Detailed Feasibility Report Borderline Pump Station

Prepared for
UNIDO – CTCN

Under the project
Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious “technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan”.

The study team is indebted to Mr. Ian Gooden, Chief Executive Officer, Solomon Island Water Authority for showing keen interest in the study and thankful to the progressive management of Solomon Water for their wholehearted support and cooperation for the study and preparation of Detailed Feasibility Report. It is well worthy to mention that the efforts being taken, and the enthusiasm shown by all the personnel towards energy efficiency was admirable. A special thanks to Mr. Mark Waite (Strategic Projects Management Advisor), Mr. Shaun Kies-Ryan (Hydrogeologist), Mr. Noel Orudiana (Project Manager) and Mr. Danny Titiri (Electrical and Mechanical Team Lead) for coordinating the field visits. We would like to thank all the staff for support including technicians, electricians i.e. Mr. Livingston, Mr. Sam and Mr. Moffat.

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Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Borderline pump station is in Green Valley area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Borderline SIWA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. At the time of study all the four bore-pumps were operational, and two transfer pumps were running in parallel. Details of Borderline pump station is presented below.

Name of the pump station	Borderline
No. of transfer pumps	3 (2 Run + 1 Standby)
No. of bore-hole pumps	4 (4 Run)
Monthly electricity consumption	24067 kWh (average of last 12 months)
Monthly water production	48394 m^3 (based on onsite measurement)
Name and details of contact person	Livingston Kute, Plumber +677-7459172 Danny Titiri, Electrical and Mechanical Team Lead dtitiri@solomonwater.com.sb, +677-8876857
Annual working days	365

A detailed feasibility study of Borderline pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Borderline pump station is in Green Valley area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m³ water receiver tank, which receives water from four boreholes. The water from receiving tanks is pumped to Borderline SIWA reservoir using three transfer pumps. The pump station produces 1591 m³ water daily consuming about 789 kWh electrical energy. The existing specific energy consumption is 0.496 kWh per m³. The study has identified four recommendations for energy conservation (table). These recommendations could save annually about 43,140 kWh of electricity. These recommendations have an estimated investment of US $ 20,584 and can yield a monetary savings of US $ 29,551 per year. The annual energy saving is estimated to be 14.9% of total energy consumption by the pump station (figure). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 28.47 tonnes of CO_2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement of transfer pump-1	7,624	$ 5,222	$ 12,250	2.3	5.03
ECM-2	Switch-off borepump-3 until maintenance	9,884	$ 6,771	$ -	0.0	6.52
ECM-3	Replacement of borepump-4 with efficient pump	25,431	$ 17,421	$ 8,094	0.5	16.78
ECM-4	Replacement of FTL with LED lights	201	$ 138	$ 240	1.7	0.13
	Total	**43,140**	**$ 29,551**	**$ 20,584**	**0.7**	**28.47**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 28**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.496 kWh/m³	0.430 kWh/m³
Specific CO_2 emission	0.328 kg CO_2/m³	0.284 kg CO_2/m³

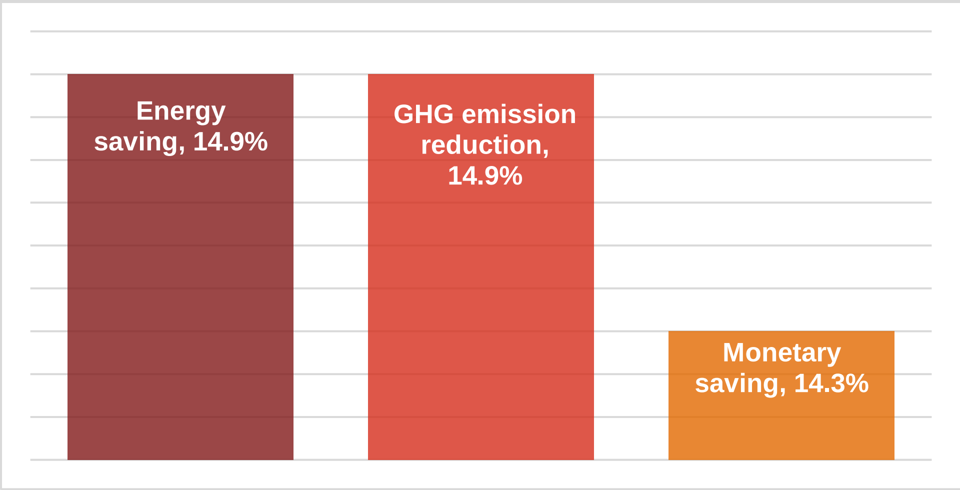
On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

Funding options

The overall investment proposed for four energy conservation measures for Borderline pump station is US$ 20,584. The simple payback on this investment is 7 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 5 months, which can be followed by transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Borderline pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Identified saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m^3	1,000 liters
1 USD	8 SBD

* *Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[1] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

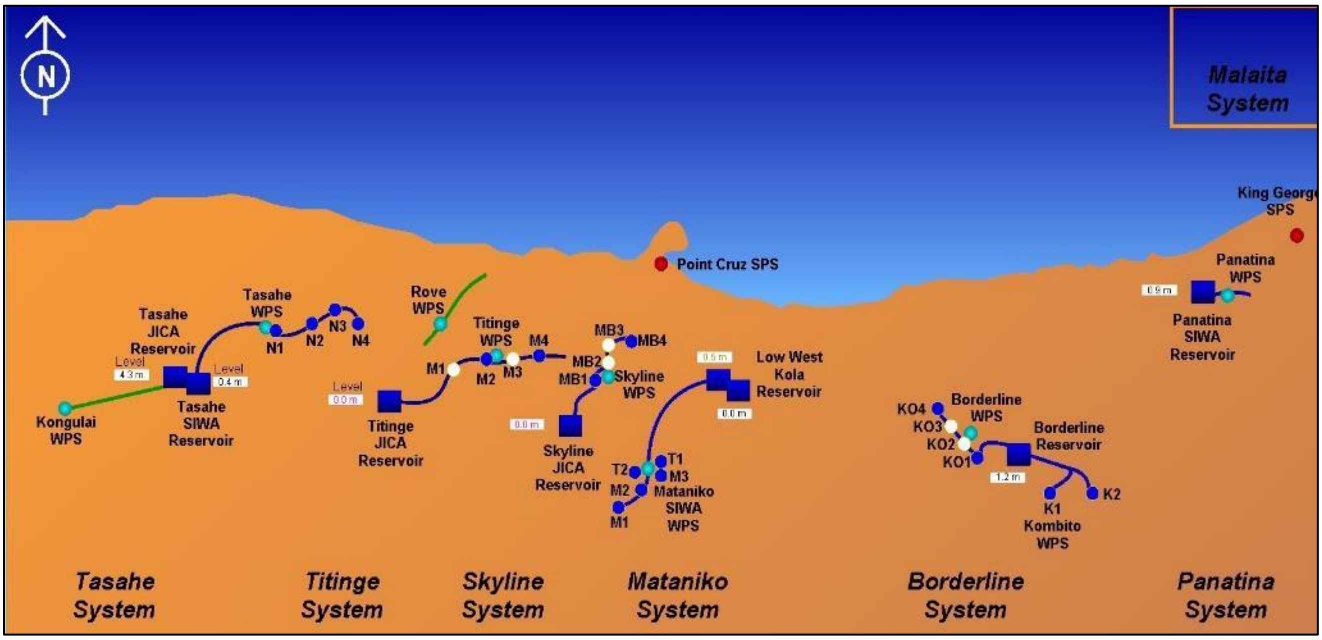

Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[1]

[1] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[2]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

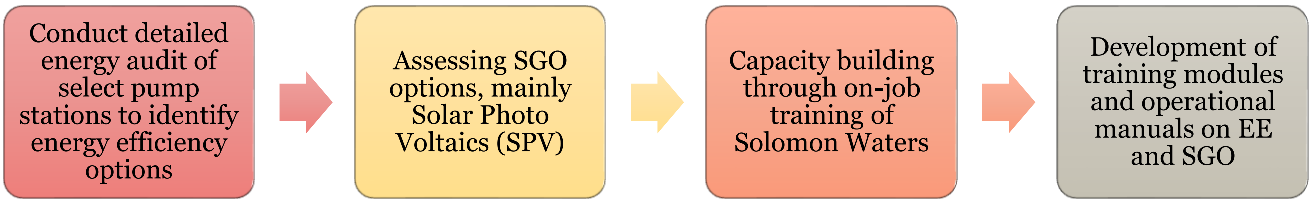

Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[2] *Response Plan, CTCN request ID: 2017000039*

Assessment of Energy Efficiency and RE options
- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options

Capacity building through on-job training for Solomon Water
- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation

Detail assessments of shortlisted EE and SGO options for Solomon Water
- Technical analysis
- Financial analysis

Monitoring of impact
- Monitoring and evaluation of Impacts
- Report on Gender co-benefits

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

Environmental Benefits	Economic Benefits	Social Benefits
• Enhanced energy efficiency • Improved energy security • Lower dependence on imported fuels • Contribution towards climate change mitigation	• Reduced operating (energy) cost for Solomon Water • Increased investments in energy efficiency and renewable energy	• Skill enhancement of Solomon Water professionals on EE and RE • Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

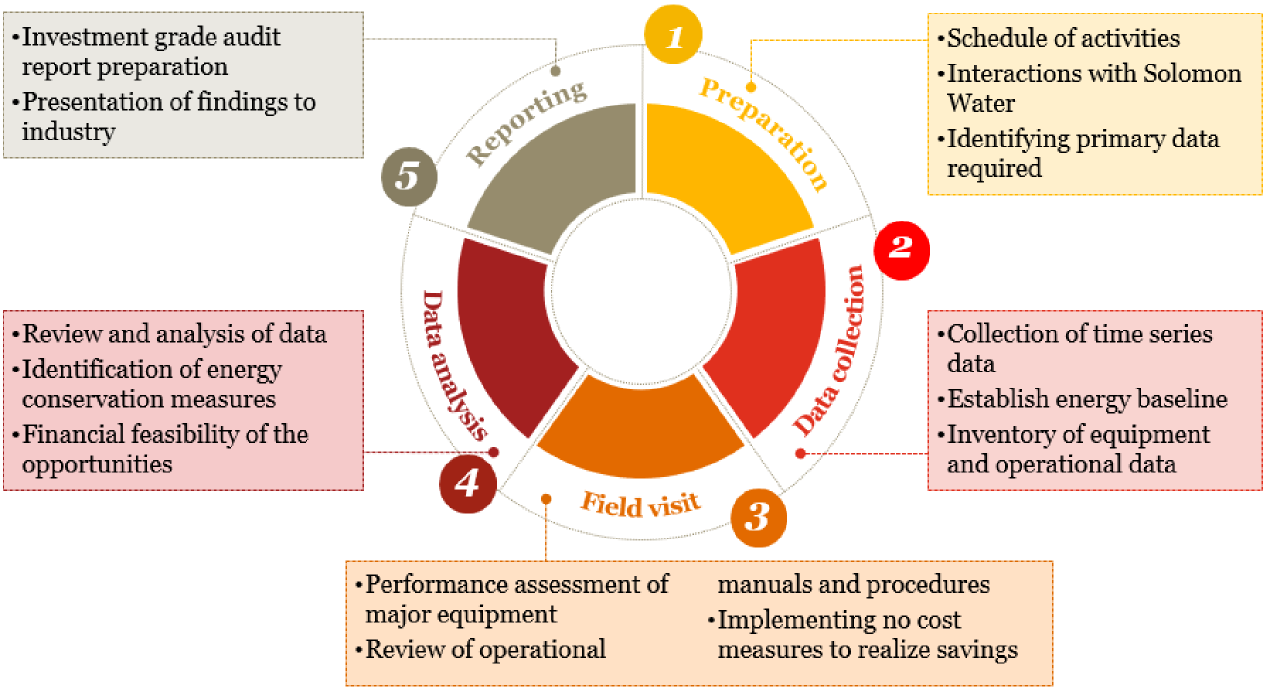

Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Borderline pump station

2.1. About Borderline pump station

Borderline pump station is in Green Valley area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Borderline SIWA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. At the time of study all the four bore-pumps were operational, and two transfer pumps were running in parallel. The overview of Borderline pump station as seen in Solomon Water SCADA system is shown in **Figure 6**.

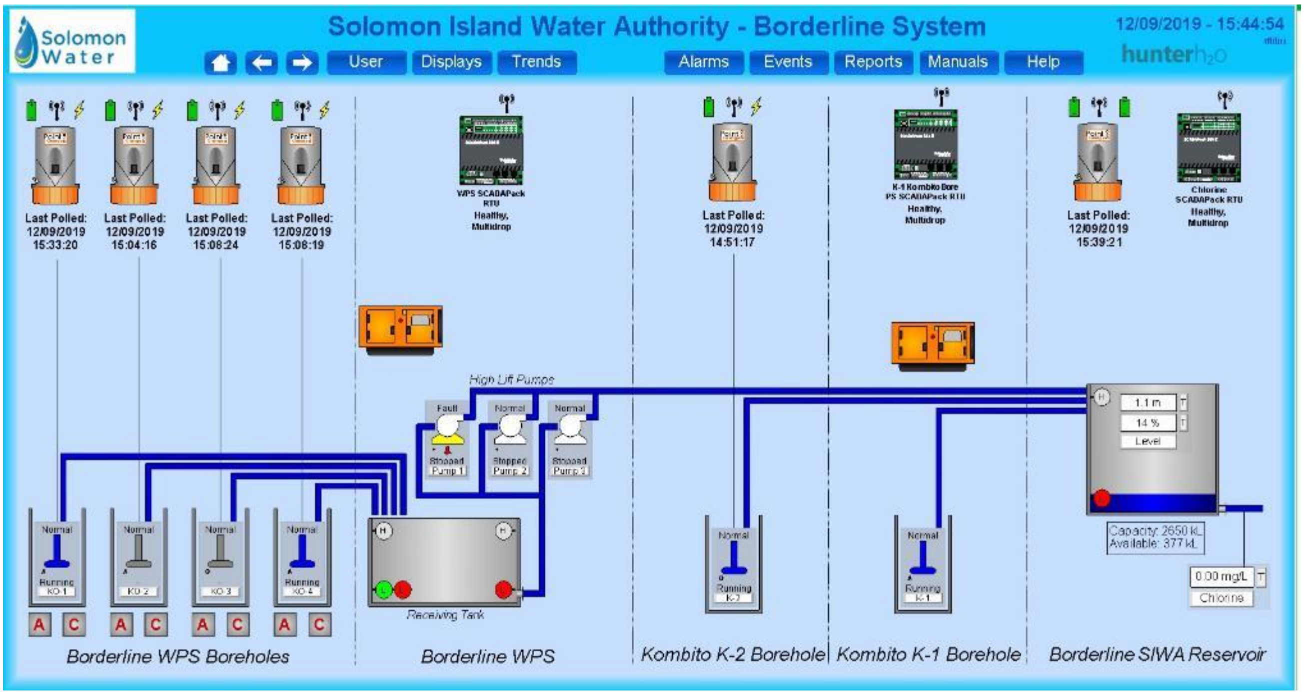

Figure 6 Borderline pump station overview - SCADA system

2.2. Transfer pumps

The Borderline pump station is equipped with three vertical multi-stage centrifugal pumps. These three pumps are connected to operate in parallel. Pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Borderline SIWA reservoir. Two transfer pump operates at any given time, with third one as standby. Design details of the transfer pumps and its corresponding motor is presented in **Table 2** and **Table 3** respectively. The pictorial view of transfer pumps is presented in **Figure 7**.

Table 2 Design details of transfer pumps

Particular	Unit	Pump #1, #2, #3
Make	-	Grundfos
Model	-	CRN 64-2-1 AFGV-HQQV
Design flow	m^3/h	64.0
Design head	m	37.2

Particular	Unit	Pump #1, #2, #3
Max. head	m	51.3
Impeller type	-	Stainless Steel
Pump speed	rpm	2924
Recommended motor rating	kW	11.0
Max. pressure	bar	16.0
Pump efficiency	%	77.1

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor #1, #2, #3
Make	-	Grundfos
Power	kW	11.0
Voltage	V	415.0
Current	I	19.8
Power Factor	-	0.89
Motor speed	rpm	2950
Frequency	Hz	50.0
Rating	-	IE3
Efficiency	%	91.2

Figure 7 Borderline transfer pumps

2.3. Borehole pumps

The Borderline pump station receives water from four borehole pumps. Water is extracted using submersible centrifugal pumps. As the pumps were underground, name plates could not be checked physically. The design details were collected from records available at Solomon Water maintenance office. Initially, the system was designed for 24 x 7 operation of four bore pumps. All four bore-pumps were operational during testing.

The design details of bore pumps is presented in **Table 4** and schematic view of Borderline bore-field is presented in **Figure 8**.

