitation in the cities. Water sector is one of the most energy-intensive sectors. In India, Water and energy in the urban environments are managed in isolation. This creates hindrance for effective management of the urban systems. This problem calls for an integrated approach such as water-energy nexus to provide effective strategies to address the gaps in the systems. Water-energy nexus is characterized by resource use efficiency terms such as energy intensity and the environmental impacts in terms of energy use of existing water systems.

This study focuses on the energy requirements in the urban water systems of Dehradun, Uttarakhand. The study maps the volumetric flow of water across the water supply and distribution represented using a SANKEY diagram. This becomes the base for input of energy used in the system, at points such as water extraction- groundwater and surface water, water treatment, distribution and wastewater treatment to find the total energy consumption. Next, to indicate the environmental impacts of the system, carbon footprint is calculated using the UMBERTO tool.

The data was collected by stakeholder interviews with officials. In Dehradun, data has been collected from the 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. For water extraction and pumping in the distribution; pump-wise data on volume, power consumption and running hours was collected. Billing information of water treatment plant and wastewater treatment was collected to find the energy input.

Mapping the volumetric flows of water and energy input in the urban water system a detailed analysis is presented for both the cities. Dehradun extracts 80% of its water from the ground making water extraction highly energy intensive[1]. The rest 20% consisting of surface water flows majorly through gravity. The surface water undergoes primary treatment hence the energy intensity is low. The water extracted is conveyed to the storage, from here water flows through gravity due to the natural gradient of the city. Though, in some areas the water needs boosting, but, due to lower volumes the total energy used for distribution is low. Lastly, after consumption major portion of the used water is directly disposed off into *nalas*. Approximately, 45 MLD[2] is treated and then released into nearby *nalas*.

Understanding the nexus of energy and water helps in achieving possible reduction in energy consumption in the water sector and a reduction of greenhouse gas emissions by adopting efficient systems.

**Keywords:** Urban water supply system, energy use in water system

## 1. Introduction

Water and energy in the urban environments are managed in isolation. Typically, in India the ministries work in silos. This creates hindrance for effective management of the urban systems. Such problems call for an integrated system. Hence, there is a need to look at the urban water-energy nexus, to provide effective strategies to address the gaps in the systems. Water-energy

[1]Energy used per litre volume of water extracted

[2] Million litres per day

nexus is typically characterized in resource use efficiency terms such as energy intensity and the environmental impacts in terms of emission intensity of existing water systems within the urban water cycles. Understanding the nexus of energy and water may help in achieving possible reduction in energy consumption in the water sector and a reduction of greenhouse gas emissions by adopting efficient systems.

The major share of energy is derived from non-renewable resources; though the percentage of renewable in total energy mix is projected to grow significantly. There is a large gap in per-capita energy use within and between countries. Also, there is trade-off between different sectors for energy use. Water sector is one of the most energy intensive sectors. Energy consumption in water 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 used for extraction of water, raw water treatment, distribution, waste water collection treatment and recycling. Non-conventional source of water such as reclaimed or desalinated water has higher energy intensity. 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)

For India, on aggregate basis the majority of energy is used for water supply than for wastewater treatment, this is true for Indian cities because the amount of water supplied is far more than the wastewater treated in the WWTPs. In Dehradun, the total energy consumption for water supply system is almost 16 times that used in the wastewater treatment as most of the wastewater doesn't reach the wastewater treatment plant. The reported average energy intensity in India was lower than that in the UK (0.46 $kWh/m^3$), owing to the preference for low-energy requirement technologies such as up flow anaerobic sludge blanket (UASB) reactors or use solar heat for sludge drying in India.(Lee, Keller, Den, & Wang, 2017) The electricity related emissions from the municipal water supply and wastewater infrastructures as a percentage of the total community, is just 6% for most of the Indian cities. (Miller, Ramaswami, & Ranjan, 2013)

## 2. Objectives

The study tries to assess the following objectives:

- To assess the energy used in the urban water system starting from the Water extraction till the final Water treatment.
- To assess the environmental impacts of the urban water systems by estimating the greenhouse gas emissions.

