NEC Consultants (Pvt.) Ltd.

Punjab Cities Governance Improvement Project

Energy Audit & Energy Efficiency Improvement Program for WASAs in Punjab

REPORT

Chiniot Well Field Area- Faisalabad

April 2016

Energy Audit & Energy Efficiency Improvement Program for WASAs in Punjab

March 2016

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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 or Pumping System Efficiency	The ratio of the water horsepower (the overall output of the plant) 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.

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 report of **Chiniot Well Field Area of Faisalabad 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/zone was prepared.
- On the basis of each subdivision/zone summary report, one consolidated report of each city for energy efficiency improvement opportunities of the WASAs was prepared.

2.0 Energy Audit Findings

There are 24 WASA water supply stations in Chiniot Well Field Area of Faisalabad city. The detail of these stations along with pumps installed capacity and actual discharge is given in Table-2:

Table-2: Detail of Chiniot Well Field Area

#	WASA Station	No. of Water Supply Pumps Installed	Installed Capacity (Cusec)	Actual Discharge (Cusec)
1	T-CWA-001	01	4.10	3.22
2	T-CWA-002	01	4.38	3.40
3	T-CWA-004	01	4.12	3.55
4	T-CWA-005	01	4.10	3.37
5	T-CWA-006	01	4.07	4.36
6	T-CWA-007	01	4.41	3.03
7	T-CWA-014	01	4.27	3.13
8	T-CWA-018	01	4.59	3.24
9	T-CWA-019	01	4.70	3.35
10	T-CWA-020	01	4.70	3.49
11	T-CWA-021	01	4.00	3.80
12	T-CWA-022	01	4.00	2.53
13	T-CWA-008	01	4.34	3.72
14	T-CWA-0010	01	4.20	2.85
15	T-CWA-011	01	5.40	4.04
16	T-CWA-0012	01	5.40	2.44
17	T-CWA-0013	01	4.20	4.38
18	T-CWA-0015	01	4.27	3.34
19	T-CWA-016	01	4.27	1.79
20	T-CWA-017	01	4.27	3.38
21	T-CWA-023	01	4.00	3.45
22	T-CWA-024	01	4.00	2.69
23	T-CWA-025	01	4.06	3.53
24	T-CWA-028	01	4.00	4.63
	Total	**24**	**103.85**	**80.71**

The installed capacity of WASA tube wells of Chiniot Well Field Area is 69.59 million m^3 per annum whereas actual discharge is 54.09 million m^3 per annum, for average 18 hours per day operation and 365 days per year. This actual discharge is about 22% lesser than the installed capacity.

2.1 Pumping System Efficiency

Pumping plant performance can be 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-3: 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

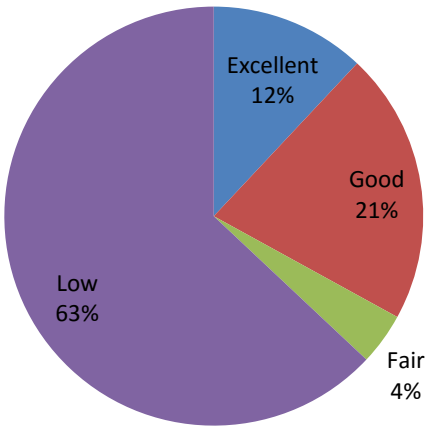
The detail of pumping system efficiency and motor loading of each WASA station is given in Table-4. The calculations for the efficiency determination are given in the energy audit report of each pump in **Annexure-1**.