Table 4 Design details of borehole pumps

Particular	Unit	KO-1	KO-2	KO-3	KO-4
Make	-	Grundfos	Grundfos	Grundfos	Grundfos
Model	-	SP46-4	SP46-9C	SP46-4	SP46-6
Design flow	m^3/h	36.5	35.0	46.0	42.0
Design head	m	39.4	88.2	33.7	53.8
Pump depth	m	37	82	23	40
Pump efficiency	%	72.0	74.5	72.1	72.1

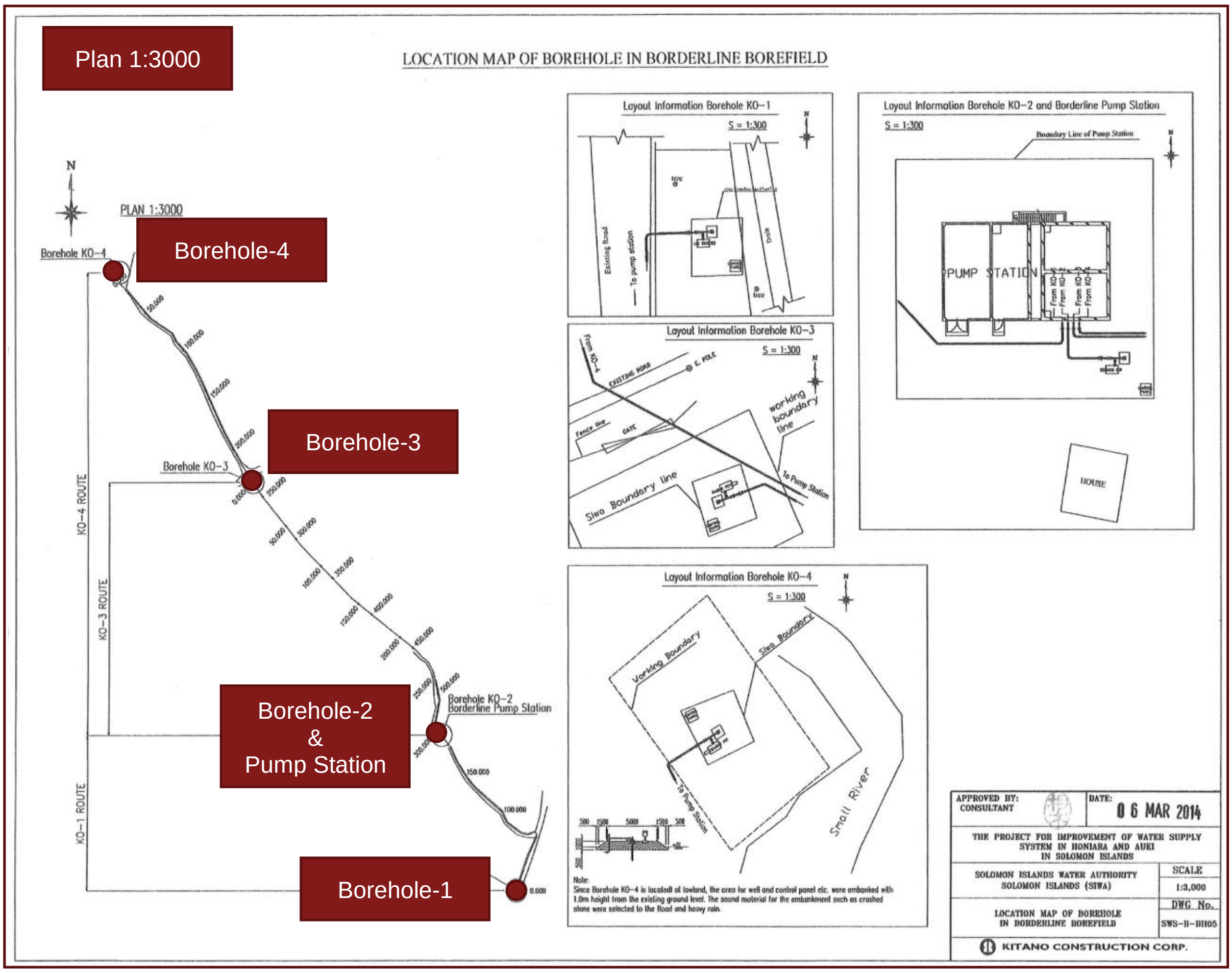

Figure 8 Location of boreholes in Borderline bore-field

3. Energy consumption analysis

3.1. Energy source and tariff details

Borderline pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Borderline pump station is under Industrial I3 type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff for last 12 months was captured during feasibility study and same is presented in **Table 5**.

Table 5 Electricity tariff details – Last 12 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)			NAC (SBD/month)[3]
		I1[4]	I2[5]	I3[6]	
Aug-18	2.85	3.68	3.16	2.81	3,175.72
Sep-18	2.85	3.7	3.18	2.83	3,199.91
Oct-18	2.71	3.71	3.19	2.84	3,204.42
Nov-18	2.83	3.72	3.2	2.85	3,218.49
Dec-18	2.81	3.75	3.23	2.87	3,242.95
Jan-19	2.77	3.77	3.24	2.89	3,258.18
Feb-19	2.49	3.11	2.68	2.38	2,690.01
Mar-19	2.71	3.79	3.26	2.90	3,277.82
Apr-19	2.53	3.61	3.11	2.77	3121.85
May-19	2.64	3.85	3.31	2.95	3328.04
Jun-19	2.21	3.85	3.31	2.95	3,324.80
Jul-19	2.38	3.84	3.3	2.94	3,316.60
Average	**2.65**	**3.70**	**3.18**	**2.83**	**3,196.57**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 18 months for Borderline pump station was analyzed. The average electricity tariff and consumption for last 12 months was evaluated. These 12-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 12 months (August 2018 to July 2019) was 288,800 kWh. The bill amount corresponding to this consumption was SBD 1.65 million i.e. USD 206,272.

The electricity consumption along with monthly energy charges is presented in **Table 6**. Variation of electricity consumption is presented in **Figure 9**.

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[3] *I3 connection electricity consumption>6000 kWh*
[4] *First 1300 units of the monthly consumption*
[5] *Next 4700 units of the monthly consumption*
[6] *Remaining consumption of the month*

Table 6 Electricity consumption details

Month	Consumption	NAC (SBD)	Fuel charge (SBD)	Non-fuel charge			Total (SBD)
	kWh			I1	I2	I3	
Aug-18	12,640	3,175.72	58938	4784	14852	41251	123001
Sep-18	26,240	3,199.91	124488	4810	14946	106634	254078
Oct-18	25,920	3,204.42	119132	4823	14993	107806	249958
Nov-18	21,920	3,218.49	107880	4836	15040	91542	222516
Dec-18	23,200	3,242.95	82502	4875	15181	67043	172844
Jan-19	26,080	3,258.18	17950	4901	15228	1387	42724
Feb-19	25,600	2,690.01	61652	4043	12596	44649	125630
Mar-19	21,600	3,277.82	86070	4927	15322	74704	184300
Apr-19	32320	3121.85	93987	4693	14617	100606	217025
May-19	26,720	3328.04	103488	5005	15557	97940	225318
Jun-19	24,640	3,324.80	84599	5005	15557	95226	203712
Jul-19	21,920	3,316.60	85109	4992	15510	87494	196422
Average	**24,067**	**3,197**	**63478**	**4808**	**14950**	**51082**	**137,514**
Annual	**288,800**	**38,359**	**761,733**	**57,694**	**179,399**	**612,989**	**1,650,173**

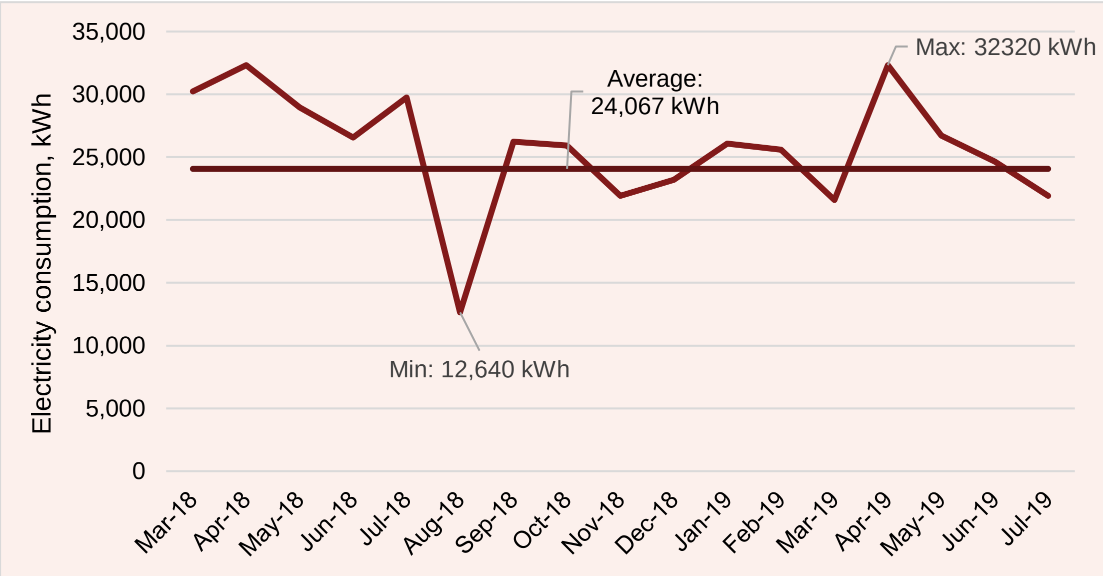


Figure 9 Electricity consumption profile March 2018 – July 2019 (18 months)

Key observations for the period August 2018 to July 2019:

- Monthly average consumption of electricity was 24,067 kWh (varying between 12,640 to 32,320)
- Average electricity tariff (excluding fixed NAC) was SDB 5.58 per kWh (US$ 0.70 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.65 per kWh (US¢ 33.1 per kWh)

Average monthly electricity consumption of Borderline Pump Station is 24,067 kWh

A sample electricity bill of Borderline pump station is presented in **Figure 10**.

Solomon Islands Electricity Authority
trading as SOLOMON POWER

INVOICE / STATEMENT

Customer

SIWA- Borderline Pump Station
P O Box 1407
Honiara

Date	06/January/2019
Customer Number	15398
Customer Type	**INDUSTRIAL**
Customer Category	**I3**

Location: Borderline Pump Station
Borderline

Previous Month

Balance at Previous Account Date	$268,355.04
Payment Received to 19 Dec Thank you	($130,500.09)
Balance Prior to 6 Jan 19	$137,854.95

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$153,659.98	$137,854.95	$0.00	$0.00	$291,514.93

Month 06/January/2019

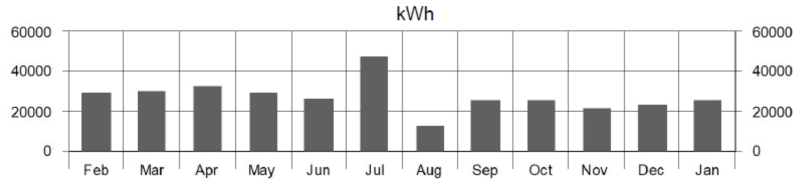
Readings from 6/Dec/2018 to 6/Jan/2019 **Days** 31

Usage

	Meter no.	Previous	Present	Multi	Units
1	217039068	687	850	160	26,080

Total **26,080.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 329760 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	I3	Days	31	3,258.18		3,258.18
Fuel	I1	kWh	26,080.00	2.7700	1.0000	72,241.60
Non-Fuel	I1	kWh	1,300.00	3.7700	1.0000	4,901.00
	I2	kWh	4,700.00	3.2400	1.0000	15,228.00
	I3	kWh	20,080.00	2.8900	1.0000	58,031.20
			26,080.00			78,160.20

TOTAL THIS PERIOD	**$153,659.98**
TOTAL DUE	**$291,514.93**
FINAL DATE FOR PAYMENT:	21/January/2019

No further notices will be issued. Unpaid accounts will have supply disconnected.
Previous month balances are payable immediately.

Figure 10 Sample electricity bill of Borderline pump station

The total electricity consumption in the pump station can be categorized in four parts: (a) transfer pumps, (b) borehole pumps, (c) lighting system and (d) electrical system losses and miscellaneous. The average consumption by each category is presented in **Figure 11**.

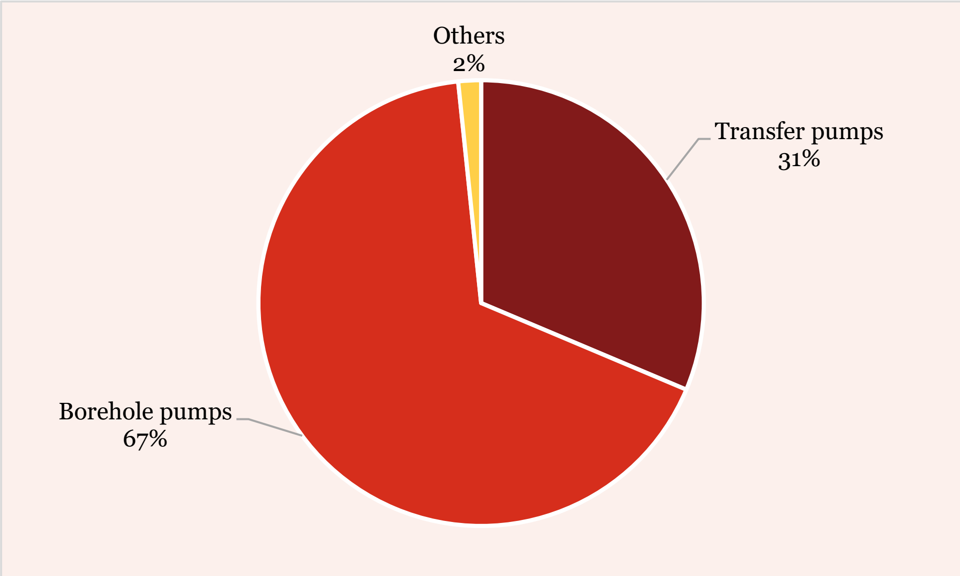


Figure 11 Electricity consumption share

3.3. Specific energy consumption

The daily water production from the bore-fields was 1591.0 m^3 and the daily energy consumption was 789 kWh of electricity. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 12 months data, which was 791 kWh. The specific energy consumption is presented in **Table 7**.

Table 7 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	1591.0
Daily electricity consumption	kWh	789.0
Specific energy consumption	**kWh/m^3**	**0.496**

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with three transfer pumps. These are multistage vertical centrifugal pumps with stainless steel impeller. Pumps are of Grundfos make and are driven by individual 11 kW motor. Typically, two pump operates in parallel at any given time and other one is standby. During the site visit all pumps were operational and performance assessment test was conducted on pumps individually and in combination of pump1+2, pump 2+3 and pump 3+1 separately.

The performance assessment of transfer pumps was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump was operating intermittently i.e. operating in ON-OFF mode. This was based on level switch control installed in receiver tank. The daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. **Figure 12** shows water flow measurement using non-intrusive ultrasonic water flow meter.

Figure 12 Water flow measurement photograph

The measured data such as operating hours and flow are verified using system data available at Solomon Water. The performance assessment of transfer pumps is presented in **Table 8**.

Table 8 Performance assessment of transfer pumps 1, 2 and 3

Particular	Unit	Pump 1	Pump 2	Pump 3
Operating flow	m^3/h	34.30	53.60	56.10
Suction head	m	-1.0	-1.0	-1.0
Discharge head	m	34.0	38.0	35.0
Total head	m	33.0	37.0	34.0
Hydraulic power	kW	3.08	5.40	5.20
Motor input power	kW	7.01	7.95	7.99
Shaft power	kW	6.39	7.25	7.29
Pump efficiency	**%**	**48.26**	**74.52**	**71.31**

The operating efficiency of the transfer pumps 2 and 3 were 74.52% and 71.31%, which is satisfactory. However, the flow rate of pump 1 was nearly half that of rated and resulted in a lower efficiency, 48.26%. The actual duty point and best efficiency point of pump 1, 2 and 3 are depicted in **Figure 13, Figure 15,** and **Figure 14.**