## 3. Study Area

The city of Dehradun is the capital of the state of Uttarakhand, India. The city has 100 wards. The city lies in the *Terai* region of the Himalaya. It is situated on the flatland called the Dun. Dehradun was chosen as one of the study area as the city has high baseline water stress of greater the 80% (WRI, India water Tool, 2018) and a high reported NRW according to the Smart city proposal[3].

The city has been divided into 4 water supply zones- namely North, South, Raipur and Pithuwala. The water supply system is managed by two organizations in Dehradun. *Jal Sansthan* is in charge of the operation and maintenance of these water supply zones is done by the *Jal Sansthan* and *Peyjal Nigam* is in charge of construction and repair of the system.

## 4. Data Source

| URBAN WATER SYSTEM | ENERGY | VOLUME | DATA SOURCE |
|---|---|---|---|
| Surface and ground water extraction and conveyance | Pump-wise rated capacity (HP)[i] Number of hours of pumping of each pump | Total volume of water extracted (lpm) | *Jal Sansthan* |
| Water treatment | Energy bill (kWh) | Volume conveyed to WTP (MLD) | *Jal Sansthan* |
| Water Distribution | Pump-wise (centrifugal) capacity rating (HP) | Volume of water for pumped (MLD) | *Jal Sansthan* |
| Wastewater treatment Plant (WWTP) | Records on units consumed in a month by the WWTPs (kWh) | Installed and Working Capacity of Wastewater treatment plant (MLD) | *Jal Sansthan*- South Zone for *Kargi* Others from *Peyjal Nigam* |

*Table 1: Major data sources*(Figures for 2019)*

## 5. Methodology

The research on the energy use in urban water system is based on secondary literature. The data is collected from the officials of *Jal Sansthan* and *Peyjal Nigam*. The energy inputs at each point is identified at each point in the urban water system- surface water extraction conveyance, groundwater extraction and conveyance, water treatment, distribution, consumption and wastewater treatment.

***Water extraction and water distribution-*** The pump-wise total energy consumption is calculated as the power times the number of hours a particular pump is used in a day. The power of the

[3] http://smartcitydehradun.uk.gov.in/

pump in HP is converted into kW. Next, the power of the pump is accounted for the efficiency losses. The efficiency is considered to be 70% referring to interview with the officials. This gives the pump-wise energy consumption of each pump. As the pump is used every day; an annual figure for energy consumption is calculated using the daily figure. The discharge in liters per minute is collected from the 4 zones of *Jal Sansthan*. This figure is used to calculate the discharge in a year based on the number of hours and days a particular pump is running. For water extracted through groundwater pumps, 30% is considered to be conveyed for direct pumping, while 70% is conveyed through the storage.

***Water treatment and wastewater treatment-*** The monthly bills collected from the North, South and *Raipur* zone of *Jal Sansthan,* gives a monthly figure of the energy consumed by a particular water treatment plant. For wastewater treatment the monthly consumption unit of energy and working capacity is collected from South Zone, *Jal Sansthan* and *Peyjal Nigam* gave a monthly figure of the energy consumed by the other wastewater treatment plant. The monthly figures are used to calculate the energy consumed in a year.

The calculation of the emissions of the urban water system is done using the UMBERTO tool.

The Umberto® solution is used for modelling and assessment of all types of material and energy flow systems, in order to identify improvement potentials, conduct scenario analysis or develop models for alternative processes. The model uses the Ecoinvent 3.3 data base, which provides well documented process data for thousands of products to account for the environmental impacts. The model is used to create a water flow analysis of the water supply in Dehradun. The emissions are accounted according to per unit of input of the energy and volume of the water in the system.

## 6. Results

### *Water Flows*

Dehradun extracts 81% of its water from groundwater, while 19% is extracted from surface water. This amounts to a total of 300 MLD (based on a total of pump-wise extraction). Out of the total, 242 MLD ground water extracted 70% is conveyed to the storage, while 30% is sent for direct distribution. Out of 58 MLD of 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[4]. From the 255 MLD available at consumption, 48 MLD (19%) is currently being treated and then disposed, while, 81% of the water is still disposed untreated in the nearby *drains*.

