NEC Consultants (Pvt.) Ltd.

Punjab Cities Governance Improvement Project

Energy Audit & Energy Efficiency Improvement Program for WASAs in Punjab

CITY REPORT
Lahore WASA

September 2015

THE URBAN UNIT
Urban Sector Planning & Management Services Unit (Pvt.) Ltd.
A Public Sector Company.

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Energy Audit & Energy Efficiency Improvement Program for WASAs in Punjab

September 2015

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CONTENTS

	Contents	4
	List of Figures	4
	List of Tables	4
	List of Acronyms and Abbreviations	5
	Glossary	5
	Executive Summary	7
1.0	**Introduction**	9
1.1	Background	9
1.2	Methodology	9
1.3	Scope	10
2.0	**Energy Audit Findings**	11
2.1	Administration of WASA of Lahore city	11
2.2	Tube wells discharge pattern	12
2.3	Wastewater disposal pumps discharge pattern	13
2.4	Energy consumption trend	15
2.5	Pumping system efficiency trend	19
3.0	**Pumping System Efficiency Improvement Potential**	22
3.1	Pumping system efficiency improvement potential of Lahore city	22
3.2	Investment and saving	23

LIST OF FIGURES

I	Installed capacity Vs actual discharge (tube wells)	13
2	Actual discharge pattern of subdivisions (tube wells)	13
3	Installed capacity Vs actual discharge (disposal pumps)	15
4	Actual discharge pattern of subdivisions (disposal pumps)	15
5	Unit electricity consumption trend (tube wells)	17
6	Unit electricity consumption trend (disposal pumps)	18
7	Electricity consumption trend of each subdivision	19
8	Pumping system efficiency category	21

LIST OF TABLES

1	Detail of WASAs pumps	10
2	Detail of WASA of Lahore city	11
3	Tube well discharge pattern	12
4	Wastewater discharge pattern	14
5	Detail of water discharge and electricity consumption	16
6	Detail of wastewater discharge and electricity consumption	17
7	Typical overall pumping system efficiency classification	19
8	Pumping system efficiency trend of subdivisions	20
9	Pumping system efficiency potential of pumps	22
10	Investment requirement for improvement of WASA pumps	24

LIST OF ACRONYMS AND ABBREVIATIONS

Bhp	Brake Horsepower
Cusec	Cubic Feet per Second
Ehp	Electrical Horsepower
Gpm	Gallon Per Minute
Hp	Horsepower
kVA	Kilo Volt Ampere
kW	Kilo Watt
kWh	Kilo Watt Hour
LESCO	Lahore Electric Supply Company
m/s	Meter Per Second
m^3/hr	Cubic Meter Per Hour
MCB	Fuses or Miniature Circuit Breaker
Mm	Millimeter
MS	Mild Steel
Psig	Pound Per Square Inch (Gauge)
RPM	Revolution Per Minute
TDH	Total Dynamic Head
VFD	Variable Frequency Drive
WASA	Water and Sanitation Agency
Whp	Water Horsepower

GLOSSARY

Discharge Pressure	The pressure obtained at center line of pump discharge pipe using a calibrated gauge (psig). Discharge pressure is converted to feet and expressed as “Discharge Head”.
Brake Horsepower	The output horsepower of a motor to a pump; may also be used to refer to the required input horsepower to the pump itself.
Deep Well Turbine Pump	A turbine pump installed inside a well casing below the pumping water level in the well.
Discharge Head	Head measured above center line of pump discharge pipe.
Drawdown	The measured distance that a well’s water level changes from standing/static level to operating pumping level during observed test conditions.
Dynamic Head	The sum of the pressure and the pumping head developed by a pump
Friction Head	The head required to overcome the fluid friction in a pipe or water system
Friction Losses	Energy losses associated with moving water against rough surfaces. In water pumping applications, it is the water pressure lost as a result of contact between moving water and a pipeline or open channel.
GPM per Foot Drawdown	The ratio of capacity (GPM) to drawdown feet is useful in determining the well’s performance.
Head	Alternate term for pressure. One pound per square inch (psi) = 2.31 feet of water head
Overall Plant	The ratio of the water horsepower (the overall output of the plant)

or Pumping System Efficiency	to input horsepower (the power input). The overall output can also be defined as the amount of horsepower required to deliver the measured capacity (water gallons per minute) and the measured total head.
Pumping Water Level	The well's operating water level below center line of discharge pipe as observed during test condition
Static Water Level	The well's water level obtained when pumping plant is at rest.
Suction Head	Head measured above center line of pump suction intake. Most often obtained with calibrated bourdon tube pressure gauge (suction pressure) and converted to feet by conversion factor 2.31 ft. water/psi
Suction Lift	The distance between pump discharge head and water level.
Total Head	The sum of the water head above and below the center line of the pump discharge pipe. For well applications, the Total Head is the sum of the Discharge Head and the Pumping Water Level. Total head is used in determination of water horsepower and pump performance.
Water Horsepower	The output horsepower of a water pump. It is the combination of flow rate and pressure.

EXECUTIVE SUMMARY

Government of the Punjab, Pakistan with financial assistance from the World Bank, is implementing "Punjab Cities Governance Improvement Project (PCGIP)" for strengthening systems for improved planning, resource management, and accountability in five large cities of Punjab i.e. Lahore, Faisalabad, Multan, Gujranwala and Rawalpindi. The project utilizes a result-based approach and, consistent with this focus, the disbursement decisions to the city and its entities are based on achievement of pre-specified results, referred to as Disbursement linked Indicators (DLIs) which reflect priority elements in furthering the Government's urban agenda, critical at the provincial level, within the existing legislative, regulative and policy framework of the Government.

Disbursement Linked Indicator 4 (DLI -4) aims for improvements in own source revenue collection system that encourages the City Local Government (CDGs), Development Authorities (DAs) and Service providers (WASAs) to bring improved systems for revenue enhancement. This DLI is linked with the initiative of WASAs to carry out the Energy Audit for resources conservation and efficiency to improved service delivery, accountability and own source revenue. One of the proposed actions and initiatives to enhance revenue was to conduct energy audit of WASAs to reduce the power cost by various systematic analysis of the energy use and finding out the energy management opportunities. In the context of existing scenario energy audit of WASAs is a technical and efficient way to obtain energy analysis and savings through improvements that optimize pumping systems of tube well stations and disposal stations to operate efficiently with significant cost saving.

The installed capacity of WASA tube wells of Lahore city is about 871.34 million m^3 per annum whereas actual discharge is 734.98 million m^3 per annum, for average 16 hours per day operation and 365 days per year. This actual discharge is about 16% lesser than the installed capacity. The installed capacity of WASA disposal pumps of Lahore city is 1,093.86 million m^3 per annum whereas actual discharge is 709.75 million m^3 per annum, for average 12 hours per day operation and 365 days per year. This actual discharge is about 35% lesser than the installed capacity.

About 79% (369) of the tube wells consume electricity more than the 0.20 kWh/m^3. In case if all the audited 465 tube wells consume optimum electricity, then annually Rs. 443 million (19%) can be saved.