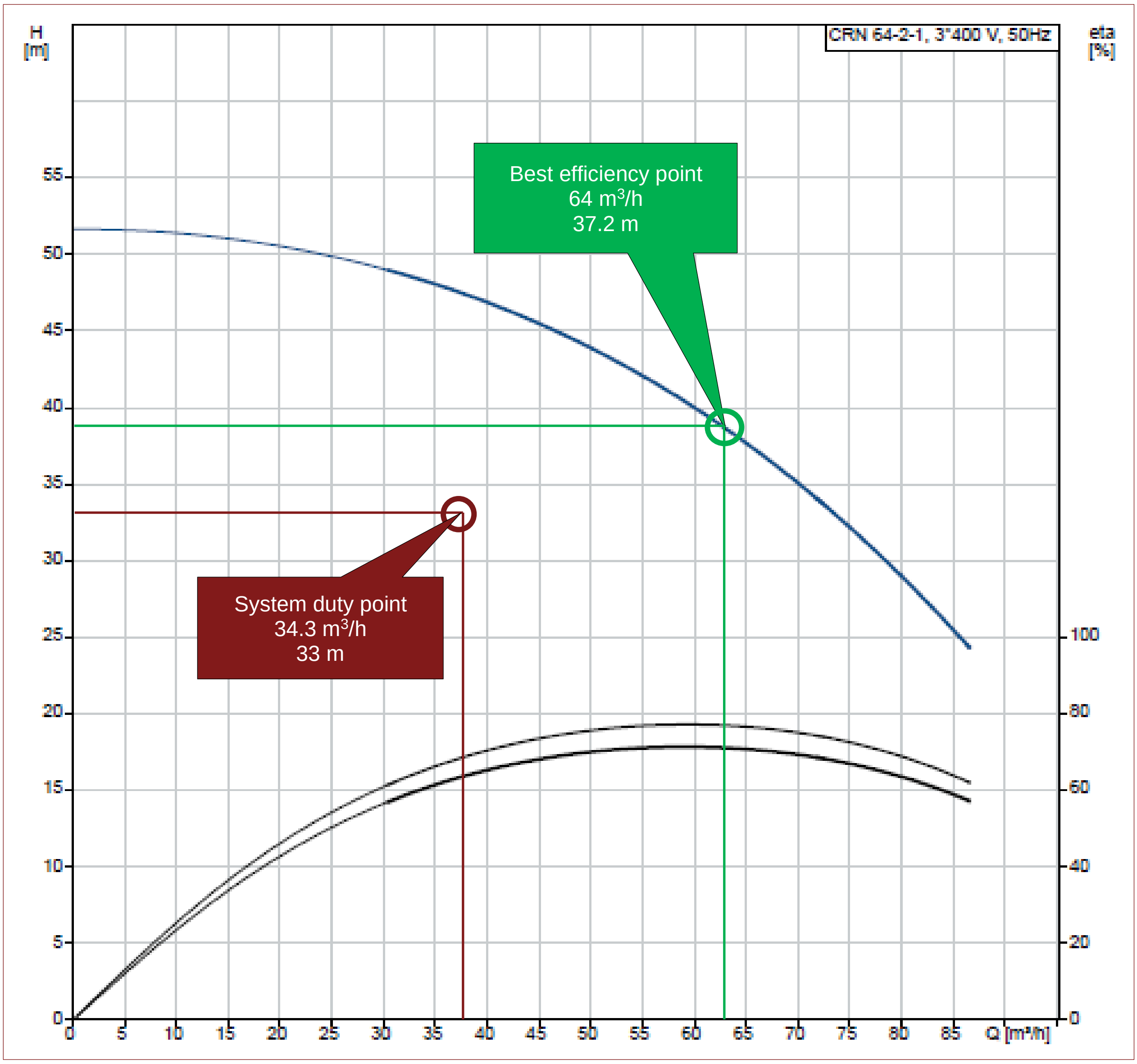


Figure 13 Transfer pump-1 duty point vs design

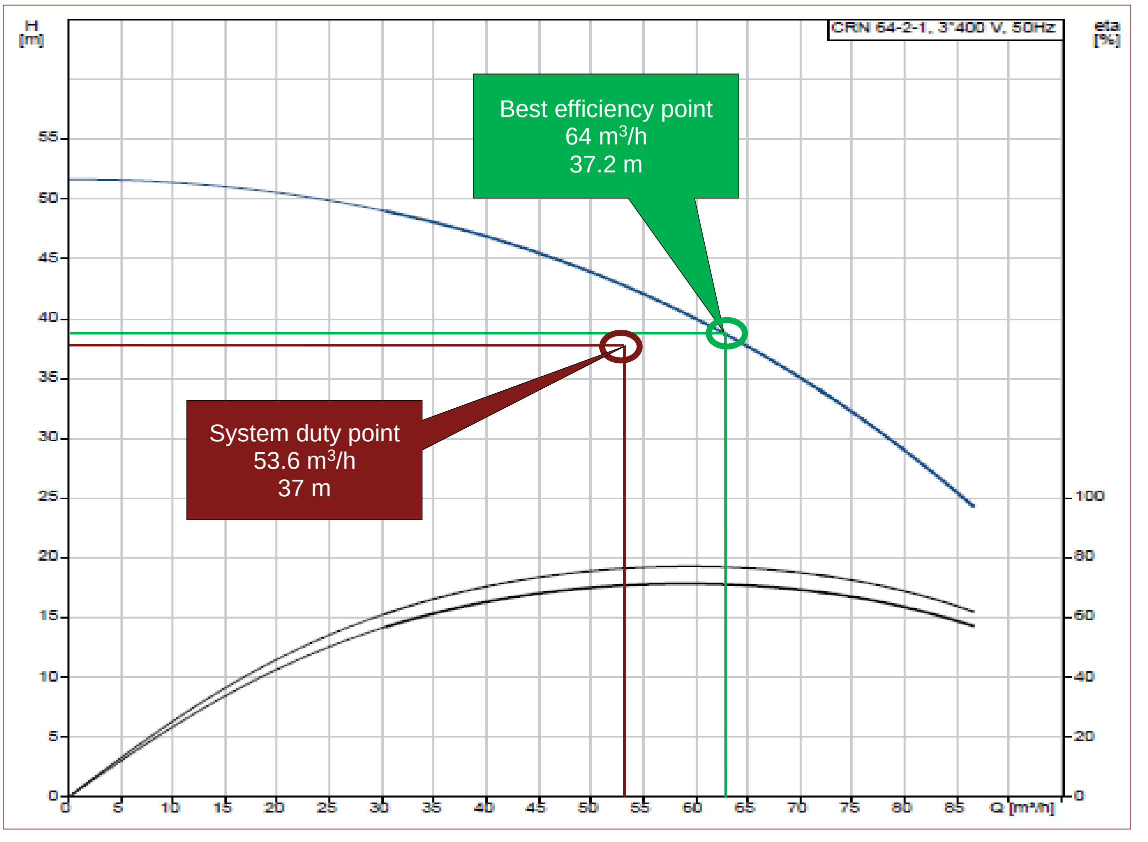


Figure 15 Transfer pump-2 duty point vs design

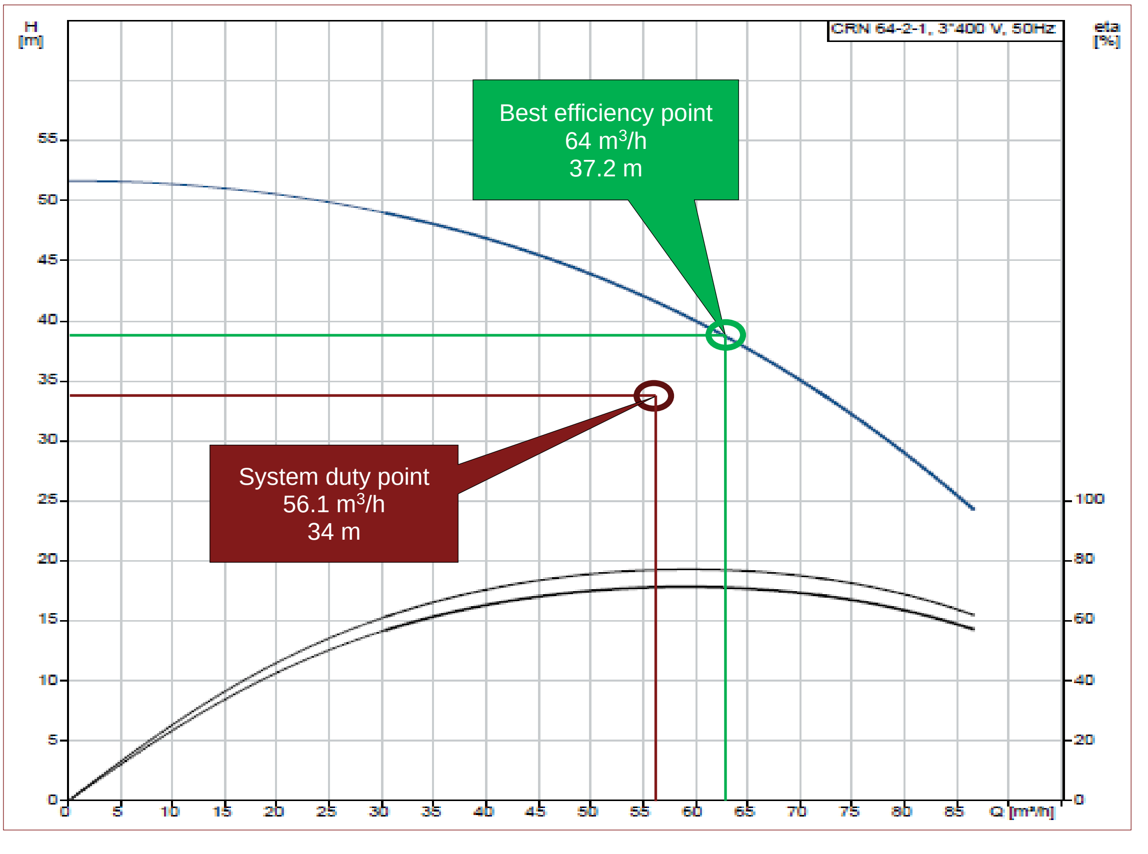


Figure 14 Transfer pump-3 duty point vs design

As seen in pump curve, the pump 2 and 3 were operating slightly away from the best efficiency point, as a result the operating efficiency is 2 and 6% less than design for pump 2 and 3 respectively. The reason for drop in flow might be slight wear on impeller due to ageing.

The operating hours of the transfer pumps was recorded using power log taken by three-phase power analyser. The total daily water pumped by transfer pumps was 1591 m^3. The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 9**.

Table 9 Transfer pumps motor performance

Particular	Unit	Motor 1	Motor 2	Motor-3
Voltage	V	436.00	431.10	438.20
Current	I	14.50	15.00	15.00
Power factor	-	0.640	0.710	0.702
Power input	kW	7.01	7.95	7.99
Motor Efficiency	%	91.2	91.2	91.2
Power shaft	kW	6.39	7.25	7.29
Motor loading	**%**	**58.10**	**65.93**	**66.26**

The performance test was conducted with two pumps running in parallel. The results of the parallel operation performance test are presented in **Table 10**.

Table 10 Performance assessment of transfer pumps in parallel

Particular	Unit	Pump 1 and 2	Pump 3 and 1	Pump 2 and 3
Operating flow (combined)	m^3/h	80.6	79.5	101.5
Suction head	m	-1.0	-1.0	-1.0
Discharge head	m	35.0	35.0	35.0
Total head	m	34.0	34.0	34.0
Combined hydraulic power	kW	7.47	7.37	9.22
2 Motors input power	kW	15.22	14.62	15.39
Shaft power	kW	13.88	13.33	14.03
Pump efficiency	**%**	**53.81**	**55.24**	**67.02**

It can be clearly seen that the efficiency of pumps is lower when pump 1 is running in combination with 2 or 3, this is result of lower flow rate of pump 1.

4.1.2. Energy conservation measure

The flow rate of transfer pump 1 was 34.3 m^3/h, which is substantially lower than the design flow rate 64 m^3/h. This resulted in lower pump operating efficiency, 48.26%. Suspected reason for drop is flow rate is damaged impeller. Replacing impeller is expected to improve the flow rate, but as the pump is seven years old, we have recommended replacement of vertical centrifugal pump with an IE4 rated motor to achieve higher efficiency.

The technical specification of proposed pump is as follows (detailed specification is presented in **Appendix A**):

- Make and model: Grundfos CRN 64-2-1
- Flow rate: 64 m^3/h
- Head: 37.2 m
- Pump Eficiency: 77.1 %
- Motor rating and efficiency: IE4, 92.6 %

The efficiency improvement and corresponding energy saving estimation is presented in **Table 11**.

Table 11 Transfer pump-1: Energy saving estimation

Particular	Unit		Value
Operating flow	m^3/h		64.00
Overall head	m		37.20
Hydraulic power	kW		6.49
Pump design efficiency	%		77.10
Shaft power required	kW		8.41
Standard motor size	kW		11.00
IE4 Motor efficiency	%		92.60
Overall power input	**kW**		**9.09**
Combined efficiency	%		71.39
Net daily water duty	m^3		350.9
Total operating hours	h/day		5.48
Annual energy consumption – proposed	kWh/year		18,185
Annual energy consumption – existing	kWh/year		25,808
Annual energy saving	kWh/year		7,624
Monetary saving	SBD/year		41,778
	USD/year	$	5,222
Cost of new pump with IE4 motor	USD	$	9,050
Freight cost for pump-motor set	USD	$	250
Cost at port in Solomon Islands	USD	$	9,300
Import duty	%		10
GST on imported goods	%		15
Net landed cost of pump-motor set	**USD**	$	12,250
Simple payback period	**years**		**2.3**
GHG emission reduction potential[7]	**tCO_2/year**		**5.03**

The annual energy saving by replacing transfer pump-1 is 7,624 kWh equivalent to monetary saving of US $ 5,222. The investment required for new pump with IE4 motor is US $ 9,050. The freight cost of shipping from Australia is US $ 250. Overall landed cost in Honiara inclusive of all applicable duties is US $ 12,250. The simple payback period of the recommendation is 2.3 years. The GHG emission reduction potential of the recommendation is 5.03 tCO_2 equivalent.

4.2. Borehole pumps

4.2.1. Performance assessment

The Borderline pump station has four borehole pumps. The power measurement was taken using three-phase power analyser, flow was measured using ultrasonic water flow meter, head was measured using a water depth measurement instrument available with Solomon Water (Shaun, Hydrogeologist) and head from borehole surface level to receiver tank is measured using digital pressure meter.

[7] *Grid emission factor is 0.66 tCO_2/MWh, Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

The duty-point and best efficiency point of the bore-hole pump-1 is depicted in **Figure 16**.

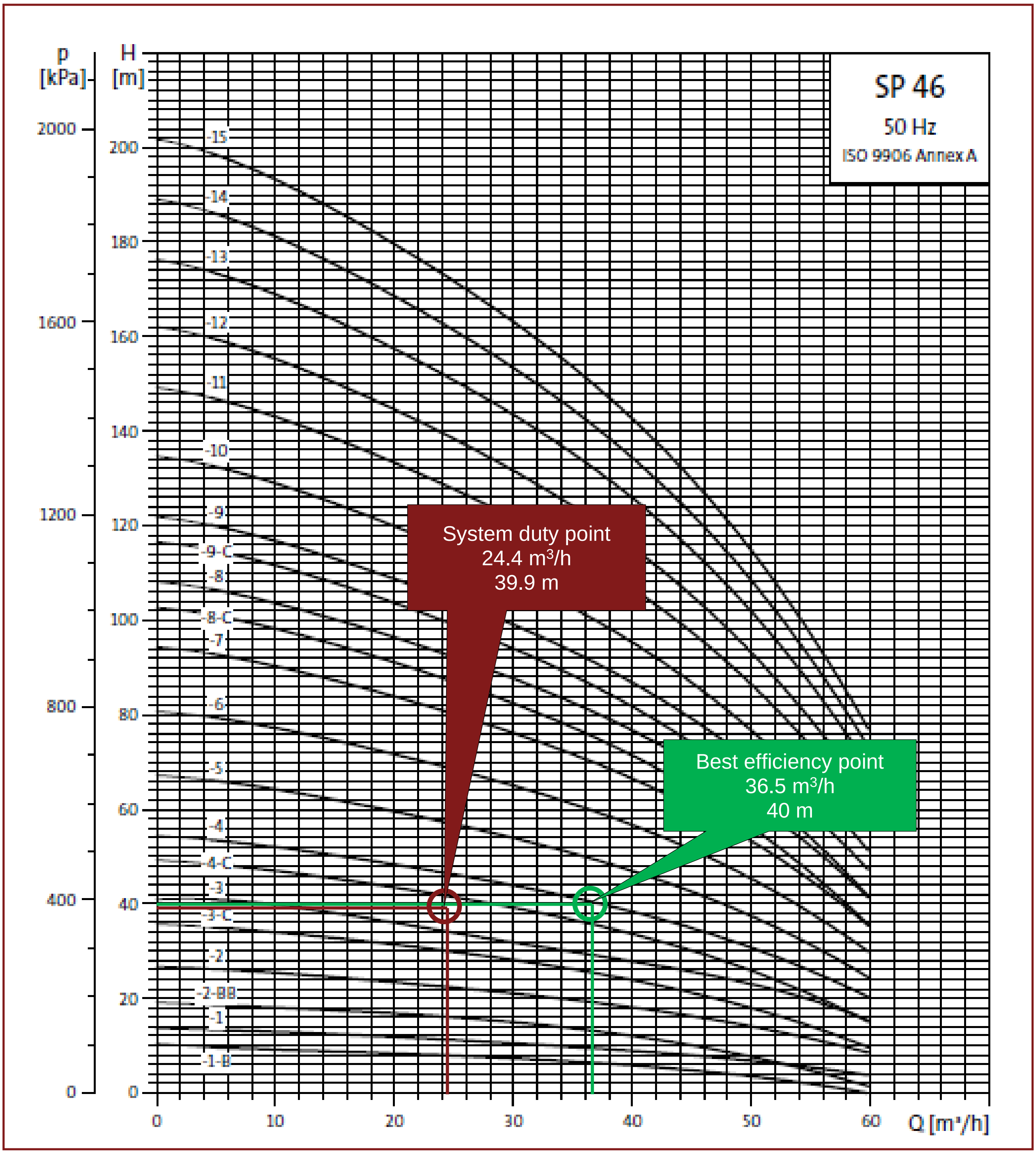


Figure 16 Borehole pump-1 duty point vs design

The borepump-1 was Grundfos SP46 series, model 4. The pump was operating close to design head however the flow rate was 33% lesser than design. The suspected reason for the less flow rate is slightly worn-out impeller. It is recommended to check the impeller during next maintenance and in case or wear and tear, repalce the impeller.

The valve on the discharge pipe coming out of well was throttlled, leading to a head of 4.3 m, which is close to actual head from this point till reservoir. Hence the throttling has marginal effect on system head.

The duty-point and best efficiency point of the bore-hole pump-2 is depicted in **Figure 17**.

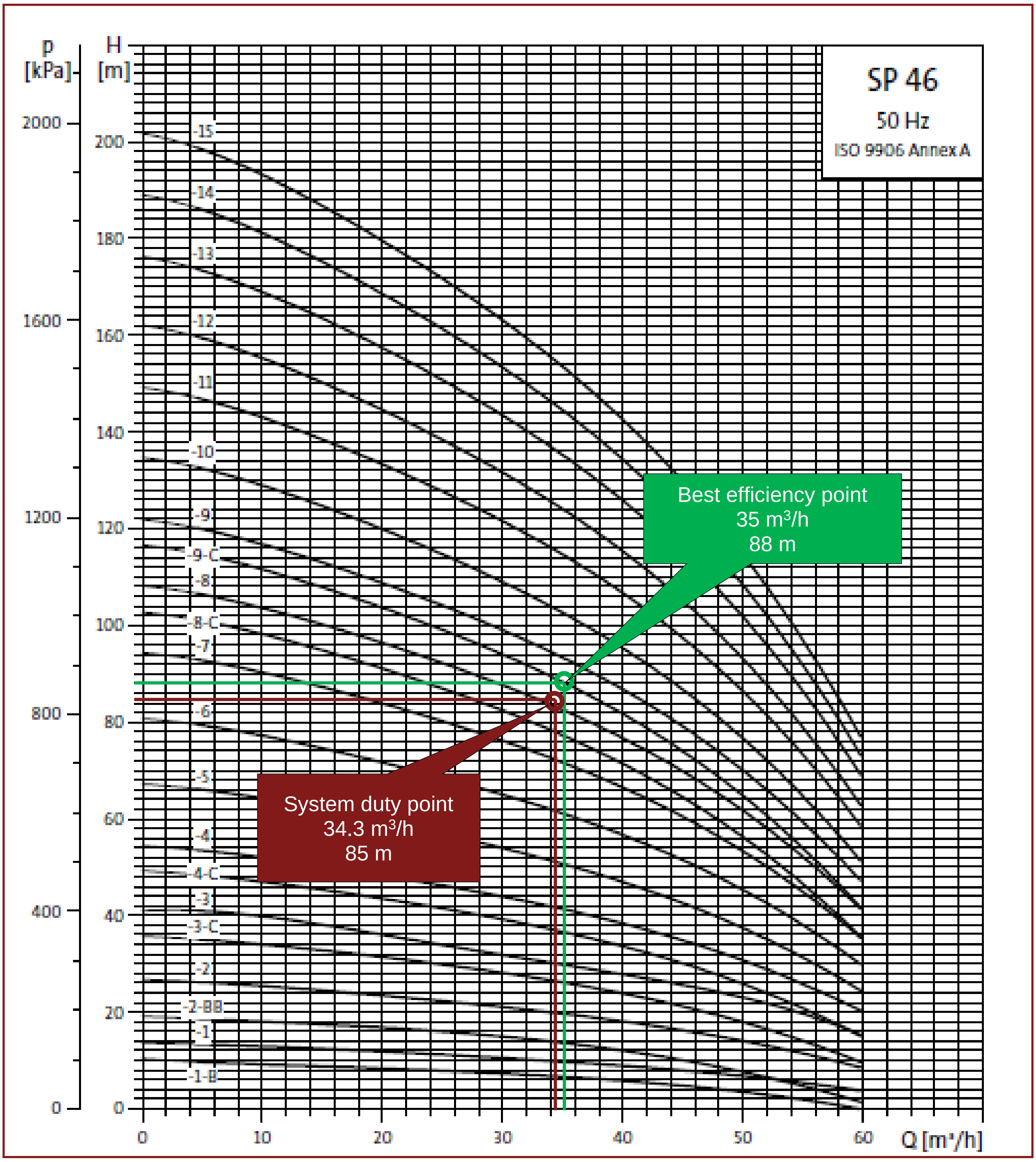


Figure 17 Borehole pump-2 duty point vs design

The borepump-2 was Grundfos SP46 series, model 9C. The pump was operating quite close to design of the pump.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 55 m. The estimated head from this point till reservoir is substantially low, hence the throttling is affecting the system head. It is recommented to carry out detailed study (long-term) to identify affect after unthrottling on system head and pump operation.