### *Energy Used in The System*

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

The total energy used in a year for the water supply system- accounting for water extraction, conveyance, treatment, distribution and waste water treatment is 82.42 GWh per annum.

92.8% of the total energy in the water supply system is used for water extraction, 92% of this is used for groundwater extraction and direct distribution to the colonies. This is followed by the energy used in water-treatment plant 4% share, as only surface water is treated in the water treatment plant. Most of the distribution in Dehradun is by gravity; hence energy use is only 3% of the total energy use in the distribution system. (Refer Figure 1)

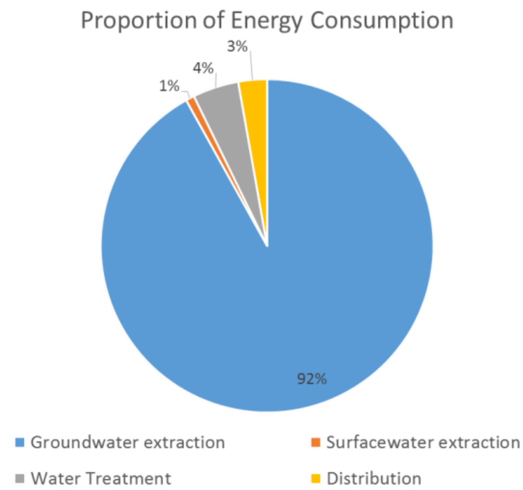


*Figure 1: Proportion of Energy Consumption by different sections of water supply system*

Next, wastewater treatment uses 3% of energy used in the system; this low energy consumption is due to the fact that approximately 81% of consumed water is directly disposed off in the *drains*. The waste water treatment plants are not working at their capacity due to lack of sewerage lines and connections to feed the wastewater plant.

While, comparing the energy consumption across the four water supply zones in Dehradun. It is found that the highest energy consumption is for Groundwater extraction in the South Zone, followed by the energy consumption for distribution, treatment and surface water extraction. The energy consumption of the South zone is the highest as the South zone extracts and treats higher amount of water as compared to the other zones. The requirement of water distribution by pumping is higher for the South Zone which is reflected by the high total energy consumption amount.

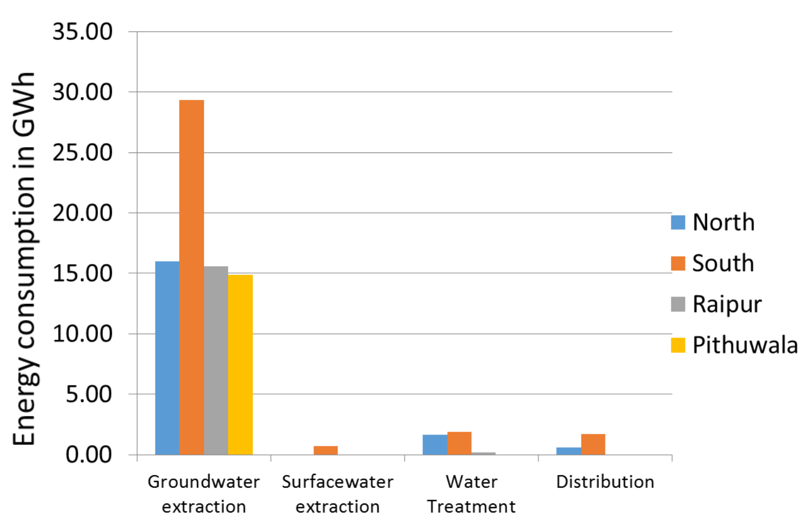


Figure 2: Energy consumption of different section of water supply system across the four zones- North, south, Pithuwala and Raipur

The energy intensity reflected as the Energy per unit Discharge is highest for groundwater extraction and direct distribution (0.00086 kWh/ liters). Followed by the energy intensity of Distribution (0.00022 kWh/liters), closely followed by the energy intensity of Water Treatment (0.0024 kWh/liters) While, the energy intensity of surface water extraction (0.0003 kWh/liters) is lowest as most of the water is being conveyed through gravity.