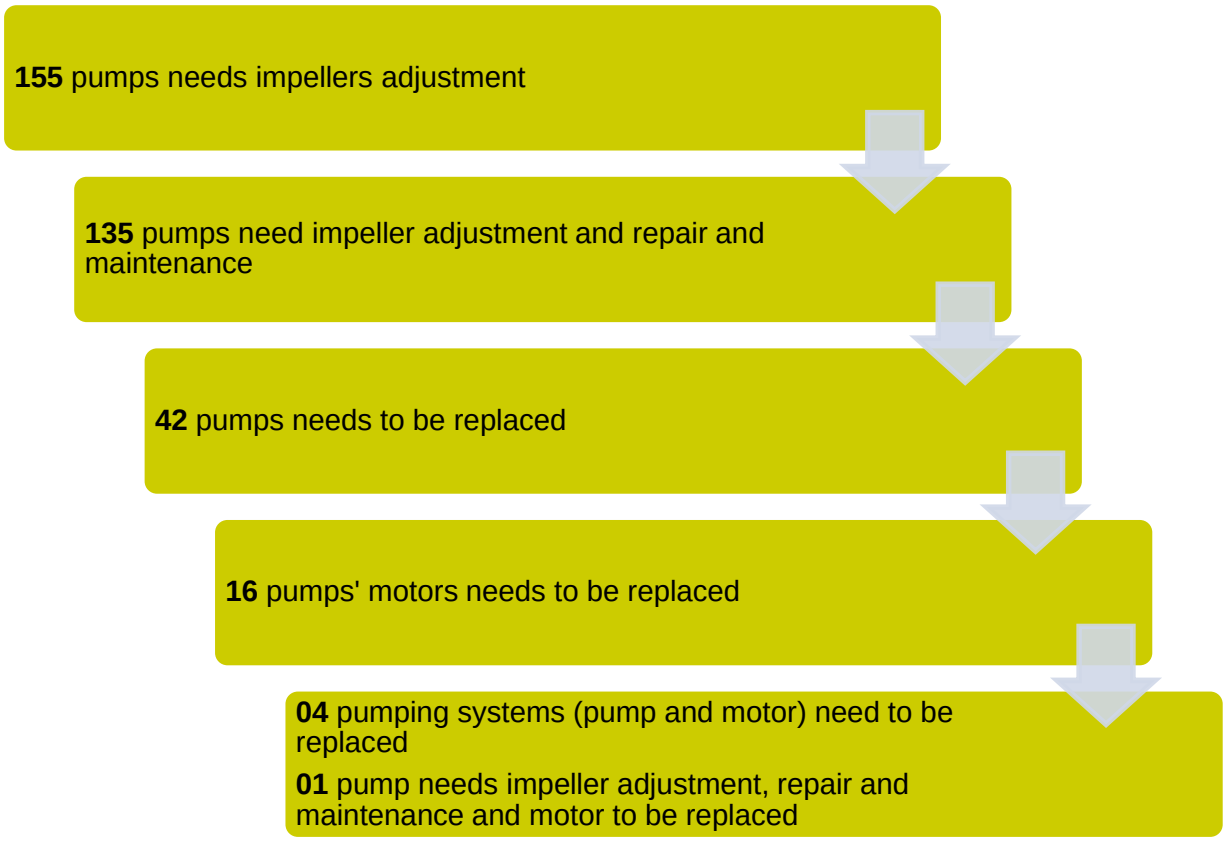
Total annual electricity consumption of Lahore city to operate tube wells and disposal pumps is about **223 million kWh**. This energy, in monetary terms, is about **Rs. 2,902 million** (@ Rs. 13/kWh). . The contribution of tube wells in the energy consumption is about 78%.

Pumping plant efficiency of each tube well and disposal pump was monitored by measuring water flow rate, head and electricity consumption. The efficiency of each pumping system was classified as "Low", "Fair", "Good", or "Excellent". About 46% of the tube wells and disposal pumps are under excellent and good category of pumping system efficiency whereas 54% are under fair and low category. The pumps of excellent and good category of system efficiency do not require any intervention to improve their efficiency whereas low and fair category pumps need efficiency improvement. The efficiency of pumping system can be improved by following interventions:

- Replacement of pump
- Replacement of motor
- Replacement of pumping system (pump and motor)
- Adjustment of pump impellers
- Repair and maintenance of pump

- Adjustment of pump impellers and repair and maintenance

There are total 353 tube wells and wastewater disposal pumps (54% of total pumps) having system efficiency in the category of FAIR to LOW, need efficiency improvement. These pumps need interventions such as:



Total investment for the efficiency enhancement and improvement of electrical and mechanical and housekeeping condition of 353 pumps is **Rs. 319** million with annual saving of Rs. **389** million. The payback period varies from 04 months to 19 months for different subdivisions. The pumping system efficiency improvement will result into **13%** energy reduction.

Energy audit activity of WASA stations of Lahore city revealed that there are certain areas of electrical, mechanical and housekeeping which needs improvement along with efficiency improvement. About **Rs. 488** million are required to improve all WASA stations of Lahore city.

1.0 Introduction

1.1 Background

Government of the Punjab, Pakistan with financial assistance from the World Bank, is implementing "Punjab Cities Governance Improvement Project (PCGIP)" for strengthening systems for improved planning, resource management, and accountability in five large cities of Punjab i.e. Lahore, Faisalabad, Multan, Gujranwala and Rawalpindi.

The project utilizes a result-based approach and, consistent with this focus, the disbursement decisions to the city and its entities are based on achievement of pre-specified results, referred to as Disbursement linked Indicators (DLIs) which reflect priority elements in furthering the Government's urban agenda, critical at the provincial level, within the existing legislative, regulative and policy framework of the Government. DLIs includes intermediate outcomes, incremental steps and results contributing to improved efficiency, effectiveness, accountability and service delivery during and beyond the project life by building capacities , system and processes .

Disbursement Linked Indicator 4 (DLI -4) aims for improvements in own source revenue collection system that encourages the City Local Government (CDGs), Development Authorities (DAs) and Service providers (WASAs) to bring improved systems for revenue enhancement. This DLI is linked with the initiative of WASAs to carry out the Energy Audit for resources conservation and efficiency to improved service delivery, accountability and own source revenue.

One of the proposed actions & initiatives to enhance revenue was to conduct energy audit of WASAs to reduce the power cost by various systematic analysis of the energy use and finding out the energy management opportunities. WASAs each year incur significant cost. It was ***Rs. 4,697 million*** in 2014 year for energy/Electricity bills, with an installed capacity of approximately 131 MW for 5,663 Million Gallons per Day (water management), which can be reduced through detailed energy audit and implementing its findings.

In the context of existing scenario energy audit of WASAs is a technical and efficient way to obtain energy analysis and savings through improvements that optimize pumping systems of tube well stations and disposal stations to operate efficiently with significant cost saving.

The Urban Planning and Management Services Unit, Pvt. Ltd. has assigned NEC Consultants Pvt. Ltd to conduct energy audits of WASAs in Punjab in five major cities of Lahore, Rawalpindi, Faisalabad, Multan and Gujranwala.

This is the energy audit summary report of **Lahore City**.