The duty-point and best efficiency point of the bore-hole pump-3 is depicted in **Figure 18**.

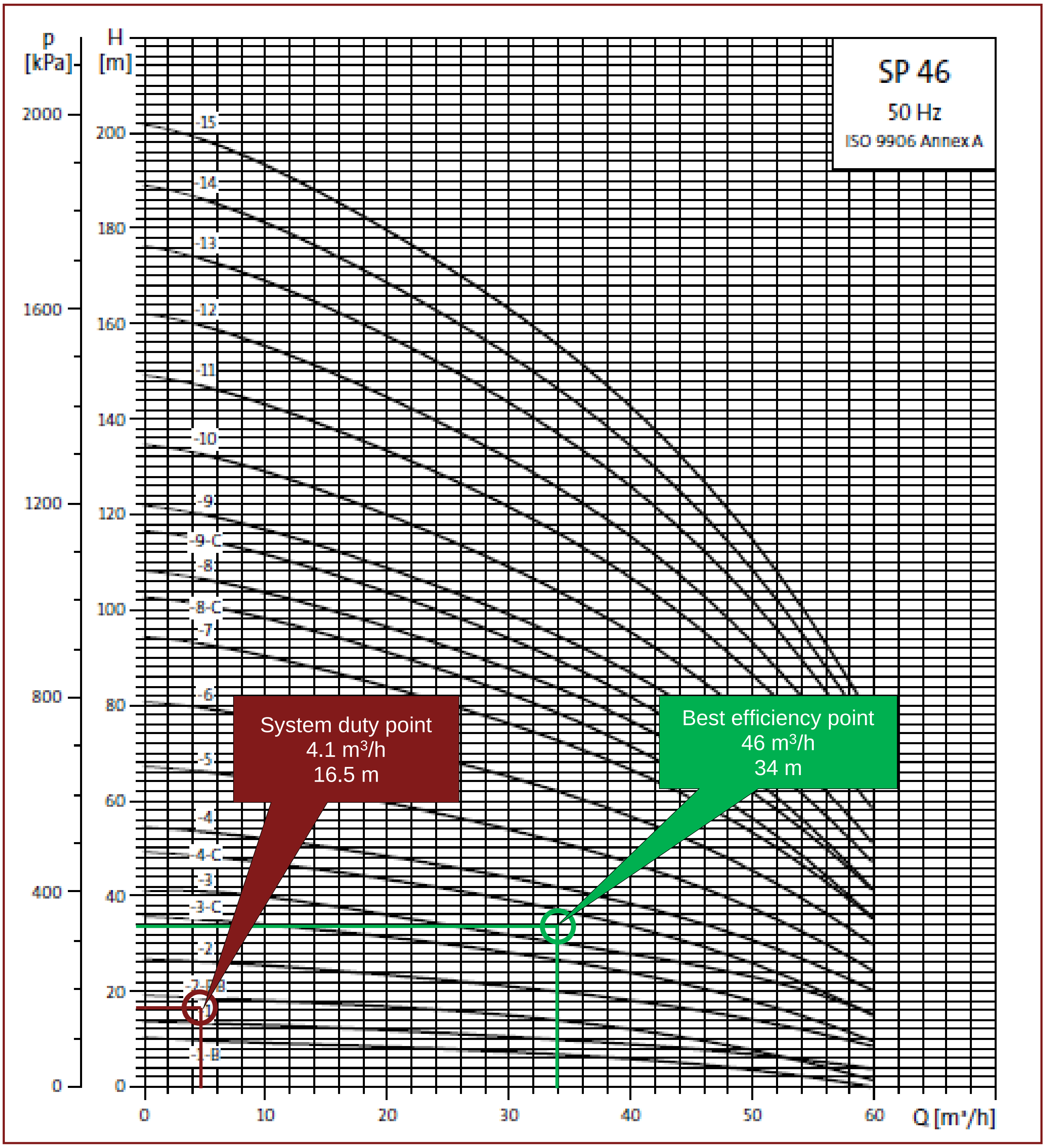


Figure 18 Borehole pump-3 duty point vs design

The borepump-3 was Grundfos SP46 series, model 4. The pump was operating away from design point. The flow rate was 4.1 m³/h against design on 46 m³/h. It appreas the screens for drawing water are blocked and unable to draw water in. It is recommended to swtich the pump OFF and not use it untill the maintenance is conducted and the screens are cleaned. Once maintenance is performed, it is suggested to conduct performance assessment of the pump once again.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 8.4 m, which is close to the actual head estimated from this point till reservoir. Hence the throttling has marginal effect on system head.

The duty-point and best efficiency point of the bore-hole pump-4 is depicted in **Figure 19**.

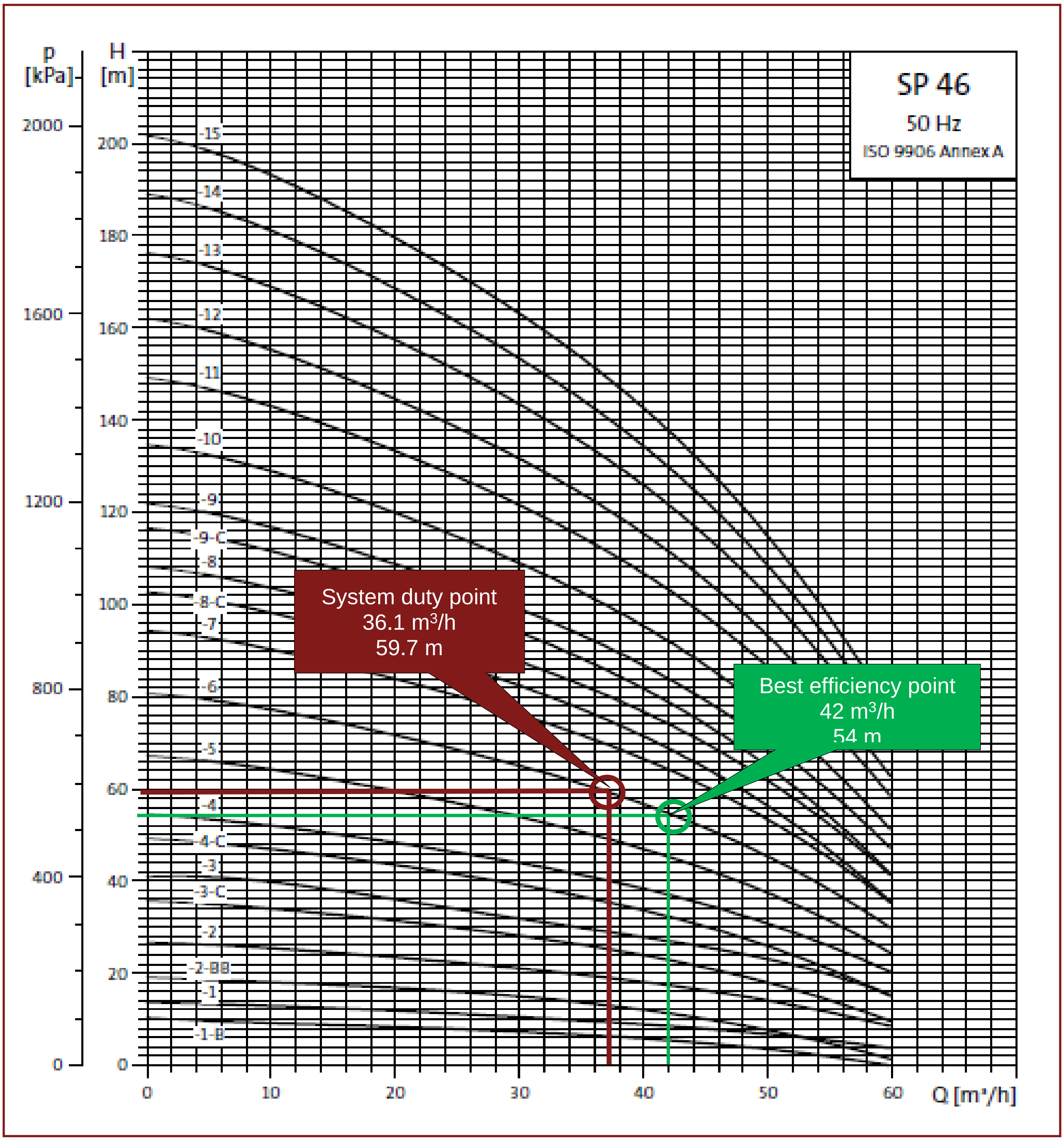


Figure 19 Borehole pump-4 duty point vs design

The borehole pump-4 was Grundfos SP46 series, model 6. The pump was operating away from design point. However, the system duty point was following the pump cruve. The SP46-10 typically should absorb about 10 kW power, but the borehole pump-4's power consumption was 13.16 kW, which is substantially higher.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 19.7 m, which is close to the actual head estimated from this point till reservoir. The reason for higher head as compared to borehole 1 & 3 is physical distance and elevation from pump station. Hence, throttling has marginal effect on system head.

The measured data such as operating hours and flow are verified using system data available at Solomon Water. The performance assessment of borehole pumps is presented in **Table 12**.

Table 12 Performance assessment of borehole pumps

Particular	Unit	Bore-pump 1	Bore-pump 2	Bore-pump 3	Bore-pump 4
Operating flow	m^3/h	24.40	34.30	4.10	36.10
Well depth to water level	m	35.60	30.00	8.14	40.00
Head from surface to reservoir	m	4.30	55.00	8.40	19.70
Total head	m	39.90	85.00	16.54	59.70
Hydraulic power	kW	2.65	7.94	0.18	5.87
Motor power	kW	4.80	18.34	4.78	13.16
Shaft power	kW	3.81	15.04	3.85	10.79
Pump efficiency	**%**	**69.56**	**52.83**	**4.80**	**54.41**

The operating hours of the bore-hole pumps was taken from the SCADA system. The measured flow rate of water was then converted to arrive at daily water production from borefields, same is presented in **Table 13**.

Table 13 Production from bore-fields

Bore-field	Flow rate (m^3/h)	Operating hours (h)	Daily production (m^3)
Bore-pump 1 (KO-1)	24.4	24.0	585.6
Bore-pump 2 (KO-2)	34.3	5.3	180.1
Bore-pump 3 (KO-3)	4.1	7.6	31.2
Bore-pump 4 (KO-4)	36.1	22.0	794.2
Total			**1591.0**

4.2.2. Energy conservation measure

The borehole pump-4 was consuming more power. The recommendation would be to replace the motor of pump, however as the pump is submersible, it is recommended to replace the pump with new submersible pump with a higher efficiency motor. The pump specification of the existing bore pump, system duty-point and recommended pump is presented in **Table 14**.

Table 14 Technical specification of existing pump, system duty point and recommended pump

Particular	Unit	Existing Pump	System duty point	Proposed pump
Bore-hole pump KO-4				
Model	-	Grundfos SP 46-6	-	Grundfos SP 46-5
Flow rate	m^3/h	42.0	36.1	32.0
Total head	m	53.8	59.7	60.0

The proposed submersible pump as replacement for bore pumps is capable of handling head variation of ± 3 m, without substantial difference in discharge head. Detailed technical specification of the recommended pump is provided in **Appendix A**. ***The energy saving is estimated considering the sustainable daily water production for the bore field shared by Solomon Water Hydrogeologist***, which is 769 m^3. For saving estimation the proposed pump's operating hours is considered 24 hours. Detailed saving estimation is presented in **Table 15**.

The annual energy saving by replacing borehole pump-4 is 25431 kWh equivalent to monetary saving of US $ 17,421. The investment required for installation of pump is US $ 5,725. The freight cost of shipping from Australia is US $ 250. Overall landed cost in Honiara inclusive of all applicable duties is US $ 8,094. The simple payback period of the recommendation is six months. The GHG emission reduction potential of the recommendation is 16.8 tCO_2 equivalent.

Table 15 Borehole pumps energy saving estimation

Particular	Unit	KO-4
Net daily water duty	m^3	769.0
Proposed pump flow rate	m^3/h	32.0
Operating hours	h/day	24.0
Proposed annual energy consumption	kWh/year	78825
Existing annual energy consumption	kWh/year	104257
Annual energy saving	kWh/year	25431
Monetary saving	SBD/year	139364
	USD/year	$ 17,421
Cost of new bore-pump	USD	$ 5,725
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 5,975
Import duty	%	10
GST	%	15
Net landed cost of bore-pump	USD	$ 8,094
Simple payback period	**years**	**0.5**
GHG emission reduction	**tCO_2/year**	**16.78**

The borehole pump-3 was consuming 4.78 kW power and delivering just 31.2 m³ per day. It is recommended to switch OFF this pump as it was operating at 4% efficiency and hardly delivering any water. It appreas the screens for drawing water are blocked and unable to draw water in. It is recommended to swtich the pump OFF and not use it untill the maintenance is conducted and the screens are cleaned. The saving estimation is done considering borehole pump-4 is delivering the additional 31.2 m³ per day and borehole is OFF untill maintenance is done, saving estimation for same is presented in **Table 16**. The monetary saving by this recommendation is US $ 6,771.

Table 16 Switch-OFF borehole pump-3

Particular	Unit	Value
Baseline flow	m^3/day	31.16
Annual energy consumption by running pump-4 to meet this requirement	kWh/year	3194
Present annual consumption	kWh/year	13078
Annual energy saving	kWh/year	9884
Monetary saving	SBD/year	54164
	USD/year	$ 6,771
GHG emission reduction	**tCO_2/year**	**6.52**

4.3. Electrical system

4.3.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel and bore-pumps panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. The logging of total power for 24 hours is shown in **Figure 20**.

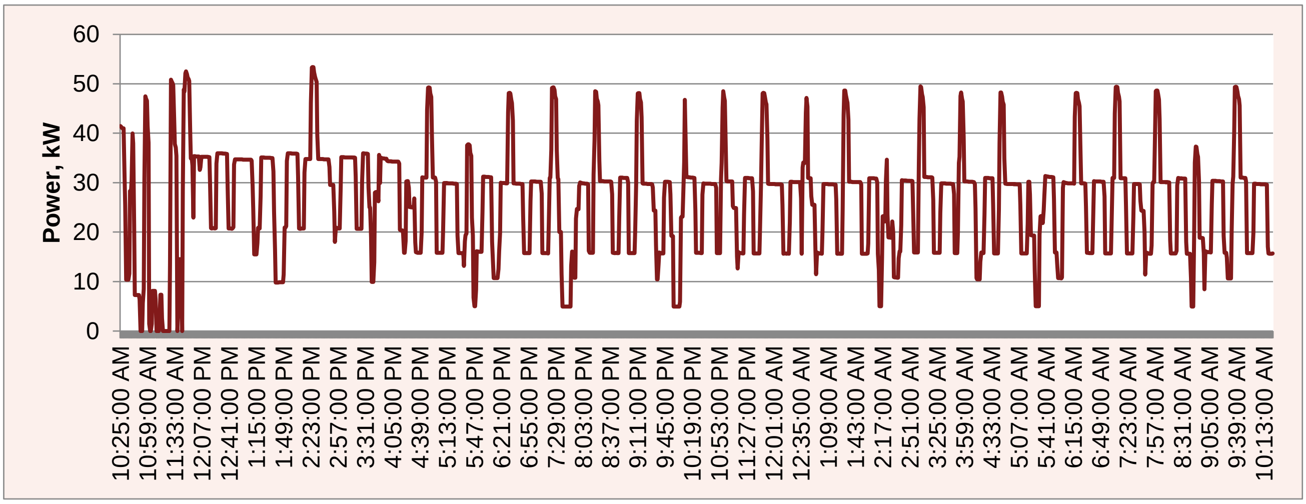


Figure 20 Borderline pump station total power log 24 hours

The power factor (PF) at the main incomer of pump station was varying between 0.492 – 0.722, with an average PF 0.645. The PF variation over 24 hours is presented in **Figure 21**.

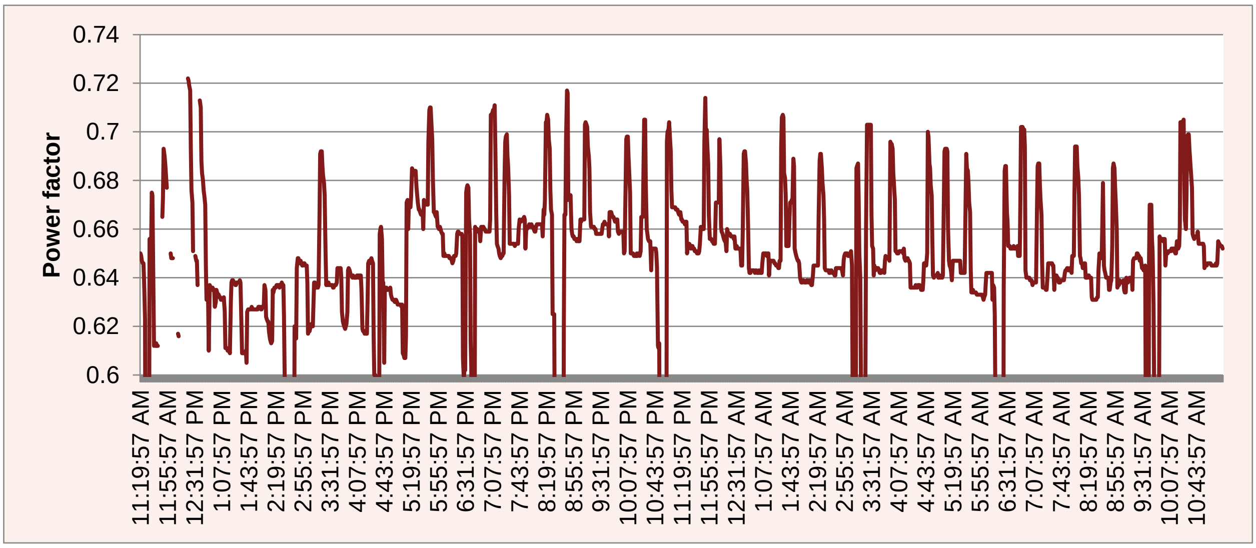


Figure 21 Power factor variation over 24 hours

4.3.2. Automatic Power Factor Correction

The average PF is 0.645 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install a 55 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 20+15+10+5+2+2+1 kVAr.

Figure 22 APFC panel

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 17** and **Table 18**. The pictorial view of APFC panel is presented is **Figure 22**.