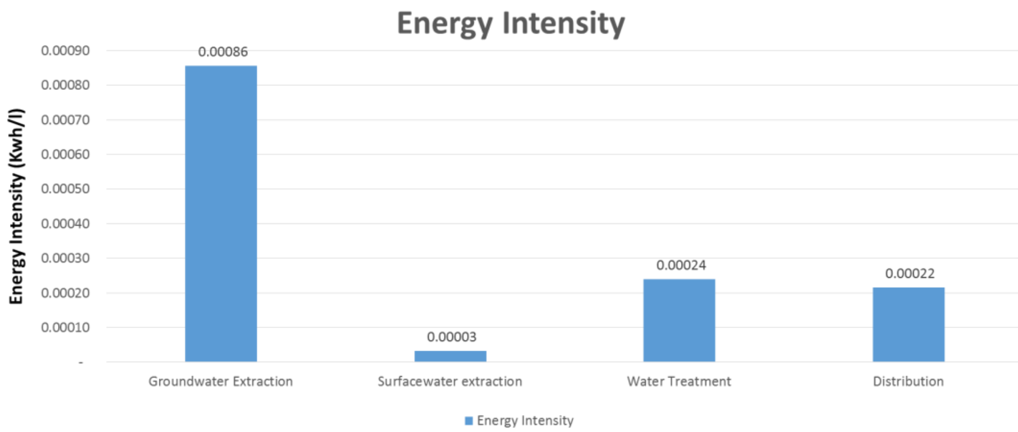


Figure 3: Energy intensity of different sections of the urban water supply system

The details for the different sections of the urban water supply system, divided into four zones are explained in the narrative below.

***Energy used for water extraction and conveyance***

242 MLD of groundwater is extracted; this extraction is highly energy intensive as water is pumped from the depth of approximately 90 meters till the ground. This groundwater is transferred directly to the colonies or to the storage (clear water reservoirs or overhead tanks), from where it is distributed. Water from 30% of the pumps is directly distributed, while from 70% the water is conveyed to the storage. Out of the 279 submersible pumps used for extraction, the 30% has been considered for water being directly distributed and 70% for distribution through the storage. A total of 242 MLD is being extracted across the regions. The energy required to extract water which is conveyed to water reservoirs i.e. Overhead tanks and clear water reservoirs and to convey to the colony for direct supply is 0.00086 kWh/liter. The energy use per unit discharge is the lowest for Raipur, followed by South, Pithuwala and North Zone. The energy intensity ranges from 0.00071 kWh/l to 0.00110 kWh/l.

The surface water accounts for 19% of the total water being supplied. A total of 43 MLD is extracted from the surface water sources, this water is pumped from five major water sources including *Bandal river, Bijapur Canal (tons river), Massi fall and Sikharfall, Galogi and Kalanga.* Other than these major sources, 16 MLD of surface water is being directly supplied in the north water supply zone.

**Table 2:** Major surface water sources

| | Source | Transport | Quantity | Designed | Feeding WTP |
|---|---|---|---|---|---|
| **1.** | *Bijapur* Canal (tons river) (S) | Pumped | 4.75 MLD | 12MLD | *Dilaram Bazar* |
| **2.** | *Bandal* River (S) | Through gravity | 10.08 MLD | 10MLD | *Dilaram Bazar* |
| **3.** | *Massi* Fall / *Shikhar* Fall (N) | Through gravity | 11.30 MLD | 14MLD | *Shehanshahi Ashram* |
| **4.** | *Galogi* (N) | Through gravity | 13.54 MLD | 12 MLD | *Purukul Gram* |
| **5.** | *Khalanga* Canal (R) | Through gravity | 3.6 MLD | 4.2 MLD | *Kesharwala* |
| | **Total** | | **43.27 MLD** | | |

[5]For surface water, energy is used at *Bijapur* canal. Energy intensity of extraction of surface water is at the lower end of energy intensity of extraction of ground water.