1.2 Methodology

The primary and secondary sources were used to collect data for different WASAs and pumps installed there. The Urban Unit provided information and contact detail of all the WASAs. An energy audit report template was developed to collect field data from each WASA subdivision. Prior to start the on field measurements of each subdivision, meetings were conducted with the respective WASA management and briefed them about the activity. The technical team then collected data by on field measurements of each pump and recorded in their energy audit report template. On the basis of this energy audit report template, The Urban Unit also developed Android based software to record data of each pump online. This data was also recorded on line in this Android based application.

On the basis of field measurements, efficiency of the pumping system was calculated and energy efficiency opportunities were identified.

1.3 Scope

The scope of the this assignment is to conduct energy audits of about 1,600 fresh water supply and wastewater disposal pumps installed at different WASA stations in five major cities of Lahore, Rawalpindi, Multan, Faisalabad and Gujranwala. The detail of these pumps is given in Table-1.

Table-1: Detail of WASAs Pumps

WASA	Population Served (Million)	Total Water Connections	Total Sewerage Connections	Total Supply Stations	Total Disposal Stations	Total No. of Pump Sets
WASA Lahore	5.48	587,595	583,532	491	99	776
WASA Gujranwala	0.54	29,375	97,236	66	23	112
WASA Faisalabad	1.55	110,452	217,002	87	43	222
WASA Multan	1.2	43,996	175,615	102	21	161
WASA Rawalpindi	1.17	92,468	38,437	362	-	362
Total	**9.94**	**863,886**	**1,111,822**	**1,108**	**186**	**1,633**

The efficiency of each pumping system was evaluated and energy efficiency improvement opportunities were identified for those pumping systems whose efficiencies were not at required level. The detail of reports prepared is as under:

- The energy audit report of each pump was prepared.
- On the basis of each pump report, summary report of findings of each WASA subdivision was prepared.
- On the basis of each subdivision summary report, one consolidated report of each city for energy efficiency improvement opportunities of the WASAs was prepared.

2.0 Energy Audit Findings

This chapter describes summary of energy audit findings of WASA tube wells and wastewater disposal pumps of Lahore city. These findings are based on energy audit summary reports of 27 subdivisions of Lahore city. These 27 reports are available with The Urban Unit of Punjab for further review.

2.1 Administration of WASA of Lahore City

Lahore city is divided into seven towns for the WASA administration. Each town is comprised of different subdivisions. The detail of these seven towns, their subdivisions and number of audited tube wells and wastewater disposal pumps is given in Table-2. There were few tube wells and pumps, which could not be monitored during energy audit activity due to various reasons, such as i) non operational due to maintenance reasons, ii) non accessible, and iii) out of order.

Table-2: Detail of WASA of Lahore City

#	Towns	Subdivisions	No. of Water Supply Pumps	No. of Wastewater Disposal Pumps	Total No. of Pumps
1	**Allama Iqbal Town**	Allama Iqbal Town	18	02	20
2		Ichra	21	05	26
3		Johar Town	14	07	21
4		Mustafa Town	02	07	09
5		Sabza Zar	14	08	22
6		Samanabad	15	02	17
	Total		***84***	***31***	***115***
7	**Gunj Buksh**	Anarkali	20	04	24
8		Islampura	23	02	25
9		Ravi Road	20	09	29
	Total		***63***	***15***	***78***
10	**Gulberg**	Gulberg	24	19	43
11		Mozang	25	04	29
12		Shimla Hill	15	07	22
	Total		***64***	***30***	***94***
13	**Nishtar Town**	Garden Town	13	04	17
14		Green Town	24	05	29
15		Industrial Area	16	10	26
16		Town Ship	12	07	19
	Total		***65***	***26***	***91***
17	**Ravi Town**	City	25	15	40
18		Data Nagar	13	07	20
19		Farukh Abad	12	12	24
20		Misri Shah	20	05	25
21		Shadbagh	21	09	30
22		Shahdara	09	09	18
	Total		***100***	***57***	***157***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	20	06	26
24		Fateh Garh	16	-	16
25		Mughal Pura	25	10	35
26		Mustafa Abad	10	03	13
27		Taj Pura	18	08	26
	Total		***89***	***27***	***116***
	G. Total		**465**	**186**	**651**

2.2 Tube Wells Discharge Pattern

The detail of water discharges of tube wells for each subdivision is given in Table-3. These discharges were monitored on field. There were few tube wells where water flow measurements were not possible. For these tube wells, the flows were estimated on the basis of loading of the electrical motor and physically observing the pump conditions.

Table-3: Tube Well Discharge Pattern

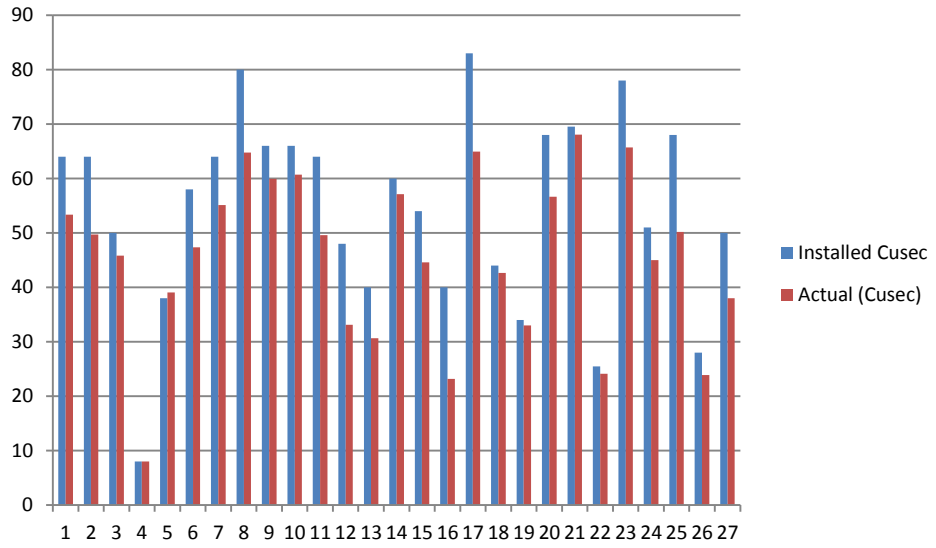
#	Towns	Subdivisions	Installed Cusec	Capacity (million m^3/yr)	Actual (Cusec)	*Avg. Discharge (million m^3/yr)
1	**Allama Iqbal Town**	Allama Iqbal Town	64	38.12	53.32	31.76
2		Ichra	64	38.12	49.73	29.62
3		Johar Town	50	29.78	45.81	27.20
4		Mustafa Town	08	04.76	08.01	04.77
5		Sabza Zar	38	22.63	39.06	23.26
6		Samanabad	58	34.54	47.36	28.21
	Total		***282***	***167.95***	***243.29***	***144.82***
7	**Gunj Buksh**	Anarkali	64	38.12	55.13	32.83
8		Islampura	80	47.65	64.74	38.56
9		Ravi Road	66	39.31	59.96	35.71
	Total		***210***	***125.08***	***179.83***	***107.1***
10	**Gulberg**	Gulberg	66	39.31	60.68	36.14
11		Mozang	64	38.12	49.61	29.55
12		Shimla Hill	48	28.59	33.13	19.73
	Total		***178***	***106.02***	***143.42***	***85.42***
13	**Nishtar Town**	Garden Town	40	23.82	30.65	18.25
14		Green Town	60	35.74	57.09	34.00
15		Industrial Area	54	32.16	44.56	26.54
16		Town Ship	40	23.82	23.19	13.81
	Total		***194***	***115.54***	***155.49***	***92.60***
17	**Ravi Town**	City	83	49.44	64.93	38.67
18		Data Nagar	44	26.20	42.65	25.40
19		Farukh Abad	34	20.25	32.98	19.64
20		Misri Shah	68	40.50	56.66	33.75
21		Shadbagh	69.5	41.39	68.07	40.54
22		Shahdara	25.5	15.18	24.11	14.36
	Total		***324***	***192.96***	***289.40***	***172.36***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	78	46.46	65.71	39.14
24		Fateh Garh	51	30.38	45.00	26.80
25		Mughal Pura	68	40.50	50.18	29.89
26		Mustafa Abad	28	16.67	23.89	14.23
27		Taj Pura	50	29.78	37.99	22.62
	Total		***275***	***163.79***	***222.77***	***132.68***
	G. Total		**1,463**	**871.34**	**1,234.20**	**734.98**