Table 17 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.645
Average daily reactive power	kVAr	31.36
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.170
Annual charge for PF	US$/year	$ 4,025
Capacitor bank requirement	**kVAr**	**55**
Investment cost	US$	$ 2,750
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 3,000
Import duty	%	10
GST	%	15
Net landed cost of APFC system	USD	$ 4,375
Simple payback period	**years**	**1.1**

Table 18 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.645
Power factor tariff as % of fuel charge	%	5.00
Annual fuel charge	US$/year	95217
Annual charge for PF	US$/year	$ 4,761
Capacitor bank requirement	kVAr	65
Investment cost	US$	$ 3,250
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 3,500
Import duty	%	10
GST	%	15
Net landed cost of APFC	USD	$ 5,000
Simple payback period	**years**	**1.1**

4.4. Lighting system

4.4.1. Performance assessment

The pump station was equipped with 24 six feet fluorescent tube lights (FTL) of 36 W rating (T8). 12 fixtures are installed in pump room and 12 fixtures in electrical & diesel set room. The details of the existing system are provided in **Table 19**.

Table 19 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	12	528
FTL T8	Electrical & DG room	36+8	12	528
Total			**24**	**1056**

4.4.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 6 LED tube pump room and 6 in DG room. Details of the present lighting system are given in **Table 20**. The pictorial view of FTL tube and LED tube is shown in **Figure 23.**

Figure 23 LED tube vs florescent tube

Table 20 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	24	12
Total rating	W	1056	252
Operating hours	h/year	250	250
Annual consumption	kWh/year	264	63
Annual saving	kWh/year		201
Monetary saving	SBD/year		1101
	USD/year		$ 138
Investment cost	USD		$ 240
Simple payback	**Years**		**1.74**
GHG emission reduction	**tCO_2/year**		**0.13**

The estimated annual energy savings with new LED lighting system is 201 kWh of electricity, effectively equivalents to a monetary savings of US $ 138. The investment requirement is US $ 240. The simple payback period of the recommendation is 1.8 years. The annual reduction in GHG emission is estimated to be 0.13 tCO_2.

5. Self-generation option

5.1. Renewable energy assessment

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic. Detailed feasibility analysis for solar is presented in this chapter.

5.2. Site description

Borderline pump station is in Green Valley area of Honiara city in Guadalcanal province. The pump station is spread across an area of about 530 m². The projected roof area as seen from the top, over the pump house building is about 160 m². The rest of the area is used servicing purpose and one of the bore-hole is situated inside pump house. There are no buildings nearby to cause shading. Roof is made of concrete and support installation of solar roof top PV modules.

5.3. Solar resource assessment

The solar data source i.e. Global Horizontal Irradiance (GHI) for Honiara, is derived from a Japan International Cooperation Agency (JICA) report on Pilot Survey for Disseminating SME's Technologies for Introduction of Utility Interactive Grid-Connected Photovoltaic Generation System Possessed in Okinawa Prefecture for Small Island Regions, 2015. These values are an estimation of the solar resource on a horizontal surface. Solar data for Honiara is presented in **Table 21**.

Table 21 Daily Global Horizontal Irradiation at site location

Daily Global Horizontal Irradiation in kWh/m²/day											
Latitude -9.438°, Longitude 159.959°											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

The roof orientation yields optimum results when the tilt angle is equal to the latitude which in this case is 9.4°. The sun elevation diagram for the pump station is presented in **Figure 24**.

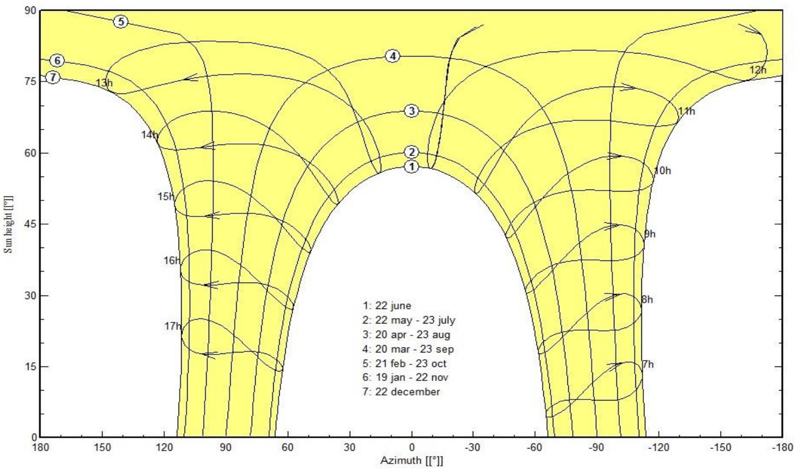


Figure 24 Sun elevation diagram for the site

5.4. System sizing and cost benefit

The effective area available for solar-roof PV installation is 136 m². Capacity for PV systems is measured at Standard Testing Conditions, of 1000 W/m², AM 1.5 and 25°C cell temperature. These conditions may not be the same on site. Site specific capacity varies intermittently with changing irradiance, ambient temperature, wind speed and air mass with respect to time, calendar day and other effects like cloud cover. The Polycrystalline technology generally has efficiency of ~16%. Monocrystalline Silicon technology can achieve ~20% although they are expensive. The power delivered at the interconnection will be further reduced due to inverter efficiency, transformer efficiency, module fouling and cabling losses. The system sizing along with cost benefit considering thin film and monocrystalline technology is presented in **Table 22**. This is considering there is no standby charges fees and the utility i.e. SIEA pays fuel charges to Solomon Water for imported energy to grid which is SBD 2.65 per kWh.

Table 22 Cost benefit of solar roof PV - Thin film and monocrystalline

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m^2	160	160
Utilization area	m^2	136	136
Nominal power	kWp	13.6	21.8
Average global horizontal irradiance	$kWh/m^2/day$	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	20974	33620
Avg fuel charges	SBD/kWh	2.65	2.65
Monetary saving	SBD/year	55547	89038
	USD/year	$ 6,943	$ 11,130
Module cost	USD	$ 12,716	$ 20,346
Supports cost	USD	$ 15,558	$ 15,558
Inverter and wiring cost	USD	$ 4,787	$ 4,787
Transport and mounting cost	USD	$ 18,370	$ 26,755
Cost at port in Solomon Islands	USD	$ 51,431	$ 67,446
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost	USD	$ 64,914	$ 84,933
Simple payback period	**years**	**9.3**	**7.6**

The cost benefit considering present tariff structure is presented in **Table 23**. With present regulation we have considered the standby changes in addition with cost system.

Table 23 Cost benefit of solar roof PV with present tariff

Particular	Unit	Thin-film	Monocrystalline
Nominal power	kWp	13.6	21.8
Annual solar yield	kWh/year	20974	33620
Monetary saving by avoided energy consumption	SBD/year	59392	95202
	USD/year	$ 7,424	$ 11,900
Annual standby charges	USD/year	$ 9,244	$ 14,818
Net landed cost	USD	$ 74,158	$ 99,751
Simple payback period	**years**	10.0	8.4

The detailed analysis for Solar roof PV system sizing was performed on PVSyst software. PVSyst software provides possibility of complex simulation input and output parameters of PV plant and is also commercially to calculate the total production of electricity. As per the PVSyst simulation results, the estimated energy generation for the first year is 21.0 MWh/year, with Specific Energy Yield of 1545 kWh/kW_p/year for thin film technology-based modules. The simulation was run considering monocrystalline cell modules and the estimated energy generation for the first year is 33.6 MWh/year. The detailed results of PVSyst are presented in **Appendix C** – PVSYST simulation results.

5.5. Regulatory framework

The policies, processes and forms for solar system connection to SIEA grid are available in Solar Manual of SIEA. Some of the key highlights are:

- Inverter energy systems that have a continuous rating of no more than 30 kVA for three-phase systems.
- The installation should as a minimum comply with Australian Standards AS3000, AS4777 and AS5033 and all other relevant Australian Standards and Solomon Islands statutory requirements.
- All energy consumed from the grid at the premises will be metered by an import-only meter and billed to the customer under the applicable tariff(s). It is only any 'excess' energy will be exported to the SIEA grid. This energy will be metered but will NOT be paid for by SIEA.

The process for solar grid connection as provided by SIEA is presented in **Figure 25**.

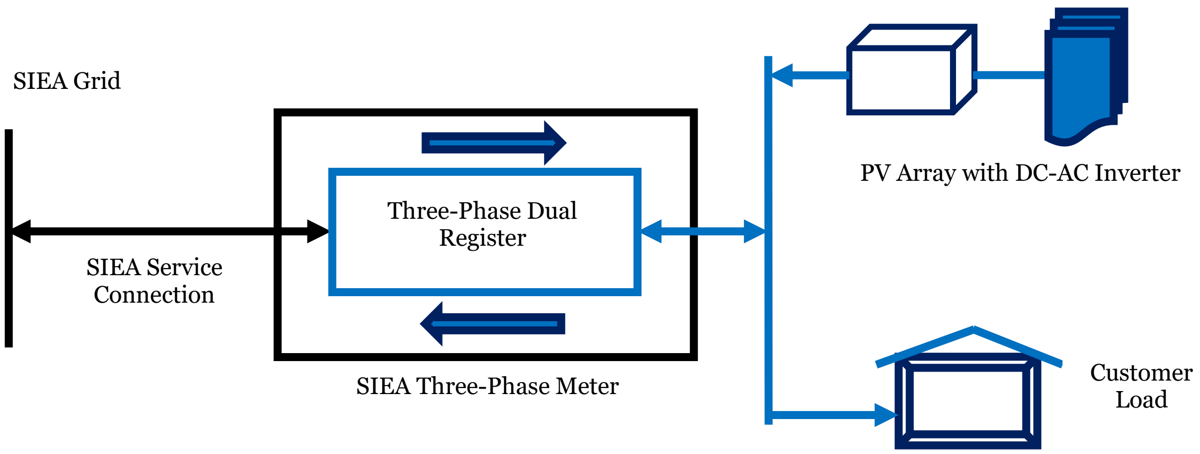


Figure 25 Schematics of solar PV interconnection with SIEA grid

Net metering is a utility billing mechanism that offers a credit to customers who are making excess electricity with their solar panel systems and sending it back to the grid. Solomon Islands at present does not have provision for net metering. However, SIEA is in process of reviewing and restructuring its electricity tariff. It may introduce the net metering option for solar roof top.

*Solar PV option for the pump station is **technically feasible**. But, the financially feasibility is dependent on future SIEA tariff structure. With present tariff structure and regulatory elements, the solar PV is not feasible.*
*The Solomon Water can **take a strategic call** if to invest in solar PV now or to wait for favorable regulatory regime.*

5.6. Other grid-connected solar initiatives in Solomon Islands

The World Bank is implementing a scaling-up of renewable energy project in Solomon Islands in the period 2018 to 2023. The Project intends to improve lifestyle and increase shared prosperity for the low-income household through scaling-up off and on-grid renewable energy projects.

The project is being implemented in four components, which are presented in **Table 24**.

Table 24 Components of WB Scaling-up RE project

Component – 1	Renewable energy hybrid mini-grids – Supply, installation and initial maintenance
Component – 2	Electricity connections in low income areas – Households, micro enterprise and community infrastructure
Component – 3	Grid-connected solar power - Supply, installation and initial maintenance
Component – 4	Enabling environment and project management – including gender related activities, technical assistance and training activities

The third component deals with grid connected solar power. World Bank intendeds to support supply, implementation and initial maintenance of grid-connected solar power projects. The project financing and source of funding for the gird connected solar power is presented in **Table 25**.

Table 25 Project financing and source of funding

Source of Fund	Project financing (US$ million)	Share of financing
International Development Association (IDA) financing credits	3.5	**70%**
IDA financing grant	0.55	**11%**
Trust funds GEF	0.95	**19%**
Total	**5.0**	**100%**

The reason for the solar power project being financially feasible as compared to solar power project proposed at pumps station are as follows:

- About 30% of the total funding for the project is through grant or funds, thus, reducing financing burden
- The remaining cost of project is also in terms of IDA financing credits, which has very low interest charge and repayments been stretched over long term
- The economy of scale, the solar power supported by World Bank is of MW capacity, however, the pump station projects capacity is in kW size
- One component of the World Bank project is on reducing regulatory barriers for solar project while creating the conditions for future replication. (This is in progress)

In case, the solar power project proposed for pump station can be financed through similar mechanism i.e. close to 30% grant/funds, the project finances will improve. Moreover, a further strengthened regulatory regime will be an advantage. The sensitivity analysis of grid connected solar power project with and without grant funding is presented in **Table 26**.

Table 26 Sensitivity analysis - Solar power project with and without grant

Particular	Unit	Without grant	With grant
Solar rooftop plant capacity for Borderline Pump Station	kWp	21.8	21.8
Monetary savings	US $	11130	11130
Investment	US $	84933	59453
Simple payback period	**Years**	**7.6**	**5.3**

6. Conclusion

6.1. Summary of study

Borderline pump station is in Green Valley area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Borderline SIWA reservoir using three transfer pumps. The pump station produces 1591 m^3 water daily consuming about 789 kWh electrical energy. The existing specific energy consumption is 0.496 kWh per m^3. The study has identified four recommendations for energy conservation (**Table 27**). These recommendations could save annually about 43,140 kWh of electricity. These recommendations have an estimated investment of US $ 20,584 and can yield a monetary savings of US $ 29,551 per year. The annual energy saving is estimated to be 14.9% of total energy consumption by the pump station (**Figure 26**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 28.47 tonnes of CO_2.

Table 27 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement of transfer pump-1	7,624	$ 5,222	$ 12,250	2.3	5.03
ECM-2	Switch-off borepump-3 until maintenance	9,884	$ 6,771	$ -	0.0	6.52
ECM-3	Replacement of borepump-4 with efficient pump	25431	$ 17,421	$ 8,094	0.5	16.78
ECM-4	Replacement of FTL with LED lights	201	$ 138	$ 240	1.7	0.13
	Total	**43140**	**$ 29,551**	**$ 20,584**	**0.7**	**28.47**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 28**.

Table 28 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.496 kWh/m^3	0.430 kWh/m^3
Specific CO_2 emission	0.328 kg CO_2/m^3	0.284 kg CO_2/m^3

On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

6.2. Funding options

The overall investment proposed for four energy conservation measures for Borderline pump station is US$ 20,584. The simple payback on this investment is 7 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 5 months, which can be followed by transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Borderline pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

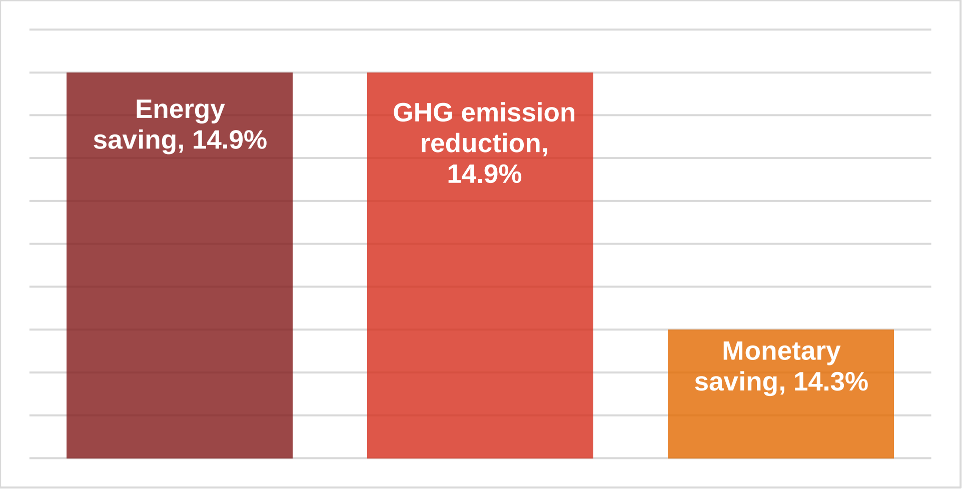


Figure 26 Identified saving potential

A collage of select pictures taken during the detailed feasibility study is presented in **Appendix D**.

Appendix

Appendix A – Proposed pump technical specification

Transfer pump-1

Position	Qty.	Description
	1	**CRN 64-2-1 A-F-A-V-HQQV**

Product No.: On request

Vertical, multistage centrifugal pump with inlet and outlet ports on same the level (inline). Pump materials in contact with the liquid are in high-grade stainless steel. A cartridge shaft seal ensures high reliability, safe handling, and easy access and service. Power transmission is via a rigid split coupling. Pipe connection is via DIN flanges.

The pump is fitted with a 3-phase, fan-cooled asynchronous motor.

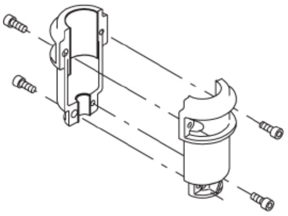
Further product details

Steel, cast iron and aluminium components have an epoxy-based coating made in a cathodic electro-deposition (CED) process. CED is a high-quality dip-painting process where an electrical field around the products ensures deposition of paint particles as a thin, well-controlled layer on the surface. An integral part of the process is a pretreatment. The entire process consists of these elements:

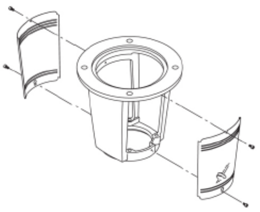
1) Alkaline-based cleaning.
2) Zinc phosphating.
3) Cathodic electro-deposition.
4) Curing to a dry film thickness 18-22 my m.
The colour code for the finished product is NCS 9000/RAL 9005.

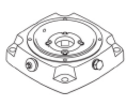
Pump

A long split coupling connects the pump and motor shaft. It is enclosed in the motor stool by means of two coupling guards. The long coupling makes it possible to replace the shaft seal without removing the motor from the pump.



The motor stool connects the pump head and motor. The pump head has a combined 1/2" priming plug and vent screw.





The pump is fitted with a balanced O-ring seal unit with a rigid torque-transmission system. This seal type is assembled in a cartridge unit which makes replacement safe and easy. Due to the balancing, this seal type is suitable for high-pressure applications. The cartridge construction also protects the pump shaft from possible wear from a dynamic O-ring between pump shaft and shaft seal.

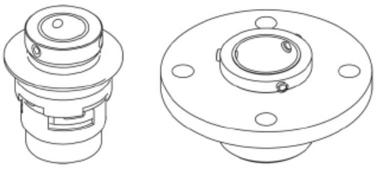
Primary seal:
- Rotating seal ring material: silicon carbide (SiC)
- Stationary seat material: silicon carbide (SiC)

This material pairing is used where higher corrosion resistance is required. The high hardness of this material pairing offers good resistance against abrasive particles.

Secondary seal material: FKM (fluorocarbon rubber)

Position	Qty.	Description

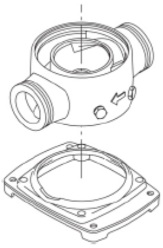
FKM has excellent resistance to oils and chemicals. Above 90 °C, FKM should only be used in media without water.



The shaft seal is retained in the pump head by a cover and screws. It can be replaced without removing the motor.