Table-4: Detail of Motor Loading and Pumping System Efficiency

WASA Station	Motor Load (%)	Pumping System Efficiency (%)	Pumping System Efficiency Rating
T-CWA-020	71	82	EXCELLENT
T-CWA-011	74	79	EXCELLENT
T-CWA-028	89	81	EXCELLENT
T-CWA-006	87	64	GOOD
T-CWA-021	79	65	GOOD
T-CWA-013	81	64	GOOD
T-CWA-017	75	67	GOOD
T-CWA-025	57	65	GOOD
T-CWA-023	85	58	FAIR
T-CWA-001	83	49	LOW
T-CWA-002	84	47	LOW
T-CWA-004	89	45	LOW
T-CWA-005	88	44	LOW
T-CWA-007	86	42	LOW
T-CWA-014	76	55	LOW
T-CWA-018	86	45	LOW
T-CWA-019	80	55	LOW
T-CWA-022	70	52	LOW
T-CWA-008	85	56	LOW
T-CWA-010	73	41	LOW
T-CWA-012	67	40	LOW
T-CWA-015	78	53	LOW
T-CWA-016	69	29	LOW
T-CWA-024	73	51	LOW

About 33% of the tube wells are under excellent and good category of pumping system efficiency whereas 67% are under fair and low category as illustrated in Fig-1.

Figure-1: Pumping System Efficiency Category



2.2 Electricity Consumption Trend

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

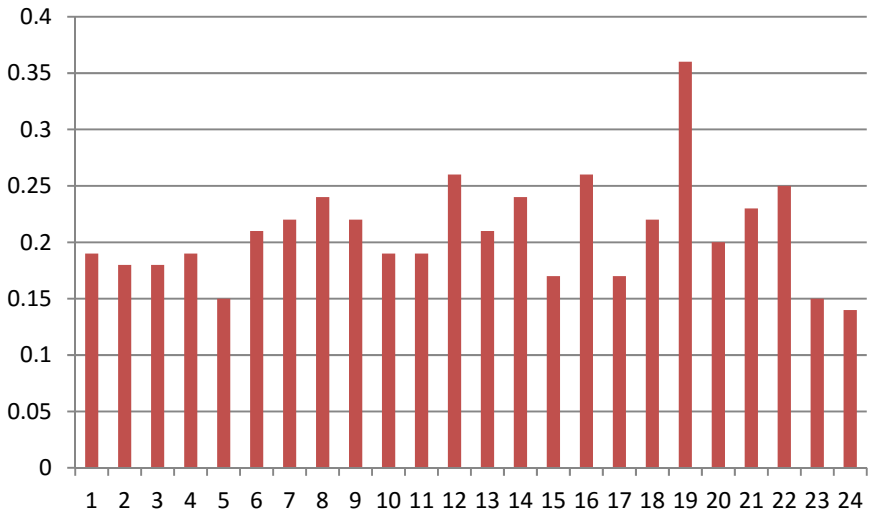
Table-5: Detail of Water Discharge and Electricity Consumption

#	WASA Station	Annual Water Discharge (m^3)	Annual Electricity Consumption (kWh)	Unit Electricity Consumption (kWh/m^3)
1	T-CWA-001	2,154,960	409,766	0.19
2	T-CWA-002	2,279,790	416,195	0.18
3	T-CWA-004	2,378,340	439,908	0.18
4	T-CWA-005	2,260,080	438,367	0.19
5	T-CWA-006	2,923,650	429,824	0.15
6	T-CWA-007	2,030,130	428,129	0.21
7	T-CWA-014	2,094,976	471,173	0.22
8	T-CWA-018	2,168,100	530,620	0.24
9	T-CWA-019	2,122,110	467,870	0.22
10	T-CWA-020	2,338,920	440,349	0.19
11	T-CWA-021	2,825,100	545,543	0.19
12	T-CWA-022	1,695,060	433,743	0.26
13	T-CWA-008	2,490,030	524,015	0.21
14	T-CWA-010	1,911,870	452,458	0.24
15	T-CWA-011	2,704,212	458,183	0.17
16	T-CWA-012	1,635,930	417,230	0.26
17	T-CWA-013	2,936,790	499,135	0.17
18	T-CWA-015	2,234,457	483,283	0.22
19	T-CWA-016	1,062,880	377,721	0.36
20	T-CWA-017	2,265,205	462,366	0.20
21	T-CWA-023	2,312,640	528,418	0.23
22	T-CWA-024	1,804,122	451,357	0.25
23	T-CWA-025	2,365,200	352,279	0.15

24	T-CWA-028	3,101,040	440,349	0.14
	Total	**54,095,592**	**10,898,281**	**0.21**

Total annual energy cost of Chiniot Well Field Area is about Rs. 142 million. The unit electricity consumption trend for each WASA station is illustrated in Fig-2.