**Avg. Discharge is based on average 16 hours per day operation and 365 days per year.*

The installed capacity of WASA tube wells of Lahore city is about 871.34 million m^3 per annum whereas actual discharge is 734.98 million m^3 per annum, for average 16 hours per day operation and 365 days per year. This actual discharge is about 16% lesser than the installed capacity.

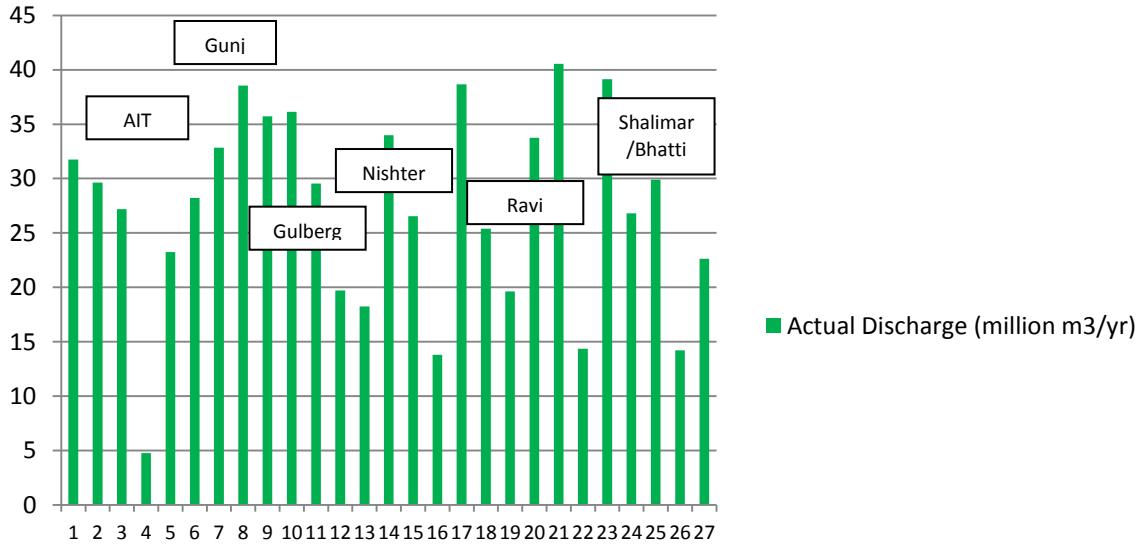
The comparison between installed capacity and actual discharge, in cusec, is illustrated in Fig-1.

Figure-1: Installed Capacity Vs Actual Discharge (Tube Wells)



The actual discharge, in million m^3/yr, for each subdivision is illustrated in Fig-2.

Figure-2: Actual Discharge Pattern of Subdivisions (Tube Wells)



2.3 Wastewater Disposal Pumps Discharge Pattern

The detail of discharges of wastewater disposal pumps for each subdivision is given in Table-4. These discharges were monitored on field. There were few pumps where water flow measurements were not possible. For these pumps, the flows were estimated on the basis of loading of the electrical motor and physically observing the pump conditions.

Table-4: Wastewater Discharge Pattern

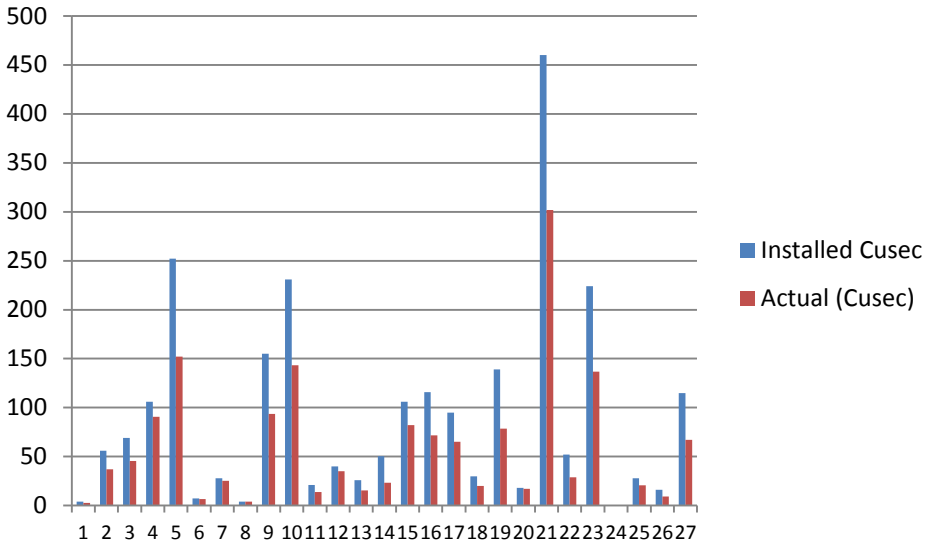
#	Towns	Subdivisions	Installed Cusec	Capacity (million m^3/yr)	Actual (Cusec)	*Avg. Discharge (million m^3/yr)
1	**Allama Iqbal Town**	Allama Iqbal Town	04	01.78	02.64	01.18
2		Ichra	56	25.01	37.19	16.62
3		Johar Town	69	30.82	45.67	20.40
4		Mustafa Town	106	47.35	90.73	40.53
5		Sabza Zar	252	112.58	152.19	67.99
6		Samanabad	07.4	03.30	06.55	02.92
	Total		***494.4***	***220.84***	***334.97***	***149.64***
7	**Gunj Buksh**	Anarkali	28	12.50	25.23	11.27
8		Islampura	04	01.78	03.96	01.76
9		Ravi Road	155	69.24	93.60	41.81
	Total		***187***	***83.52***	***122.79***	***54.84***
10	**Gulberg**	Gulberg	231	103.20	143.35	64.04
11		Mozang	21	09.38	13.99	06.25
12		Shimla Hill	40	17.87	34.98	15.62
	Total		***292***	***130.45***	***192.32***	***85.91***
13	**Nishtar Town**	Garden Town	26	11.61	15.62	06.97
14		Green Town	50.5	22.56	23.48	10.48
15		Industrial Area	106	47.35	82.18	36.71
16		Town Ship	116	51.82	71.74	32.05
	Total		***298.5***	***133.34***	***193.02***	***86.21***
17	**Ravi Town**	City	95	42.44	65.06	29.06
18		Data Nagar	30	13.40	20.12	08.98
19		Farukh Abad	139	62.09	78.66	35.14
20		Misri Shah	18	08.04	17.27	07.71
21		Shadbagh	460	205.5	301.92	134.88
22		Shahdara	52	23.23	28.87	12.89
	Total		***794***	***354.7***	***511.90***	***228.66***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	224	100.00	136.80	61.11
24		Fateh Garh	-	-	-	-
25		Mughal Pura	28	12.50	20.63	09.21
26		Mustafa Abad	16	07.14	09.24	04.12
27		Taj Pura	115	51.37	67.28	30.05
	Total		***383***	***171.01***	***233.95***	***104.49***
	G. Total		**2,448.90**	**1,093.86**	**1,588.95**	**709.75**