***Energy for water treatment plants***

Only surface water extracted is sent for water treatment. The total water being treated is 40.43 MLD. The energy used for treatment is taken from the electricity bills which come out to be:

**Table 3:** Description of the water treatment plants

| Water Treatment Plants | Capacity in MLD | Amount treated in MLD | Energy (kwh/annum) |
|---|---|---|---|
| Dilaram Bazaar (South) | 27.50 | 14.83 | 1,852,844 |
| Shahanshahi (North) | 14 | 11.30 | 1,586,280 |
| Purukul Gram (North) | 15 [10 MLD (softening plant)+ 5 MLD (filtering)] | 13.54 | 34,944 |
| Kesharwala (Raipur) | | 3.6 | 206,928 |
| Total | | 43.27 | 3680996.04 |

The energy intensity for water treatment is highest for south zone (0.00034 kwh/l), followed by North Zone (0.00018 kwh/l) which is closely followed by Raipur (0.00016 kwh/l).

***The energy required for distribution***

[5] ADB report

In Dehradun, most of the distribution is through gravity. Through the OHT water is supplied to the households. 29 MLD of water is boosted from the storage and in the distribution line by the centrifugal/boosting pumps in the North and South Zone. The energy intensity for boosting is higher for North Zone (0.00034 kwh/l) as compared with South (0.00019 kwh/l ).

The total population in Dehradun water supply zones including the extended ward is 674,361 according to Census 2011. Considering a standard 15% loss due to NRW the total water reaching for consumption is 255 MLD. Accordingly, the total water reaching each domestic connection is 1573 liters per day[6]. The average household size is 4.58 people, the water supplied is per person is 343 liters per day.

***Energy for wastewater treatment***

There are a total of 8 STP in the city of Dehradun.

**Table 4:** Details of STP

| STP location | Installed capacity (MLD) | Working capacity (MLD) | Technology | Energy used per day (kWH) | Energy used per annum (kWH) |
|---|---|---|---|---|---|
| Indira Nagar | 5 | 2.5 | SBR | 1772.1 | 646816.5 |
| Mothorowala | 20 | 15 | SBR | 6023.3 | 2198504.5 |
| Jakhan | 1 | 0.1 | SBR | | 0 |
| Vijay Colony | 0.42 | 0.42 | SBR | 70 | 25550 |
| Salawala | 0.71 | 0.3 | SBR | 447.6 | 163374 |
| Mothorowala-II | 20 | 15 | SBR | | 0 |
| Kaulagarh (under construction) | 3 | 0 | SBR | 0 | 0 |
| Kargi | 68 | 14.5 | SBR | 2682 | 965520 |
| Total | 118.13 | 47.82 | | | 3,999,765 |

The total installed capacity of the Sewage treatment plant is 118.13 MLD. The STP at *Kargi* has been constructed by Asian Development Bank, is operated by *Jal Sansthan*. The rest of the STPs constructed under JNNURM are currently run by *Peyjal Nigam*. A total 47.82 MLD of sewage is being treated in these wastewater treatment plants using the SBR technology. The total energy used for treating the sewage is approximately 4 GWH per annum.

The total number of sewer connection for North, South, *Pithuwala* and *Raipur* are 5273, 26687, 7937 and 5481 respectively. This amounts to a total of 45,278 individual sewer connections, amounting to 30% of the 1, 44,112 households in Dehradun (Census 2011) having sewer connection.

[6] Average water available for consumption is calculated as total water available for consumption divided by the number of connections.

***Energy used for reuse or final disposal***

A total of 47.82 MLD treated in the water treatment plant is being disposed of directly in the nearby rivers/ *Nalas*. There is a filling station at the *Kargi* water treatment plant, this water is used for horticultural purposes in the nearby areas.

## ***MATERIAL FLOW ANALYSIS***

Material flow analysis for standard loss for the system:

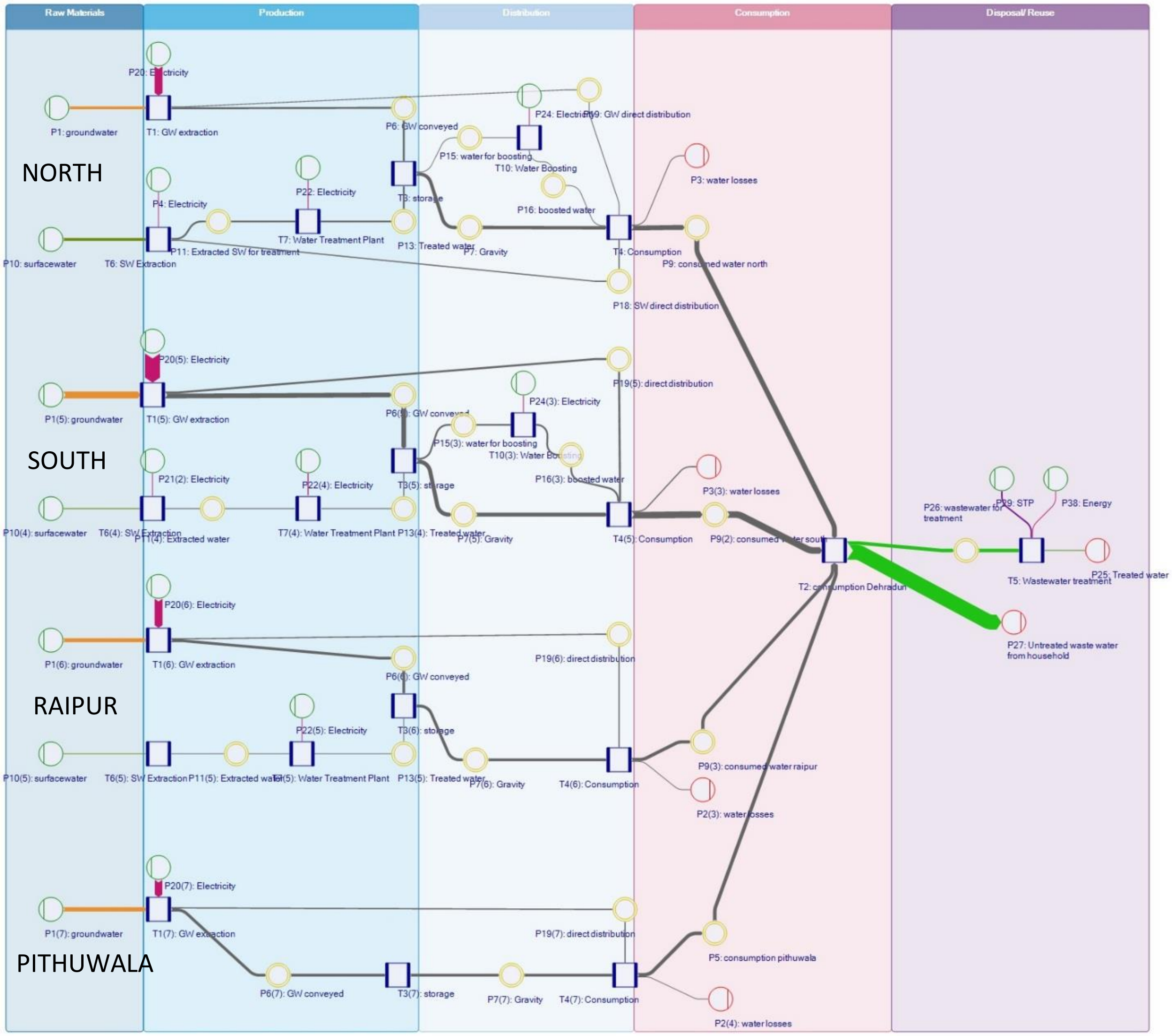


*Figure 4: Material flow analysis (Water and energy) for Dehradun city*

The total GHG emission for the production of water in Dehradun is 104,502,199.21 kg CO2 eq. The total emissions for water supply systems in the Dehradun are 0.00112 kg CO2 eq. per liter of water available for consumption. Production of water which includes extraction of water, water treatment and conveyance to the storage accounts for 57% of total GHG emissions, followed by disposal amounting to 47% of the total emissions.