The chambers and impellers are made of stainless-steel sheet. The chambers are provided with a PTFE neck ring offering improved sealing and high efficiency. The impellers have smooth surfaces, and the shape of the blades ensure a high efficiency.

The pump has a stainless-steel base mounted on a separate base plate. The base and base plate are kept in position by the tension of the staybolts which hold the pump together. Both the inlet and the outlet side of the base have two pressure gauge tappings. The pump is secured to the foundation by four bolts through the base plate. The flanges are fastened to the base by means of locking rings.



Motor

The motor is a totally enclosed, fan-cooled motor with principal dimensions to IEC and DIN standards. The motor is flange-mounted with free-hole flange (FF).

Motor-mounting designation in accordance with IEC 60034-7: IM B 5 (Code I) / IM 3001 (Code II).

Electrical tolerances comply with IEC 60034.

The motor efficiency is classified as IE3 in accordance with IEC 60034-30-1.

The motor has thermistors (PTC sensors) in the windings in accordance with DIN 44081/DIN 44082. The protection reacts to both slow- and quick-rising temperatures, e.g. constant overload and stalled conditions.

Thermal switches must be connected to an external control circuit in a way which ensures that the automatic reset cannot cause accidents. The motors must be connected to a motor-protective circuit breaker according to local regulations.

The motor can be connected to a variable speed drive for adjustment of pump performance to any duty point. Grundfos CUE offers a range of variable speed drives. Please find more information in Grundfos Product Center.

Technical data

Controls:

Frequency converter:	NONE

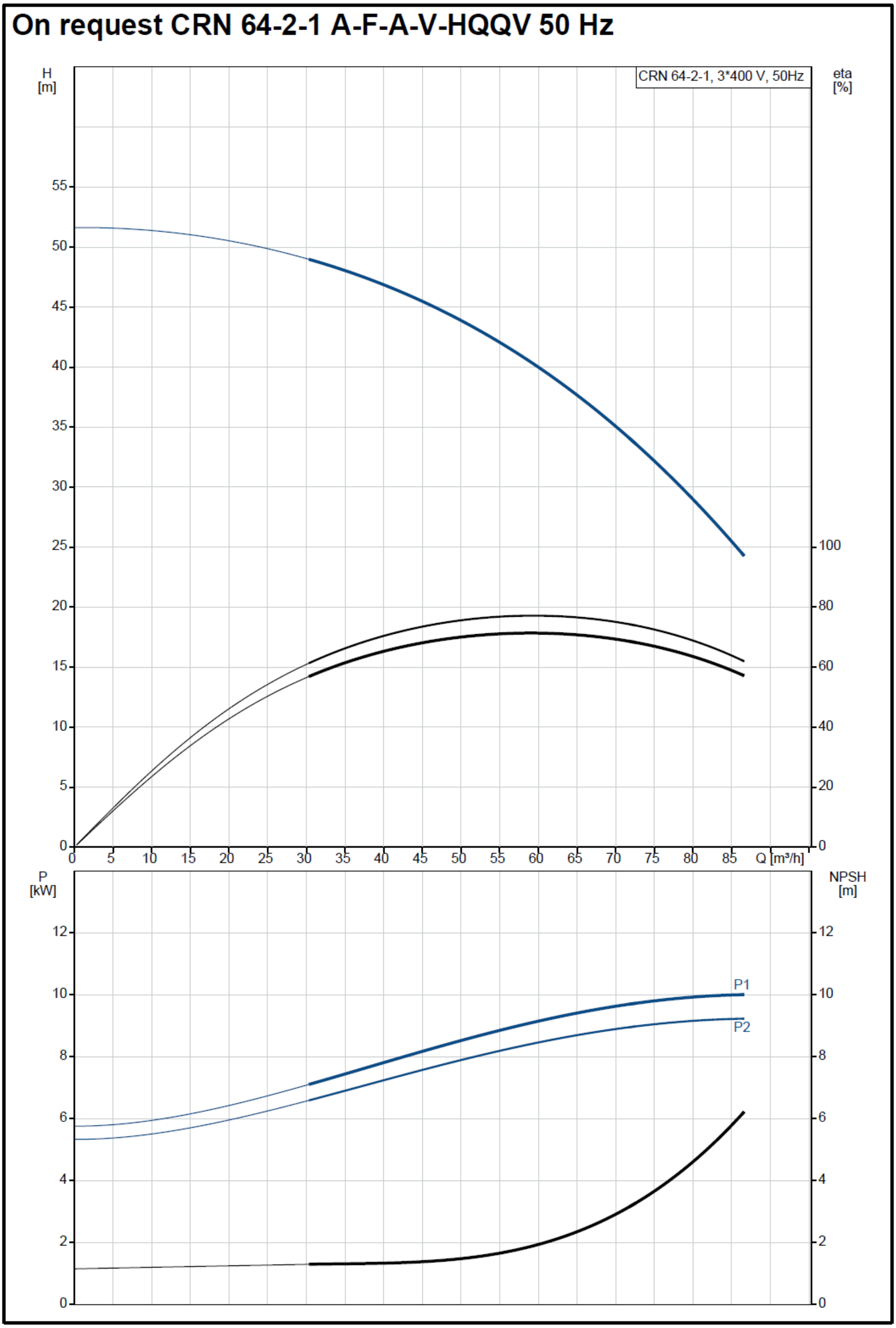
Liquid:

Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temperature during operation:	20 °C
Density:	998.2 kg/m³

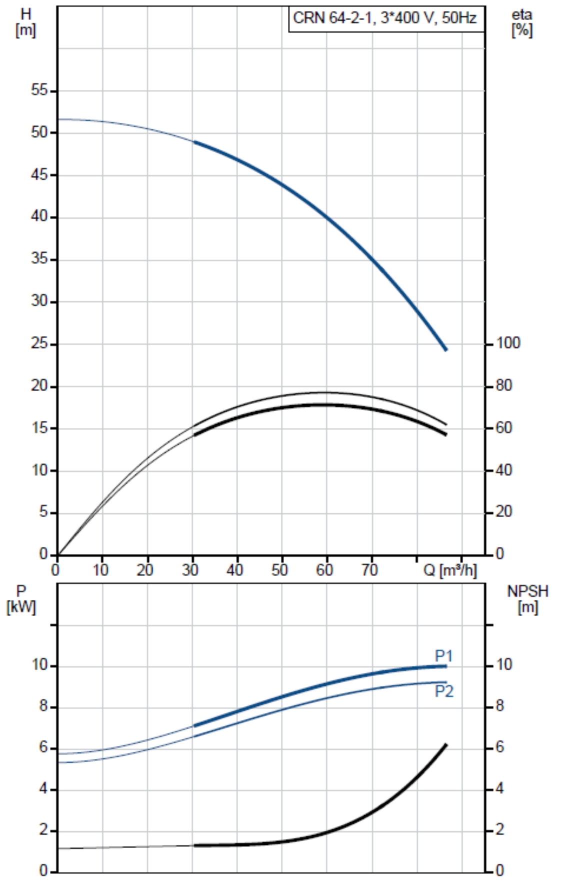
Technical:

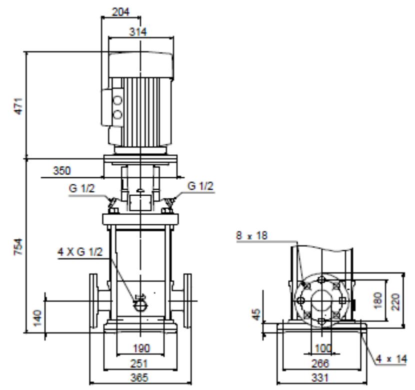
Rated flow:	64 m³/h
Rated head:	37.2 m
Pump orientation:	Vertical
Shaft seal arrangement:	Single

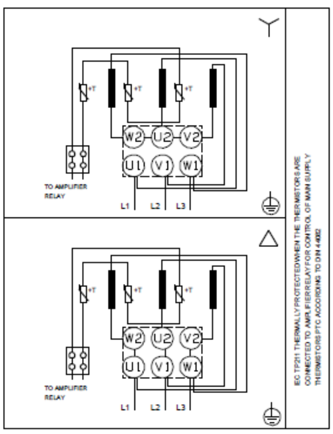
Position	Qty.	Description	
		Code for shaft seal:	HQQV
		Approvals on nameplate:	CE, EAC
		Curve tolerance:	ISO9906:2012 3B
		Materials:	
		Base:	Stainless steel EN 1.4408 AISI 316
		Impeller:	Stainless steel EN 1.4401 AISI 316
		Bearing:	SIC
		Support bearing:	Graflon
		Installation:	
		Maximum ambient temperature:	60 °C
		Maximum operating pressure:	16 bar
		Max pressure at stated temp:	16 bar / 90 °C 16 bar / -20 °C
		Type of connection:	DIN
		Size of inlet connection:	DN 100
		Size of outlet connection:	DN 100
		Pressure rating for pipe connection:	PN 16
		Flange size for motor:	FF300
		Electrical data:	
		Motor standard:	IEC
		Motor type:	160MB
		IE Efficiency class:	IE3
		Rated power - P2:	11 kW
		Power (P2) required by pump:	11 kW
		Mains frequency:	50 Hz
		Rated voltage:	3 x 380-415D/660-690Y V
		Rated current:	20,8-19,8/12,0-11,8 A
		Starting current:	660-780 %
		Cos phi - power factor:	0.88-0.84
		Rated speed:	2940-2950 rpm
		Efficiency:	IE3 91,2%
		Motor efficiency at full load:	91.2-91.2 %
		Motor efficiency at 3/4 load:	91.8 %
		Motor efficiency at 1/2 load:	91.3 %
		Number of poles:	2
		Enclosure class (IEC 34-5):	55 Dust/Jetting
		Insulation class (IEC 85):	F
		Others:	
		Minimum efficiency index, MEI ≥:	0.7
		Net weight:	162 kg
		Gross weight:	195 kg
		Shipping volume:	0.495 m^3


On request CRN 64-2-1 A-F-A-V-HQQV 50 Hz
CRN 64-2-1, 3*400 V, 50Hz
H [m]
eta [%]
Q [m³/h]
P [kW]
NPSH [m]
P1
P2

Description	Value
General information:	
Product name:	CRN 64-2-1 A-F-A-V-HQQV
Product No:	On request
EAN number:	On request
Technical:	
Rated flow:	64 m³/h
Rated head:	37.2 m
Stages:	2
Impellers:	2
Number of reduced-diameter impellers:	1
Low NPSH:	N
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQV
Approvals on nameplate:	CE, EAC
Curve tolerance:	ISO9906:2012 3B
Pump version:	A
Model:	B
Materials:	
Base:	Stainless steel
	EN 1.4408
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Material code:	A
Code for rubber:	V
Bearing:	SIC
Support bearing:	Graflon
Installation:	
Maximum ambient temperature:	60 °C
Maximum operating pressure:	16 bar
Max pressure at stated temp:	16 bar / 90 °C
	16 bar / -20 °C
Type of connection:	DIN
Size of inlet connection:	DN 100
Size of outlet connection:	DN 100
Pressure rating for pipe connection:	PN 16
Flange size for motor:	FF300
Connect code:	F
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temperature during operation:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor standard:	IEC
Motor type:	160MB
IE Efficiency class:	IE3
Rated power - P2:	11 kW
Power (P2) required by pump:	11 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-415D/660-690Y V
Rated current:	20,8-19,8/12,0-11,8 A
Starting current:	660-780 %
Cos phi - power factor:	0.88-0.84
Rated speed:	2940-2950 rpm
Efficiency:	IE3 91,2%
Motor efficiency at full load:	91.2-91.2 %
Motor efficiency at 3/4 load:	91.8 %
Motor efficiency at 1/2 load:	91.3 %
Number of poles:	2
Enclosure class (IEC 34-5):	55 Dust/Jetting







Borehole pump KO-4

Company name:
Created by:
Phone:

Date: 05/02/2020

Qty.	Description
1	**SP 46-5**

Note! Product picture may differ from actual product

Product No.: 15A00005

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

Liquid:
Pumped liquid: Water
Maximum liquid temperature: 60 °C
Selected liquid temperature: 20 °C
Density: 998.2 kg/m³

Technical:
Pump speed on which pump data are based: 2900 rpm
Rated flow: 46 m³/h
Rated head: 43 m
Curve tolerance: ISO9906:2012 3B

Materials:
Pump: Stainless steel
EN 1.4301
AISI 304
Impeller: Stainless steel
EN 1.4301
AISI 304

Installation:
Pump outlet: RP4
Motor diameter: 6 inch

Electrical data:
Power (P2) required by pump: 7.5 kW

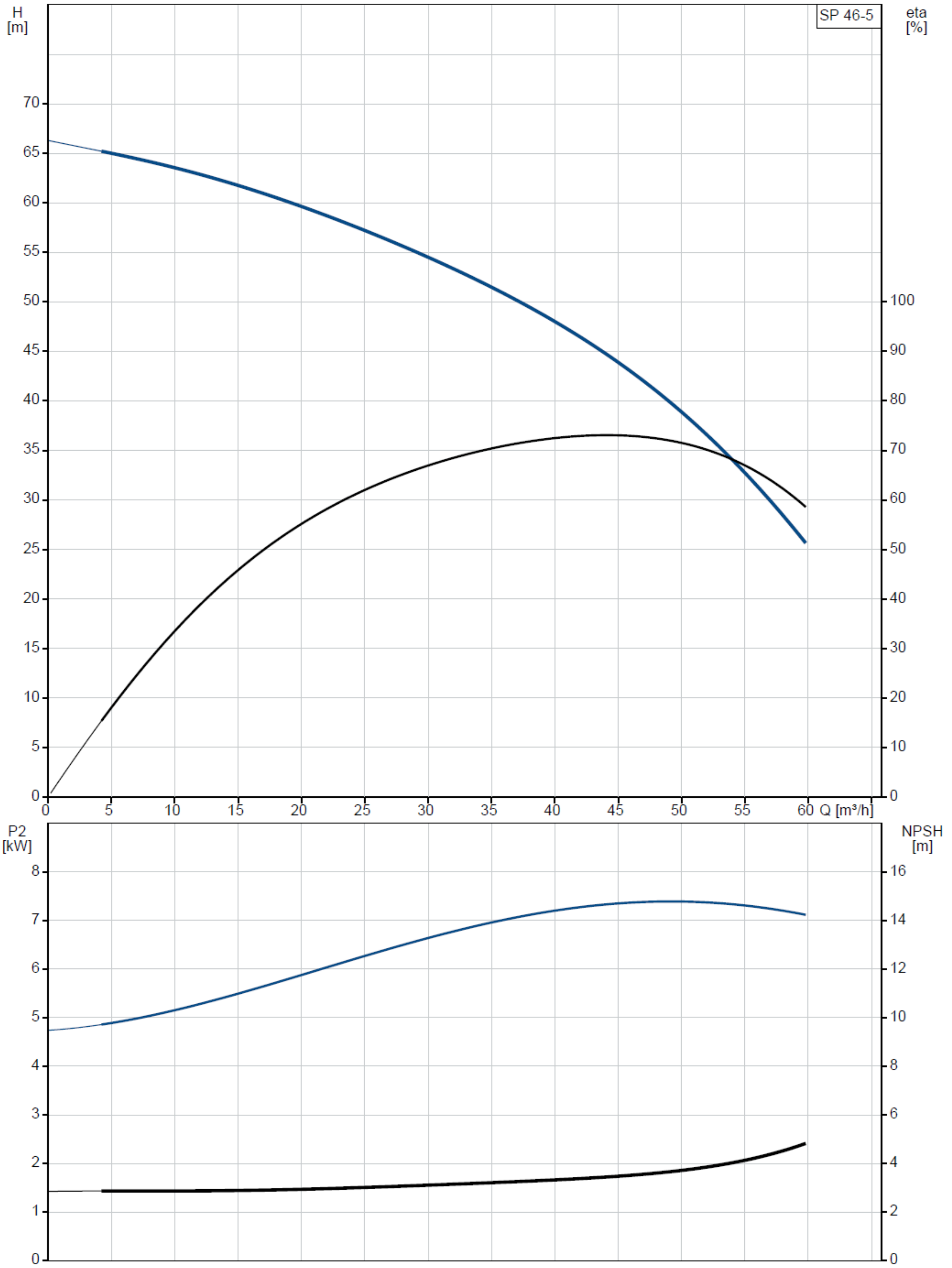
Others:
Minimum efficiency index, MEI ≥: 0.40
ErP status: EuP Standalone/Prod.
Net weight: 17.2 kg
Gross weight: 19.8 kg
Shipping volume: 0.032 m³

GRUNDFOS

Company name:
Created by:
Phone:

Date: 05/02/2020

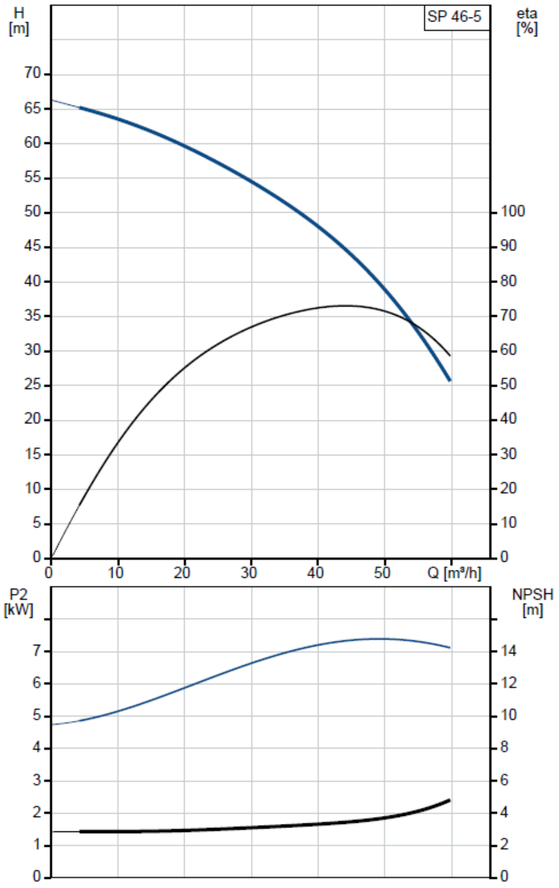
15A00005 SP 46-5 50 Hz

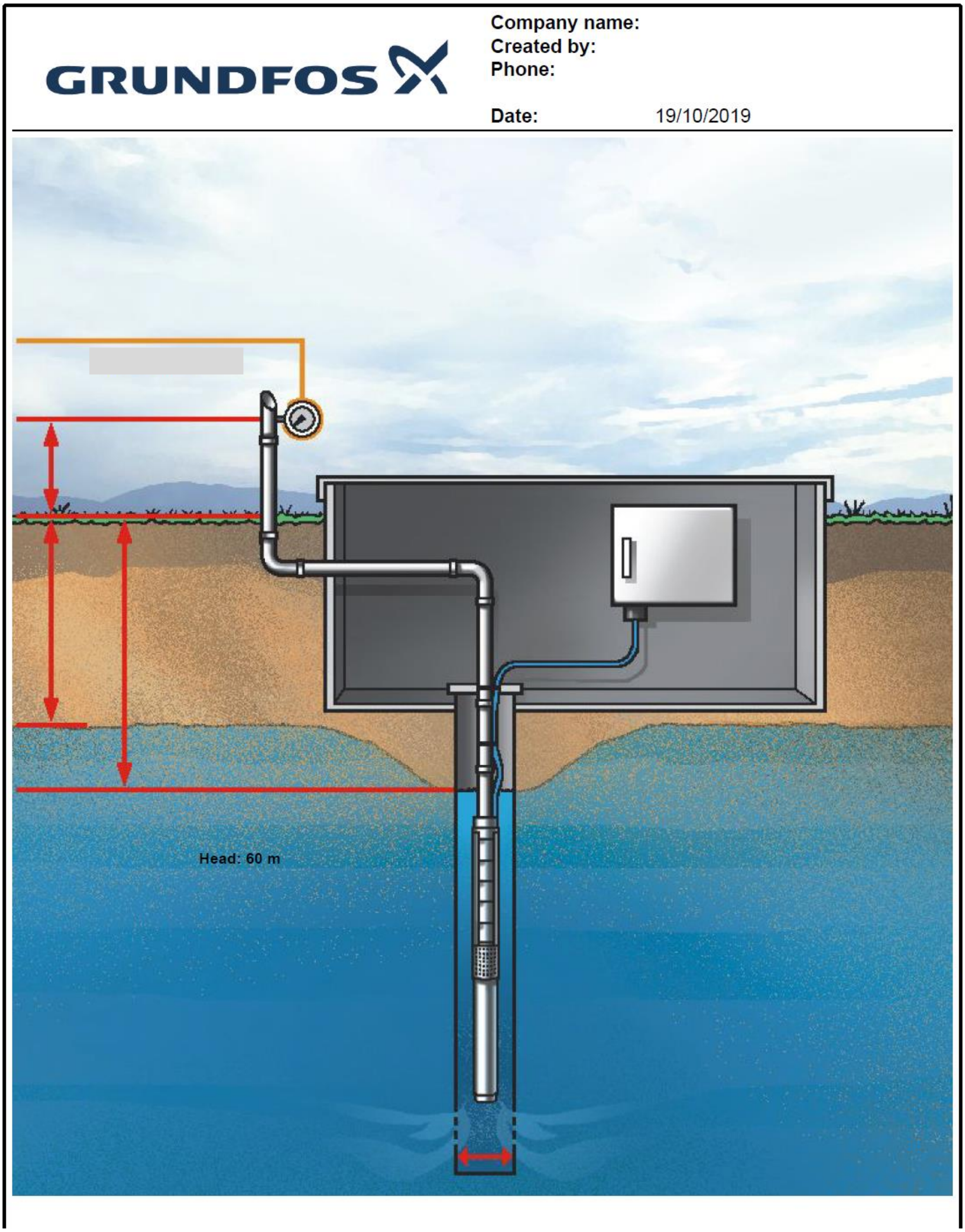


Company name:
Created by:
Phone:

Date: 05/02/2020

Description	Value
General information:	
Product name:	SP 46-5
Product No:	15A00005
EAN number:	5700391148262
	5700391148262
Technical:	
Pump speed on which pump data are based:	2900 rpm
Rated flow:	46 m³/h
Rated head:	43 m
Stages:	5
Impeller reduc.:	NONE
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Installation:	
Pump outlet:	RP4
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	60 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Applic. motor:	GRUNDFOS
Power (P2) required by pump:	7.5 kW
Others:	
Minimum efficiency index, MEI ≥:	0.40
ErP status:	EuP Standalone/Prod.
Net weight:	17.2 kg
Gross weight:	19.8 kg
Shipping volume:	0.032 m³




GRUNDFOS
Company name:
Created by:
Phone:
Date: 19/10/2019
Head: 60 m

Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
09/04/2019	11:19:57 AM	50.002	414.3	414.3	414.5	130.0	128.3	129.5	79.65	0.860
09/04/2019	11:20:57 AM	49.999	416.4	416.5	416.9	98.2	96.6	96.9	46.23	0.750
09/04/2019	11:21:57 AM	50.000	419.1	419.2	419.6	54.4	51.7	50.7	28.59	0.750
09/04/2019	11:22:57 AM	50.001	419.4	419.2	419.5	54.5	51.8	50.6	28.59	0.750
09/04/2019	11:23:57 AM	50.001	419.4	419.1	419.5	54.5	51.7	50.5	28.59	0.750
09/04/2019	11:24:57 AM	50.002	419.2	419.3	419.2	54.4	51.9	50.6	28.59	0.750
09/04/2019	11:25:57 AM	50.001	418.9	419.1	419.3	54.3	51.7	50.7	28.59	0.750
09/04/2019	11:26:57 AM	50.000	418.9	419.1	419.4	54.3	51.6	50.7	28.59	0.750
09/04/2019	11:27:57 AM	50.000	418.9	419.0	419.3	54.4	51.7	50.7	28.59	0.750
09/04/2019	11:28:57 AM	50.002	418.6	419.1	419.3	54.2	51.6	50.8	28.59	0.750
09/04/2019	11:29:57 AM	50.000	418.9	419.5	419.5	54.2	51.7	50.9	28.59	0.750
09/04/2019	11:30:57 AM	50.000	419.0	419.5	419.3	54.2	51.9	50.7	28.59	0.750
09/04/2019	11:31:57 AM	50.000	417.4	417.7	417.5	91.6	90.8	90.5	33.81	0.710
09/04/2019	11:32:57 AM	49.999	414.1	414.3	414.3	131.4	129.9	130.9	79.74	0.850
09/04/2019	11:33:57 AM	50.003	414.4	414.4	414.8	130.2	128.2	129.9	79.8	0.860
09/04/2019	11:34:57 AM	49.999	414.4	414.5	414.5	130.1	128.5	129.5	79.74	0.860
09/04/2019	11:35:57 AM	49.999	414.5	414.8	414.8	129.8	128.4	129.7	79.74	0.860
09/04/2019	11:36:57 AM	50.002	415.7	415.9	416.0	114.6	113.2	113.7	58.92	0.770
09/04/2019	11:37:57 AM	50.000	419.6	419.8	419.8	54.4	51.9	50.7	28.65	0.750
09/04/2019	11:38:57 AM	50.001	419.7	419.9	420.0	54.5	51.8	50.8	28.65	0.750
09/04/2019	11:39:57 AM	49.999	419.8	419.8	420.0	54.5	51.8	50.7	28.65	0.750
09/04/2019	11:40:57 AM	50.004	419.6	419.8	420.1	54.5	51.8	50.8	28.65	0.750

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
09/04/2019	11:41:57 AM	50.001	419.6	420.0	420.0	54.4	51.9	50.9	28.65	0.750
09/04/2019	11:42:57 AM	50.000	419.7	420.1	419.9	54.3	52.0	50.8	28.65	0.750
09/04/2019	11:43:57 AM	49.997	419.8	420.0	420.0	54.4	51.9	50.8	28.65	0.750
09/04/2019	11:44:57 AM	49.999	420.0	420.1	420.3	54.5	51.9	50.8	28.65	0.750
09/04/2019	11:45:57 AM	49.995	419.9	420.1	420.1	54.5	51.9	50.8	28.65	0.750
09/04/2019	11:46:57 AM	50.004	420.1	420.2	420.4	54.5	51.9	50.8	28.68	0.750
09/04/2019	11:47:57 AM	49.999	420.2	420.3	420.5	54.6	52.0	50.8	28.68	0.750
09/04/2019	11:48:57 AM	50.001	414.3	414.2	414.2	142.5	141.1	141.8	76.02	0.790
09/04/2019	11:49:57 AM	50.001	415.3	415.6	415.3	129.9	128.9	129.4	79.83	0.860
09/04/2019	11:50:57 AM	50.001	415.3	415.6	415.3	129.8	128.9	129.3	79.83	0.860
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09/04/2019	11:58:57 AM	49.999	421.5	421.3	421.6	52.9	52.1	50.9	28.23	0.740
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09/04/2019	12:02:57 PM	49.995	421.1	421.2	421.3	52.7	52.1	50.9	28.23	0.750
09/04/2019	12:03:57 PM	49.994	421.1	421.1	421.3	52.8	52.1	50.9	28.23	0.750
09/04/2019	12:04:57 PM	49.996	421.5	421.3	421.6	52.9	52.1	50.9	28.23	0.740

Appendix C – PVSYST simulation results

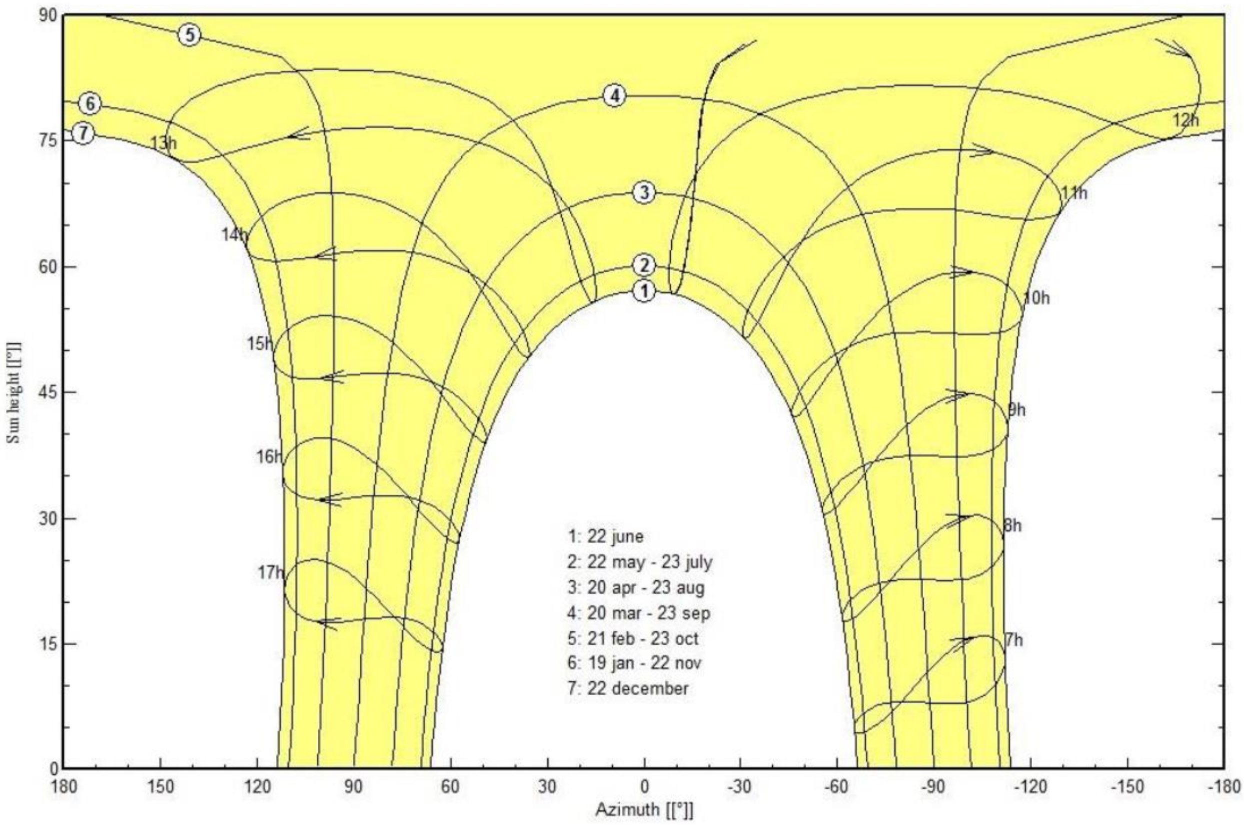
Definition of Geographical Site

Geographical Site	**Honiara**	Country	**Solomon Islands**
	File New.SIT of 01/10/19 12h40		
Situation	Latitude: -9.45° S		Longitude: 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10 m

Monthly Meteo values

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m² day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m² day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

Solar paths at Honiara, (Lat. -9.4517° S, long. 159.9612° E, alt. 10 m) - Legal Time



Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt: 10°		Azimuth 0°

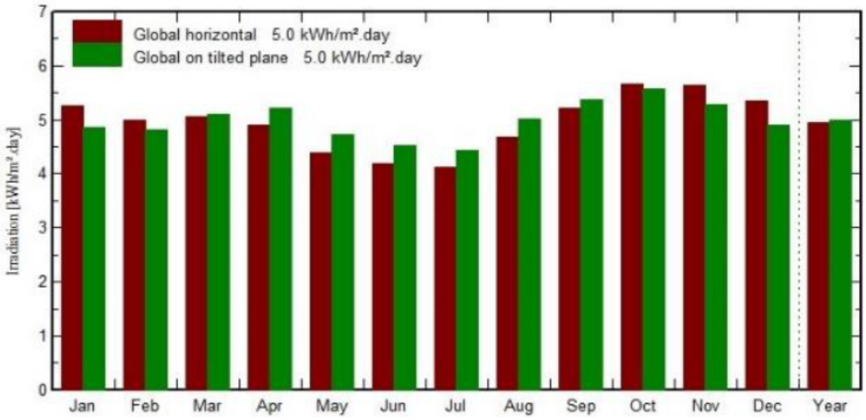
PV Installation main features

Module Type	Standard
Technology	Thin film
Mounting method	Flat roof
Back ventilation properties	Free Standing

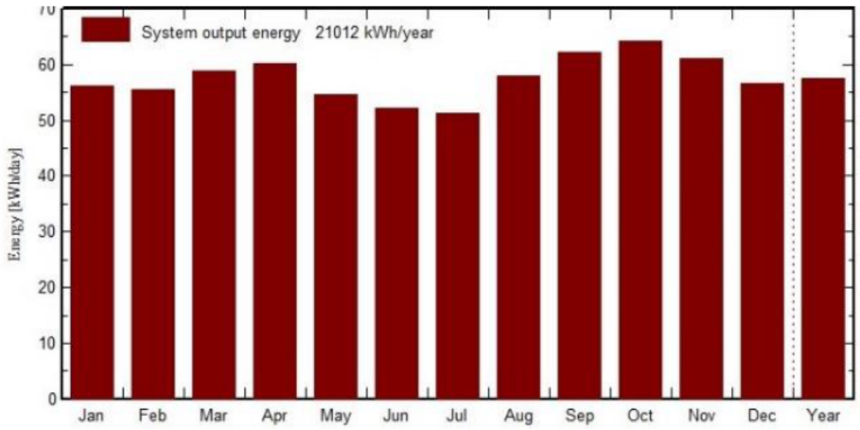
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	13.6 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	21.0 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	56.16	1741
Feb	4.99	4.81	55.58	1556
Mar	5.05	5.10	58.93	1827
Apr	4.91	5.21	60.18	1806
May	4.39	4.72	54.53	1690
June	4.19	4.52	52.16	1565
Jul	4.12	4.43	51.22	1588
Aug	4.67	5.02	58.03	1799
Sept	5.21	5.38	62.09	1863
Oct	5.67	5.57	64.29	1993
Nov	5.64	5.28	61.02	1831
Dec	5.35	4.90	56.59	1754
Year	4.95	4.98	57.57	21012

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt:10°		Azimuth: 0°

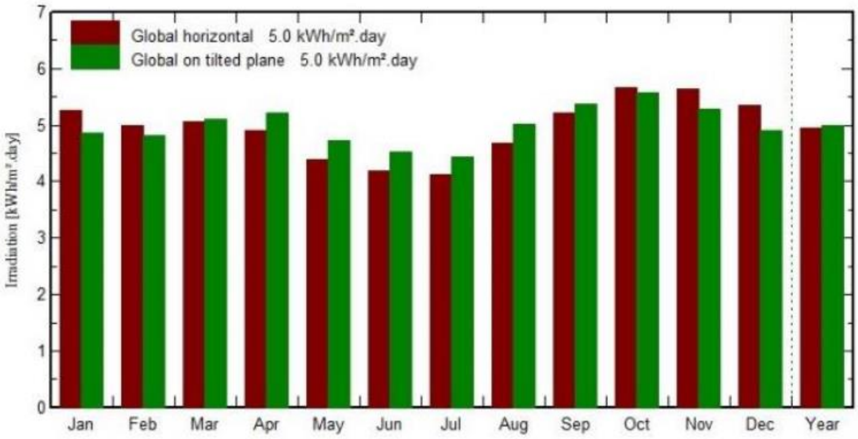
PV Installation main features

Module Type	Standard
Technology	Monocrystalline cell
Mounting method	Flat roof
Back ventilation properties	Free Standing

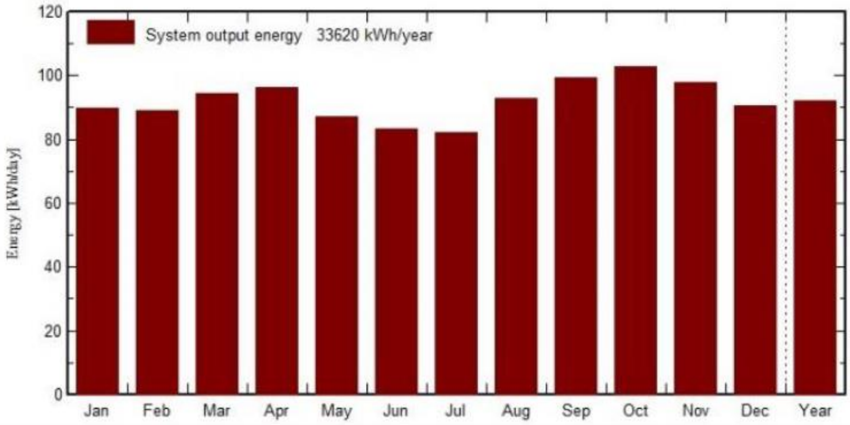
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	21.8 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	33.6 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy

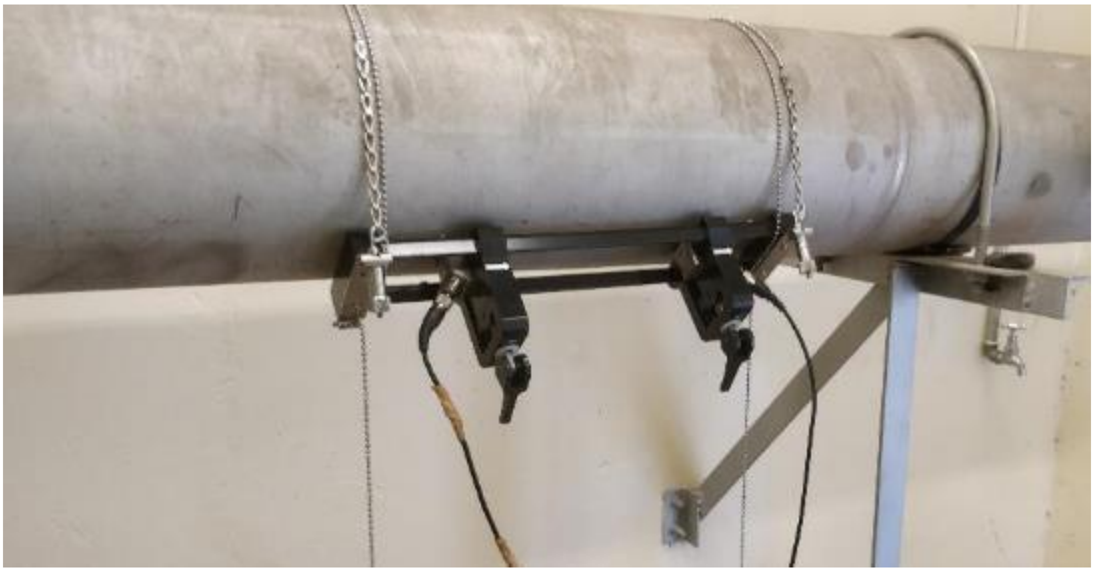


System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	89.85	2785
Feb	4.99	4.81	88.93	2490
Mar	5.05	5.10	94.29	2923
Apr	4.91	5.21	96.29	2889
May	4.39	4.72	87.25	2705
June	4.19	4.52	83.45	2504
Jul	4.12	4.43	81.95	2540
Aug	4.67	5.02	92.86	2879
Sept	5.21	5.38	99.34	2980
Oct	5.67	5.57	102.9	3189
Nov	5.64	5.28	97.63	2929
Dec	5.35	4.90	90.55	2807
Year	4.95	4.98	92.11	33620

Appendix D – Photographs taken during the study



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Detailed Feasibility Report Kwaibala Pump Station

Prepared for
UNIDO – CTCN

Under the project
Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious “technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan”.