**Avg. Discharge is based on for average 12 hours per day operation and 365 days per year.*

The installed capacity of WASA disposal pumps of Lahore city is 1,093.86 million m^3 per annum whereas actual discharge is 709.75 million m^3 per annum, for average 12 hours per day operation and 365 days per year. This actual discharge is about 35% lesser than the installed capacity.

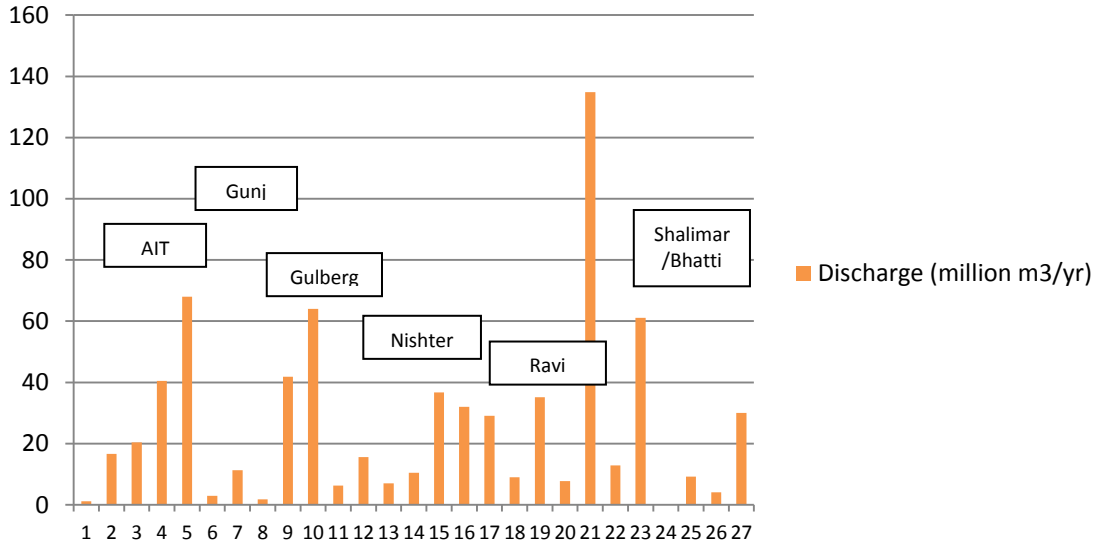
The comparison between installed capacity and actual discharge, in cusec, is illustrated in Fig-3.

Figure-3: Installed Capacity Vs Actual Discharge (Disposal Pumps)



The actual discharge, in million m^3/yr, for each subdivision is illustrated in Fig-4.

Figure-4: Actual Discharge Pattern of Subdivisions (Disposal Pumps)



2.4 Energy Consumption Trend

The detail of annual water discharge and correspondingly electricity consumption and unit electricity consumption of each subdivision of WASA station tube wells is given in Table-5.

Table-5: Detail of Water Discharge and Electricity Consumption

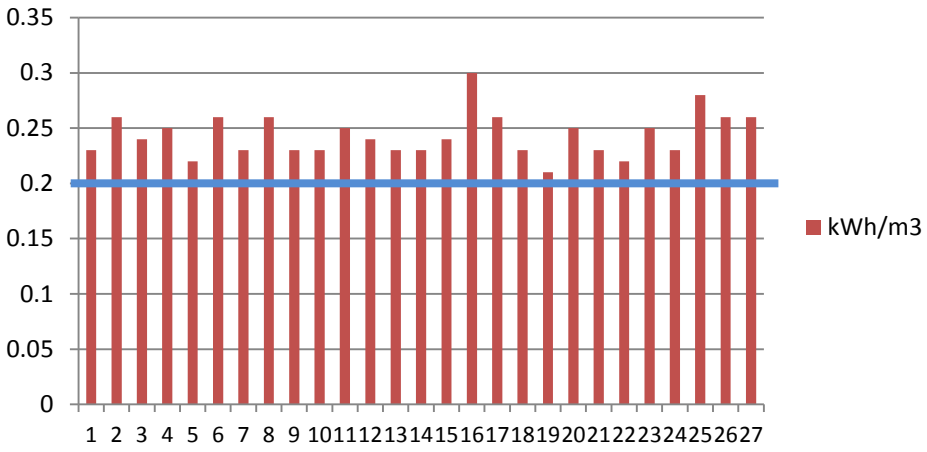
#	Towns	Subdivisions	*Actual Discharge (million m^3/yr)	Annual Electricity Consumption (million kWh/yr)	Unit Electricity Consumption (kWh/m^3)
1	**Allama Iqbal Town**	Allama Iqbal Town	29.79	6.92	0.23
2		Ichra	27.22	7.22	0.26
3		Johar Town	21.73	5.32	0.24
4		Mustafa Town	04.19	01.08	0.25
5		Sabza Zar	24.82	05.58	0.22
6		Samanabad	30.47	07.97	0.26
	Total		***138.22***	***34.09***	***0.24***
7	**Gunj Buksh**	Anarkali	32.65	07.67	0.23
8		Islampura	38.86	10.45	0.26
9		Ravi Road	34.29	08.06	0.23
	Total		***105.80***	***26.18***	***0.24***
10	**Gulberg**	Gulberg	36.17	08.33	0.23
11		Mozang	29.52	07.62	0.25
12		Shimla Hill	18.37	04.55	0.24
	Total		***84.06***	***20.50***	***0.24***
13	**Nishtar Town**	Garden Town	19.06	04.50	0.23
14		Green Town	34.34	08.19	0.23
15		Industrial Area	28.95	07.08	0.24
16		Town Ship	13.98	04.28	0.30
	Total		***96.33***	***24.05***	***0.24***
17	**Ravi Town**	City	34.16	09.02	0.26
18		Data Nagar	25.93	06.07	0.23
19		Farukh Abad	16.94	03.59	0.21
20		Misri Shah	31.54	08.14	0.25
21		Shadbagh	30.41	07.06	0.23
22		Shahdara	13.42	02.98	0.22
	Total		***152.40***	***36.86***	***0.24***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	38.90	09.99	0.25
24		Fateh Garh	27.43	06.54	0.23
25		Mughal Pura	28.19	07.92	0.28
26		Mustafa Abad	13.30	03.52	0.26
27		Taj Pura	21.26	05.58	0.26
	Total		***129.08***	***33.55***	***0.25***
	G. Total		**705.89**	**175.23**	**0.24**

**Actual discharge is based on actual water flow rate measurement and actual no. of operational hours of tube wells per year.*

The unit electricity consumption trend for each subdivision is illustrated in Fig-5. From figure, it is clear that 0.20 kWh/m^3 is considered to be optimum figure for water supply pumps. This figure is based on NEC experience of conducting water turbine audits of different industries.