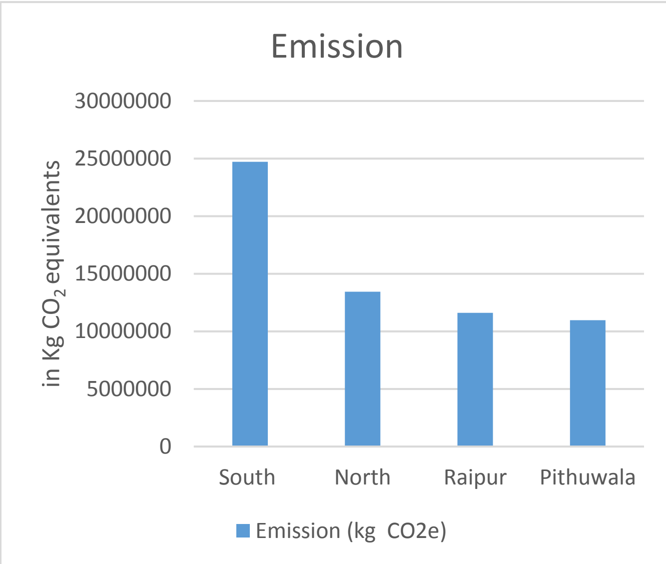


Figure 5: Total emission of the water supply system for the four water supply zone

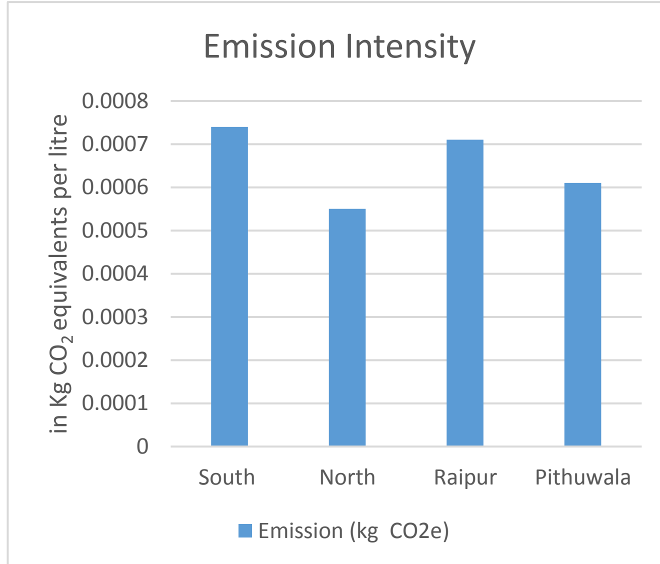


Figure 6: Emission intensity of the water supply system for the four water supply zone

On comparing the four zones of Dehradun namely North, South, Raipur and Pithuwala zone, the total emissions is the highest for the South Zone, which is double that of north zone, followed by Raipur and Pithuwala. The emissions are in proportion to the total volume of water extracted in the four zone of Dehradun. Emission intensity is the highest for the South zone, closely followed by Raipur, Pithuwala and the North zone. The North zone has low emission intensity as groundwater flows naturally till the water treatment plant due to gravity, hence no energy used. Also, the need for boosting is minimal as distribution is by gravity flow.

## 7. Discussion

The study started by quantifying the water extracted and supplied and its environmental impacts using material flow analysis. Such comprehensive analysis of the system provides scientific basis to city managers in making balanced decisions.

- There is lack of understanding of the water losses in the system- Mending leakages in the system would ensuring no reservoir losses will drastically reduce the water losses
- The major source of supply water in Dehradun is groundwater. There is a need to diversify from the groundwater, as extracting groundwater increases the need of the energy demand in the system.
- Replacing the pumps to make the system more energy efficient, reducing the total electricity used in the system

- Adopting cleaner energy source for driving the water supply system would reduce the carbon footprint of the city.
- The wastewater doesn't reach the WWTPs due to the Lack of sewerage network. The carbon footprint of the system reduced when most of the water undergoes treatment.
- Also possibility of reusing the water can be explored to encourage circularity.

This study can be used as a benchmark to which any other improvements in the system can be compared.

**Acknowledgement**

The study was conducted as a party of initiative by Development Alternatives and is funded by Heinrich Boll Foundation. I want to acknowledge the inputs given to the study by the officials of *Jal Sansthan* and *Peyjal Nigam* in Dehradun.

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[i] HP- Horse Power, kWh- Kilowatt-hour, lpm- litres per minute, MLD- million litres per day