Figure-2: Unit Electricity Consumption Trend (Tube Wells)



2.3 Pumping System Efficiency Improvement Potential

The 16 tube wells having system efficiency in the category of FAIR to LOW, as given in Table-4, have the potential of efficiency improvement into the GOOD category. Table-6 gives detail of this efficiency improvement potential.

Table-6: System Energy Efficiency Potential of Pumps

WASA Station	Existing Pumping Efficiency (%)	Improved Pumping Efficiency (%)	Annual Saving (kWh)	(Rs)	Intervention Imp .Adj	Rep & Main	Motor Repl.	Pump Repl.
T-CWA-001	49	63	94,170	1,224,214	X	X		
T-CWA-002	47	63	105,993	1,377,911	X	X		
T-CWA-004	45	63	126,665	1,646,643	X	X		
T-CWA-005	44	63	130,022	1,690,288	X	X		
T-CWA-007	42	63	141,633	1,841,226	X	X		
T-CWA-014	55	64	66,101	859,315	X			
T-CWA-018	45	64	161,043	2,093,561	X	X		
T-CWA-019	55	64	68,970	896,605	X			
T-CWA-022	52	64	83,670	1,087,716	X	X		
T-CWA-008	56	64	62,453	811,889	X			
T-CWA-010	41	64	159,109	2,068,420	X	X		
T-CWA-012	40	64	154,960	2,014,475	X	X		
T-CWA-015	53	64	76,521	994,779	X	X		

T-CWA-016	29	64	205,407	2,670,297				**X**
T-CWA-023	58	64	46,246	601,202	**X**			
T-CWA-024	51	64	89,693	1,166,009	**X**	**X**		
Total			**1,772,656**	**23,044,550**				

2.4 Interventions for the Improvement of WASA Stations

Energy audit activity of Chiniot Well Field Area revealed that there are certain areas of electrical, mechanical and housekeeping which needs improvement. Table-7 presents detail of interventions and investment requirement in each WASA station for better, efficient and safe operation of WASA station.

About Rs. 15.58 million are required to improve WASA stations of Chiniot Well Field Area of Faisalabad city.

Table-7A: Interventions & Investment Required in WASA Stations- Chiniot Well Field Area

Intervention	WASA Stations														
	T-CWA-001	T-CWA-002	T-CWA-004	T-CWA-005	T-CWA-006	T-CWA-007	T-CWA-014	T-CWA-018	T-CWA-019	T-CWA-020	T-CWA-021	T-CWA-022	T-CWA-008	T-CWA-010	T-CWA-011
Electrical															
Install VFD	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Install hour meter	x	x	x	x	x	x	X	x	X	x	X	x	x	x	x
Replace ampere meter	x	x		x		x		x			X	x		x	x
Replace volt meter	x	x						x	X	x	X	x		x	x
Replace over current relays								x				x			
Replace over voltage relay															
Install/maintain PFI plant	x	x	x		x		X	x	x	x	X	x		x	x
Install/connect capacitors at PFI plant													x		
Install PFI control/relay															
Install/replace motor terminal box /Improve open and loose motor connection															
Improve panel condition		x	x				X	x		x		x	x		x
Improve wiring condition		x	x		x		X	x		x		x	x		
Replace de-rated capacitors															
Relocate panel away from bore hole															
Replace electrical motor															
Install fan in the panel															
Replace PFI HRC fuses															
Replace PFI display meter															
Correct date & time of electrical meter															
Replace/correct electrical meter															
Replace change over															
Replace main circuit breaker															
Mechanical															
Replace damaged/install new flow meter						x			x	x		x	x	x	X