WASA audits also reflect the similar figure.

Figure-5: Unit Electricity Consumption Trend (Tube Wells)



About 79% (369) of the tube wells consume electricity more than the 0.20 kWh/m^3. In case if all the 465 tube wells consume optimum electricity, then annually Rs. 443 million (19%) can be saved.

The detail of annual wastewater discharge and correspondingly electricity consumption and unit electricity consumption of each sub division of WASA station disposal pumps is given in Table-6.

Table-6: Detail of Wastewater Discharge and Electricity Consumption

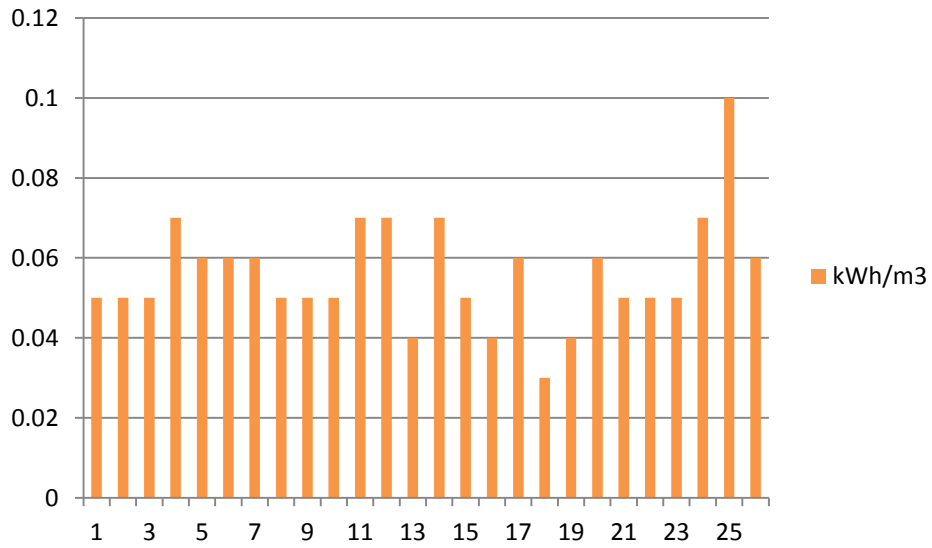
#	Towns	Subdivisions	*Actual Discharge (million m^3/yr)	Annual Electricity Consumption (million kWh/yr)	Unit Electricity Consumption (kWh/m^3)
1	**Allama Iqbal Town**	Allama Iqbal Town	01.10	0.06	0.05
2		Ichra	11.70	0.67	0.05
3		Johar Town	15.80	0.90	0.05
4		Mustafa Town	40.00	3.10	0.07
5		Sabza Zar	68.01	4.59	0.06
6		Samanabad	02.93	0.18	0.06
	Total		***139.54***	***9.50***	***0.06***
7	**Gunj Buksh**	Anarkali	12.93	0.88	0.06
8		Islampura	02.65	0.14	0.05
9		Ravi Road	24.06	1.41	0.05
	Total		***39.64***	***2.43***	***0.06***
10	**Gulberg**	Gulberg	121.85	6.60	0.05
11		Mozang	03.52	0.27	0.07
12		Shimla Hill	17.66	1.30	0.07
	Total		***143.03***	***8.17***	***0.05***
13	**Nishtar Town**	Garden Town	06.98	0.31	0.04
14		Green Town	05.14	0.41	0.07
15		Industrial	57.32	3.13	0.05

		Area			
16		Town Ship	62.87	2.70	0.04
	Total		***132.31***	***6.55***	***0.05***
17	**Ravi Town**	City	36.31	2.18	0.06
18		Data Nagar	17.41	0.63	0.03
19		Farukh Abad	62.42	2.61	0.04
20		Misri Shah	7.72	0.48	0.06
21		Shadbagh	134.82	7.24	0.05
22		Shahdara	12.91	0.69	0.05
	Total		***271.59***	***13.83***	***0.05***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	61.13	3.12	0.05
24		Fateh Garh	-	-	-
25		Mughal Pura	9.58	0.71	0.07
26		Mustafa Abad	6.89	0.69	0.10
27		Taj Pura	43.76	2.97	0.06
	Total		***121.36***	***7.49***	***0.06***
	G. Total		**847.47**	**47.97**	**0.05**

**Actual discharge is based on actual wastewater flow rate measurement and actual no. of operational hours of disposal pumps per year.*

The unit electricity consumption trend of each subdivision for disposal pumps is illustrated in Fig-6.

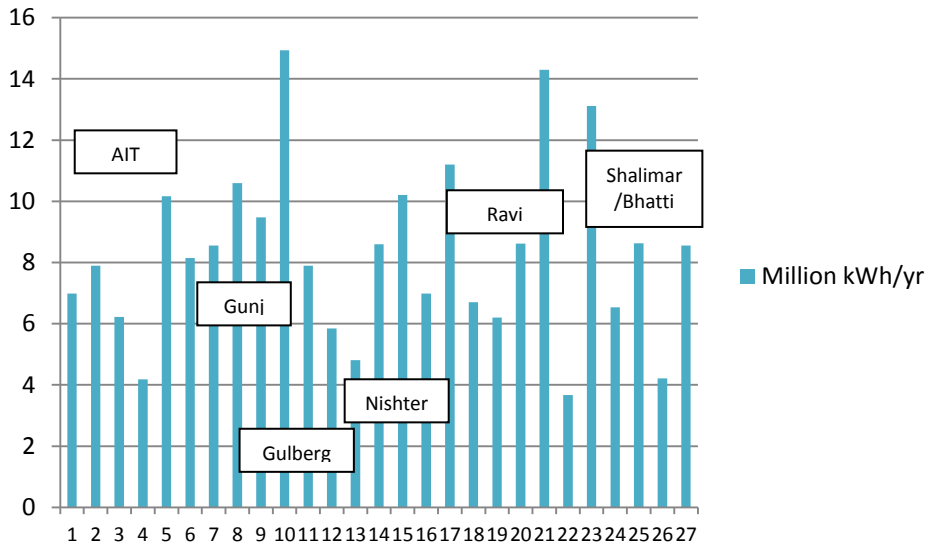
Figure-6: Unit Electricity Consumption Trend (Disposal Pumps)



Total annual electricity consumption of Lahore city to operate tube wells and disposal pumps is about **223 million kWh**. This energy, in monetary terms, is about **Rs. 2,902 million** (@ Rs. 13/kWh). . The contribution of tube wells in the energy consumption is about 78%.

Energy consumption trend of each WASA subdivision is illustrated in Fig-7.

Figure-7: Electricity Consumption Trend of Each Subdivision



2.5 Pumping System Efficiency Trend

Pumping plant efficiency of each tube well and disposal pump was monitored by measuring water flow rate, head and electricity consumption. The efficiency of each pumping system was classified as “Low”, “Fair”, “Good”, or “Excellent” by referring to the following table, which is based upon the results of thousands of pump tests conducted by Pacific Gas & Electric Company, USA. This classification is used to categorize WASA pumps.

Table-7: Typical Overall Pumping System Efficiency Classification

Motor HP	Low	Fair	Good	Excellent
3-7.5	<44.0	44-49.9	50-54.9	>54.9
10	<46.0	46-52.9	53-57.9	>57.9
15	<47.1	48-53.9	54-59.9	>59.9
20-25	<48.0	50-56.9	57-60.9	>60.9
30-50	<52.1	52.1-58.9	59-61.9	>61.9
60-75	<56.0	56-60.9	61-65.9	>65.9
100	<57.3	57.3-62.9	63-66.9	>66.9
150	<58.1	58.1-63.4	63.5-68.9	>68.9
200	<59.1	59.1-63.8	63.9-69.4	>69.4
250	<59.1	59.1-63.8	63.9-69.4	>69.4
300	<60	60-64.0	64.1-69.9	>69.9

Source: Pacific Gas & Electric Company, USA

The pumping system efficiency trend of each subdivision is given in Table-8:

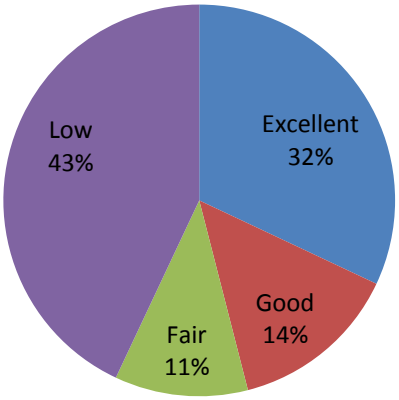
Table-8: Pumping System Efficiency Trend of Subdivisions

#	Towns	Subdivisions	Number of Pumps				Total No. of Pumps
			LOW	FAIR	GOOD	EXCELLENT	
1	**Allama Iqbal Town**	Allama Iqbal Town	07	02	01	10	20
2		Ichra	15	05	-	06	26
3		Johar Town	04	01	01	15	21
4		Mustafa Town	02	-	01	06	09
5		Sabza Zar	06	02	03	11	22
6		Samanabad	11	01	03	02	17
	Total		***45***	***11***	***09***	***50***	***115***
7	**Gunj Buksh**	Anarkali	07	03	04	10	24
8		Islampura	11	06	03	05	25
9		Ravi Road	16	03	01	09	29
	Total		***34***	***12***	***08***	***24***	***78***
10	**Gulberg**	Gulberg	08	04	08	23	43
11		Mozang	14	03	05	07	29
12		Shimla Hill	08	02	07	05	22
	Total		***30***	***09***	***20***	***35***	***94***
13	**Nishtar Town**	Garden Town	06	03	01	07	17
14		Green Town	13	03	03	10	29
15		Industrial Area	13	01	02	10	26
16		Town Ship	09	06	01	03	19
	Total		***41***	***13***	***07***	***30***	***91***
17	**Ravi Town**	City	16	05	13	06	40
18		Data Nagar	04	02	-	14	20
19		Farukh Abad	11	01	03	09	24
20		Misri Shah	14	05	02	04	25
21		Shadbagh	11	01	09	09	30
22		Shahdara	08	01	04	05	18
	Total		***64***	***15***	***31***	***47***	***157***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	13	02	05	06	26
24		Fateh Garh	03	03	05	05	16
25		Mughal Pura	26	06	-	03	35
26		Mustafa Abad	07	02	01	03	13
27		Taj Pura	15	02	05	04	26
	Total		***64***	***15***	***16***	***21***	***116***
	G. Total		**278**	**75**	**91**	**207**	**651**

About 46% of the tube wells and disposal pumps are under excellent and good category of pumping system efficiency whereas 54% are under fair and low category as illustrated in Fig-8.

The pumps of excellent and good category of system efficiency do not require any intervention to improve their efficiency whereas low and fair category pumps need efficiency improvement.

Figure-8: Pumping System Efficiency Category



3.0 Pumping System Efficiency Improvement Potential

This chapter describes pumping system efficiency improvement potential of WASA pumps of Lahore city. The efficiency of pumping system can be improved by following interventions:

- Replacement of pump
- Replacement of motor
- Replacement of pumping system (pump and motor)
- Adjustment of pump impellers
- Repair and maintenance of pump
- Adjustment of pump impellers and repair and maintenance

3.1 Pumping System Efficiency Improvement Potential of Lahore City

There are total 353 tube wells and wastewater disposal pumps (54% of total pumps) having system efficiency in the category of FAIR to LOW, as given in Table-8, have the potential of efficiency improvement into the GOOD category. Table-9 gives detail of this efficiency improvement potential.

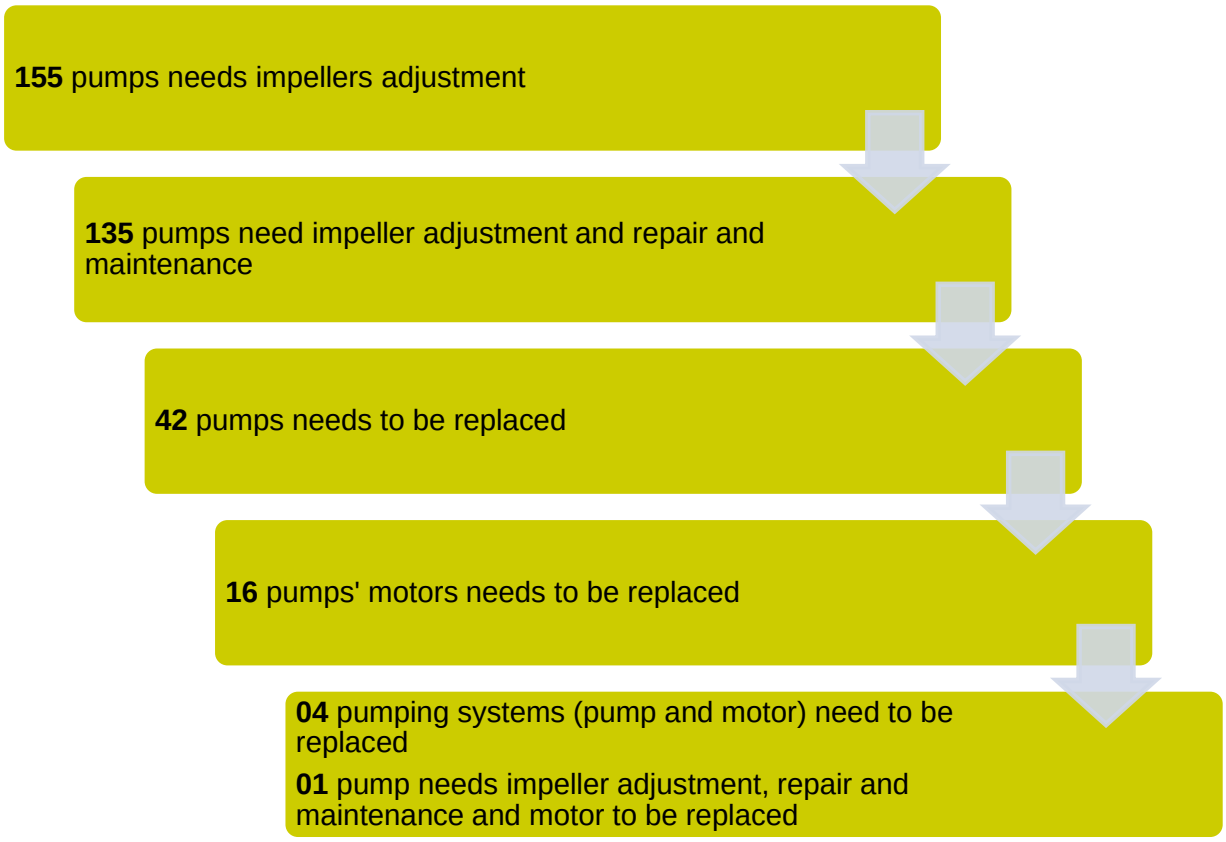
Table-9: Pumping System Efficiency Potential of Pumps