Intervention	WASA Stations														
	T-CWA-001	T-CWA-002	T-CWA-004	T-CWA-005	T-CWA-006	T-CWA-007	T-CWA-014	T-CWA-018	T-CWA-019	T-CWA-020	T-CWA-021	T-CWA-022	T-CWA-008	T-CWA-010	T-CWA-011
Replace damaged/install new digital pressure gauge	x	x	x	x	x	x	x	x		x		x	x	x	X
Control gland leakage	x	x									x	x	x	x	X
Make operational/install new chlorinator															
Maintain ratchet plate											x	x			
Adjust impeller	x	x	x	x		x	X	x	x			x	x	x	
Repair & maintenance of pump	x	x	x	x		x		x				x		x	
Replace existing pumping system															
Maintain/install new non return valve															
Housekeeping															
Improve general housekeeping	x	x	x	x	X	x	X	x	x	x	x	x	x	x	X
Install shades on motor & pump															
Rain protection of motor & pump															
Fix panel properly															
Proper support of discharge pipeline															
Maintain monthly record of fuel consumption															
Station Wise Investment (M. Rs)	0.550	0.550	0.520	0.528	0.180	0.695	0.260	0.550	0.455	0.435	0.150	0.820	0.620	0.800	0.440
Annual Saving (M. Rs)	1.224	1.378	1.647	1.690	---	1.841	0.859	2.094	0.897	--	---	1.088	0.812	2.068	**--**
Payback (Year)	0.449	0..399	0.316	0.312	---	0.378	0.303	0.263	0.507	--	---	0.754	0.764	0.387	**--**

Table-7B: Interventions & Investment Required in WASA Stations-Chiniot Well Field Area

Intervention	WASA Stations															
	T-CWA-012	T-CWA-013	T-CWA-015	T-CWA-016	T-CWA-017	T-CWA-023	T-CWA-024	T-CWA-025	T-CWA-028							
Electrical																
Install VFD	x	x	x	x	x	x	x									
Install hour meter	x	x	x	x	x	x										
Replace ampere meter			x	x	x											
Replace volt meter			x				x									
Replace over current relays		x	x	x	x		x									
Replace over voltage relay																
Install/maintain PFI plant	x	x		x	x	x	x	x	x							
Install/connect capacitors at PFI plant																
Install PFI control/relay																
Install/replace motor terminal box																
Improve panel condition	x		x					x	x							
Improve wiring condition	x		x		x	x	x	x	x							
Replace de-rated capacitors																
Relocate panel away from bore hole																
Replace electrical motor																
Install fan in the panel																
Replace PFI HRC fuses																
Replace PFI display meter																
Correct date & time of electrical meter																
Replace/correct electrical meter																
Replace change over																
Replace main circuit																

Intervention	WASA Stations														
	T-CWA-012	T-CWA-013	T-CWA-015	T-CWA-016	T-CWA-017	T-CWA-023	T-CWA-024	T-CWA-025	T-CWA-028						
breaker															
Mechanical															
Replace damaged/install new flow meter	x			x				x	x						
Replace damaged/install new digital pressure gauge	x	x	x	x	x	x	x	x	x						
Control gland leakage	x	x	x		x				x						
Make operational/install new chlorinator															
Maintain ratchet plate						x									
Adjust impeller	x		x			x	x								
Repair & maintenance of pump	x		x				x								
Replace existing pumping system				x											
Maintain/install new non return valve															
Housekeeping															
Improve general housekeeping	x	x	x	x		x	x								
Install shades on motor & pump															
Rain protection of motor & pump															
Fix panel properly															
Proper support of discharge pipeline															
Maintain monthly record of fuel consumption															
Station Wise Investment (M. Rs)	0.790	0.180	0.430	4.455	0.205	0.280	0.790	0.450	0.455						
Annual Saving (M. Rs)	2.014	---	0.995	2.670	---	0.601	1.166	---	---						
Payback (Year)	0.392	---	0.432	1.669	---	0.466	0.678	---	---						

ANNEXURE-1

Energy Audit Reports