#	Towns	Subdivision	No. Pumps for Efficiency Improvement	Annual Saving		Intervention				Invest. (M. Rs)	Pay Back (Yr)
				Million (kWh)	Million (Rs)	IA	R & M	MR	PR		
1	**Allama Iqbal Town**	Allama Iqbal Town	9	0.69	9.04	*8	*4	*1	1	10.59	1.17
2		Ichra	20	1.13	14.70	*13	*7	5	2	23.20	1.57
3		Johar Town	5	0.30	4.26	*5	*3	-	-	4.02	0.94
4		Mustafa Town	2	0.03	0.44	*2	*1	-	-	0.36	0.82
5		Sabza Zar	8	0.87	11.39	5	-	-	3	9.8	0.86
6		Samanabad	12	1.30	16.90	*12	*5	-	-	7.81	0.46
	Total		***56***	***4.32***	***56.73***	***45***	***20***	***6***	***6***	***55.78***	***0.98***
7	**Gunj Buksh**	Anarkali	10	0.63	8.18	*10	*6	-	-	4.75	0.58
8		Islampura	17	2.00	26.08	*15	*4	1	1	14.7	0.56
9		Ravi Road	19	1.63	21.17	*13	*9	**2	**6	26.8	1.26
	Total		***46***	***4.26***	***55.43***	***38***	***19***	***3***	***7***	***46.25***	***0.83***
10	**Gulberg**	Gulberg	12	1.13	14.75	*9	*3	1	2	10.99	0.74
11		Mozang	17	1.07	13.97	*14	*5	-	3	15.92	1.13
12		Shimla Hill	10	0.54	6.98	*9	*5	-	1	7.32	1.04
	Total		***39***	***2.74***	***35.7***	***32***	***13***	***1***	***6***	***34.23***	***0.95***
13	**Nishtar Town**	Garden Town	9	0.75	9.77	*7	*3	1	1	10.14	1.03
14		Green Town	16	1.46	19.08	*15	*10	-	1	9.36	0.49
15		Industrial Area	14	1.86	24.25	*7	*4	2	5	17.69	0.72
16		Town Ship	15	1.75	22.84	*9	*3	**2	**5	22.23	0.97
	Total		***54***	***5.82***	***75.94***	***38***	***20***	***5***	***12***	***59.42***	***0.78***
17	**Ravi Town**	City	21	1.88	24.20	*16	*5	2	3	18.03	0.74
18		Data Nagar	6	0.37	4.77	5	-	1	-	5.14	1.07
19		Farukh	12	0.83	10.85	*9	*5	-	3	12.71	1.17

		Abad									
20		Misri Shah	19	1.15	15.05	*18	*7	1	-	11.91	0.79
21		Shadbagh	12	1.58	20.48	*12	*4	-	-	6.33	0.30
22		Shahdara	9	0.28	3.60	*9	*6	-		2.86	0.79
	Total		***79***	***6.09***	***78.95***	***69***	***27***	***4***	***6***	***56.98***	***4.86***
23	**Shalimar Town & Aziz Bhatti Town**	Baghban Pura	15	2.10	27.41	*14	*8	-	1	11.11	0.40
24		Fateh Garh	6	0.38	5.00	*4	*1	1	1	7.25	1.45
25		Mughal Pura	32	1.89	24.57	*28	*13	**1	** 4	26.57	1.08
26		Mustafa Abad	9	0.72	9.35	9	*5	-	-	6.22	0.66
27		Taj Pura	17	1.59	19.71	*14	*10	-	3	14.95	0.75
	Total		***79***	***6.68***	***86.04***	***69***	***37***	***2***	***9***	***66.1***	***0.76***
	G. Total		**353**	**29.91**	**388.79**	**291**	**136**	**21**	**46**	**318.76**	**0.82**

IA *Impeller Adjustment,* ***R&M*** *Repair & Maintenance,* ***MR*** *Motor Replace,* ***PR*** *Pump Replace*
/ Both interventions*

The 353 pumps require interventions, such as:



3.2 Investment and Saving

Total investment for the efficiency enhancement and improvement of electrical and mechanical and housekeeping condition of 353 pumps is **Rs. 319** million with annual saving of Rs. **389** million. The payback period varies from 04 months to 19 months for different subdivisions. The pumping system efficiency improvement will result into **13%** energy reduction.

Energy audit activity of WASA stations of Lahore city revealed that there are certain areas of electrical, mechanical and housekeeping which needs improvement along with efficiency improvement. About **Rs. 488** million are required to improve all WASA stations of Lahore city.

The detail of investment of each subdivision of Lahore city is given in Table-10 along with improvement interventions.

Table-10: Investment Requirement for Improvement of WASA Pumps

#	Town	Subdivision	Investment (Rs. Million)	Improvement Interventions
1	**Allama Iqbal Town**	Allama Iqbal Town	18.85	- Impeller adjustment - Repair & maintenance of pump - Replacement of motor/pump - Installation of PFI plant, VFD, water flow meter, digital pressure gauge, current & voltage relays, volt & ammeter, motor terminal box, fuses, hour meter, and chlorinator - Proper/safe wiring - Maintenance (ratchet plate/gland leakage, non return valve leakage)
2		Ichra	27.16	
3		Johar Town	15.45	
4		Mustafa Town	2.68	
5		Sabza Zar	17.24	
6		Samanabad	12.13	
	Total		***93.51***	
7	**Gunj Buksh**	Anarkali	14.18	
8		Islam Pura	19.73	
9		Ravi Road	34.83	
	Total		***68.74***	
10	**Gulberg**	Gulberg	25.16	
11		Mozzang	20.67	
12		Shimla Hill	13.54	
	Total		***59.37***	
13	**Nishtar Town**	Garden Town	14.51	
14		Green Town	16.34	
15		Industrial Area	24.80	
16		Town Ship	24.35	
	Total		***80.00***	
17	**Ravi Town**	City	26.25	
18		Data Nagar	11.45	
19		Farrukh Abad	18.13	
20		Misri Shah	15.88	
21		Shadbagh	16.14	
22		Shahdara	7.83	
	Total		***95.68***	
23	**Shalimar/Aziz Bhatti**	Baghban Pura	19.89	
24		Fateh Garh	13.82	
25		Mughal Pura	27.89	
26		Mustafa Abad	9.23	
27		Taj Pura	20.04	
	Total		***90.87***	
	G. Total		**488.17**	