The study team is indebted to Mr. Ian Gooden, Chief Executive Officer, Solomon Island Water Authority for showing keen interest in the study and thankful to the progressive management of Solomon Water for their wholehearted support and cooperation for the study and preparation of Detailed Feasibility Report. It is well worthy to mention that the efforts being taken, and the enthusiasm shown by all the personnel towards energy efficiency was admirable. A special thanks to Mr. Mark Waite (Strategic Projects Management Advisor), Mr. Shaun Kies-Ryan (Hydrogeologist), Mr. Noel Orudiana (Project Manager) and Mr. Danny Titiri (Electrical and Mechanical Team Lead) for coordinating the field visits. We would like to thank all the staff for support including technicians, electricians i.e. Mr. Livingston, Mr. Sam and Mr. Moffat.

PwC is grateful to Mr. Hudson Kauhiona, Director Climate Change for his committed support from Ministry of Environment, Climate Change, Disaster Management and Meteorology for executing the technical assistance.

Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Kwaibala pump station is in Auki city in Malaita province. The pump station is over a decade old. The pump station has a 250 m^3 water receiver tank, which receives water from Kwaibala spring source. The water from receiving tanks is pumped to Gallery Tank reservoir using two transfer pumps. The system is designed for continuous operation of transfer pumps. At the time of study only one out of the two transfer pumps were operational. Details of Kwaibala pump station is presented below.

Name of the pump station	Kwaibala
No. of transfer pumps	2 (1 operational)
No. of bore-hole pumps	0
Monthly electricity consumption	6,081 kWh (average of last 6 months)
Monthly water production	17,136 m^3 (based on onsite measurement)
Name and details of contact person	Noel Orudiana, Project manager norudiana@solomonwater.com.sb, +677-8534816
Annual working days	365

A detailed feasibility study of Kwaibala pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Kwaibala pump station is in Auki city in Malaita province. The pump station is over a decade old. The pump station has a 250 m^3 water receiver tank, which receives water from Kwaibala spring source. The water from receiving tanks is pumped to Gallery Tank reservoir using two transfer pumps. The pump station produces 571.2 m^3 water daily consuming about 194.2 kWh electrical energy. The existing specific energy consumption is 0.340 kWh per m^3. The study has identified recommendations for energy conservation (**Table**). These recommendations could save annually about 25,925 kWh of electricity. These recommendations have an estimated investment of US $ 25080 and can yield a monetary savings of US $ 17,910 per year. The annual energy saving is estimated to be 35.5 % of total energy consumption by the pump station (**Figure**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 17.11 tonnes of CO_2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM	Replacement of pump with an efficient pump[1]	25880	$ 17,878	$ 25,000	1.4	17.08
	Replacement of FTL with LED lights	45	$ 32	$ 80	2.5	0.03
	Total	**25925**	**17910**	**25080**	**1.4**	**17.11**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.340 kWh/m^3	0.224 kWh/m^3
Specific CO_2 emission	0.216 kg CO_2/m^3	0.142 kg CO_2/m^3

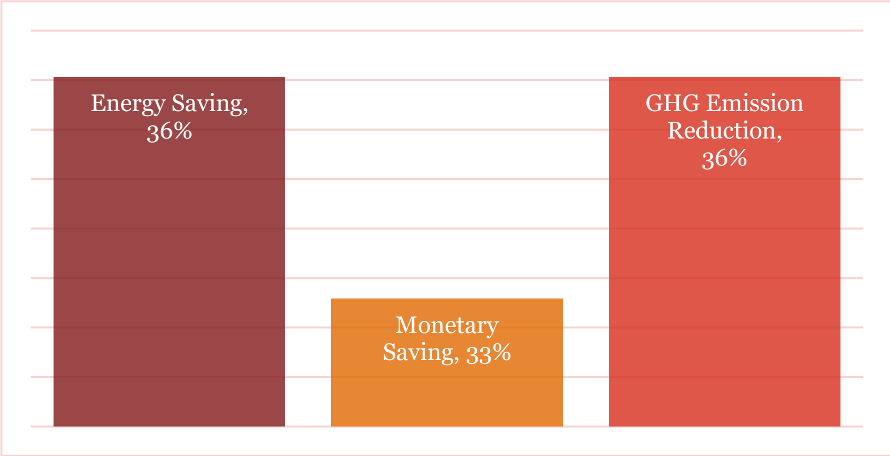
[1] *Considering option 2 with flow rate 45 m^3 (Grundfos CRN 45-3)*

Funding options

The overall investment proposed for the energy conservation measures for Kwaibala pump station is US$ 25,080. The simple payback on this investment is 1.4 years. Solomon Water can fund the project through internal funds. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Kwaibala pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Identified saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m^3	1,000 liters
1 USD	8 SBD

* *Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[2] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

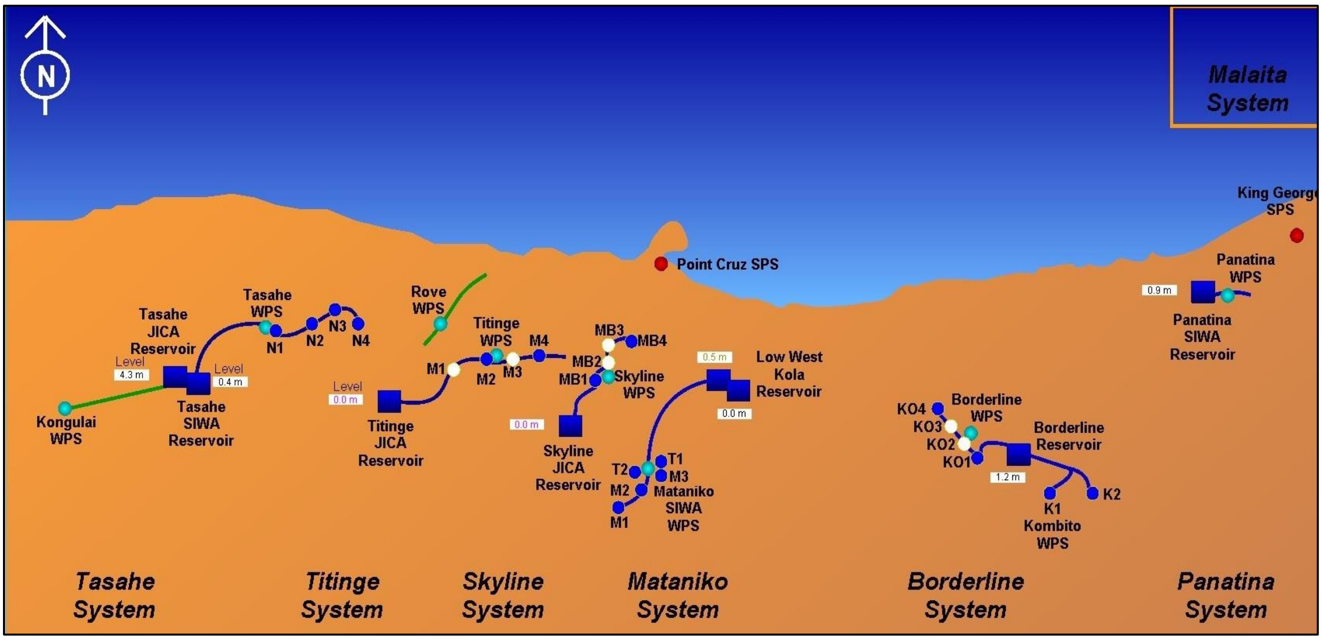


Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[2]

[2] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[3]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

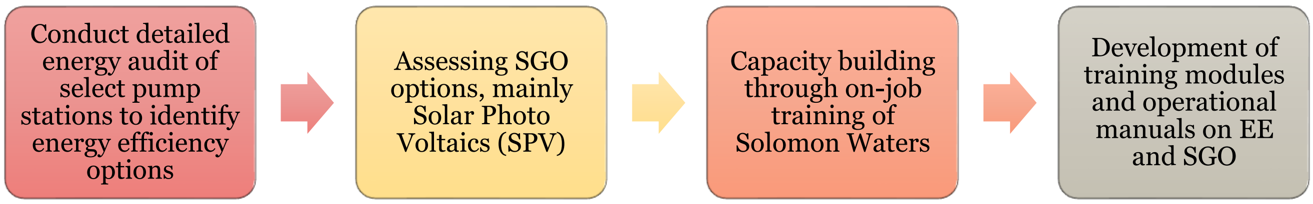


Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[3] *Response Plan, CTCN request ID: 2017000039*

Assessment of Energy Efficiency and RE options

- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options

Capacity building through on-job training for Solomon Water

- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation

Detail assessments of shortlisted EE and SGO options for Solomon Water

- Technical analysis
- Financial analysis

Monitoring of impact

- Monitoring and evaluation of Impacts
- Report on Gender co-benefits

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

Environmental Benefits	Economic Benefits	Social Benefits
• Enhanced energy efficiency • Improved energy security • Lower dependence on imported fuels • Contribution towards climate change mitigation	• Reduced operating (energy) cost for Solomon Water • Increased investments in energy efficiency and renewable energy	• Skill enhancement of Solomon Water professionals on EE and RE • Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

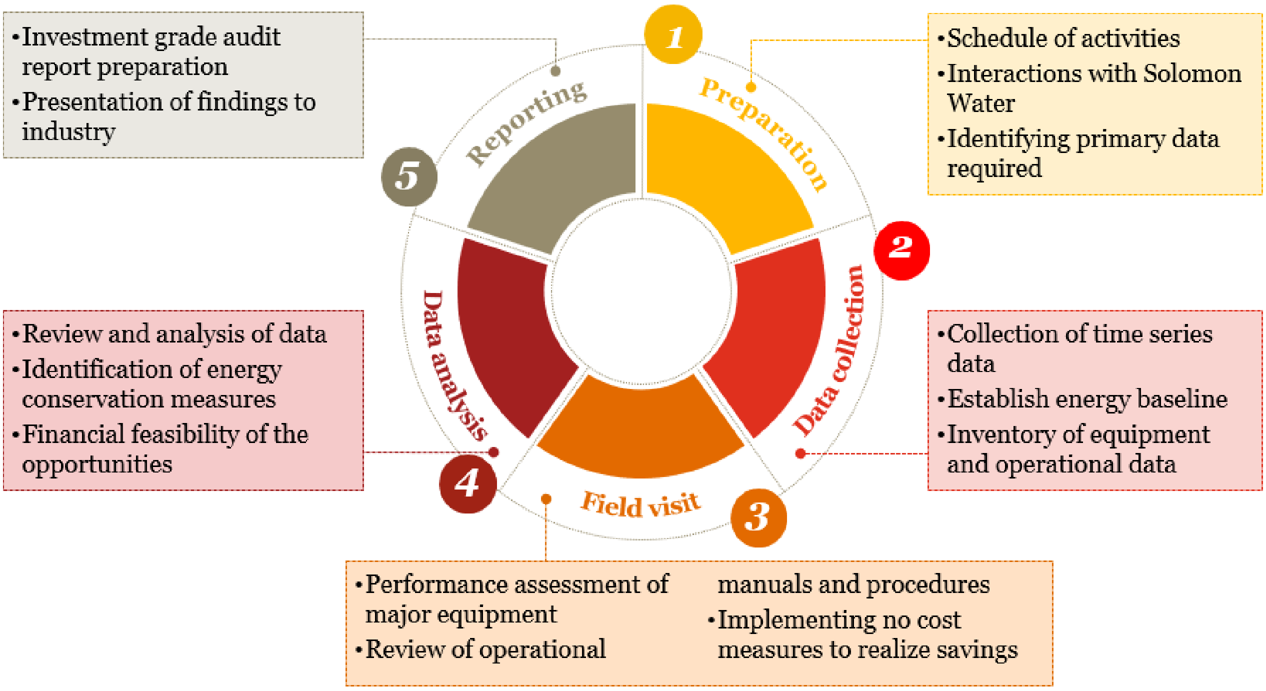


Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Kwaibala pump station

2.1. About Kwaibala pump station

Kwaibala pump station is in Auki city of Malaita province. The pump station is over a decade old. The town water supply of Auki comes from the Kwaibala spring source which is located 2 kms away from the town. The Kwaibala pump station has two transfer pumps for pumping the water from the spring source to the Gallery Tank. Gallery tank is 23 meters higher than Kwaibala and has a capacity of 250 m^3. There is also a provision of a larger water reservoir (ADB reservoir), having a capacity of 500 m^3. At the time of study, the only one transfer pump was operational, and it was supplying water to Gallery tank.

2.2. Transfer pumps

The Kwaibala pump station is equipped with two vertical centrifugal end-suction pumps. These two pumps are connected to operate in parallel, however one of the pumps is currently not operational. Pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Gallery Tank reservoir. Design details of the transfer pumps and its corresponding motor is presented in **Table 2** and **Table 3** respectively. The pictorial view of transfer pumps is presented in **Figure 6**.

Table 2 Design details of transfer pumps

Particular	Unit	Pump #1	Pump #
Make	-	Southern Cross	Southern Cross
Model	-	45-03B SQQE	45-03B SQQE
Design flow	m^3/h	45.0	45.0
Design head	m	59.6	59.6
Max. head	m	77.2	77.2
Pump speed	rpm	2900	2900
Recommended motor rating	kW	11.0	11.0
Max. pressure	bar	25.0	25.0
Pump efficiency	%	NA	NA

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor #1	Motor #2
Make	-	Monarch	Monarch
Power	kW	11	11
Voltage	V	415.0	415.0
Current	I	19.5	19.5
Power Factor	-	0.89	0.89
Motor speed	rpm	2940	2940
Frequency	Hz	50.0	50.0
Rating	-	MEPS Compliant	MEPS Compliant
Efficiency	%	89.5	89.5

Figure 6 Kwaibala transfer pumps

3. Energy consumption analysis

3.1. Energy source and tariff details

Kwaibala pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Kwaibala pump station is under Commercial C5[4] type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff from January 2019 to June 2019 was captured during feasibility study and same is presented in **Table 4**.

Table 4 Electricity tariff details – Last 6 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)					NAC (SBD/month)
		C1[5]	C2[6]	C3[7]	C4[8]	C5[9]	
Jan-19	2.77	4.11	3.7	3.41	3.07	2.91	1629.09
Feb-19	2.49	4.16	3.75	3.45	3.10	2.94	1629.09
Mar-19	2.71	4.14	3.73	3.43	3.08	2.93	1638.91
Apr-19	2.65	4.17	3.76	3.46	3.11	2.95	1652.22
May-19	2.64	4.20	3.78	3.48	3.13	2.98	1664.20
Jun-19	2.21	4.2	3.78	3.48	3.13	2.97	3324.80
Average	**2.58**	**4.04**	**3.64**	**3.51**	**3.01**	**2.86**	**11,538**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 6 months for Kwaibala pump station was analyzed. These 6-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 6 months (January 2019 to June 2019) was 6,081 kWh. The bill amount corresponding to this consumption was SBD 214,604 i.e. USD 26,825.

The electricity consumption along with monthly energy charges is presented in **Table 5**. Variation of electricity consumption is presented in **Figure 7**.

Table 5 Electricity consumption details

Month	Consumption	NAC (SBD)	Fuel charge (SBD)	Non-fuel charge					Total (SBD)
	kWh			C1	C2	C3	C4	C5	
Jan-19	5,006	1629	13867	1028	1295	2387	3684	7292	**31182**
Feb-19	6,000	1629	14940	1041	1313	2416	3725	10318	**35382**
Mar-19	5,531	1639	14989	1035	1306	2401	3696	8881	**33946**

4 Commercial C5 connection is >2500 kWh
5 First 250 units of monthly consumption
6 Next 350 units of monthly consumption
7 Next 700 units of monthly consumption
8 Next 1200 units of monthly consumption
9 Remaining consumption of the month

Month	Consumption	NAC (SBD)	Fuel charge (SBD)	Non-fuel charge					Total (SBD)
	kWh			C1	C2	C3	C4	C5	
Apr-19	6702	1652	17760	1043	1316	2422	3732	12396	**40321**
May-19	7,038	1664	18580	1050	1323	2436	3756	13523	**42333**
Jun-19	6,206	1662	13715	1050	1323	2436	3756	11007	**34949**
Average	**6,081**	**1646**	**15642**	**1041**	**1313**	**2416**	**3725**	**10570**	**36352**
Annual	**72,996**	**19751**	**31284**	**2082**	**2625**	**4833**	**7450**	**20162**	**430364**

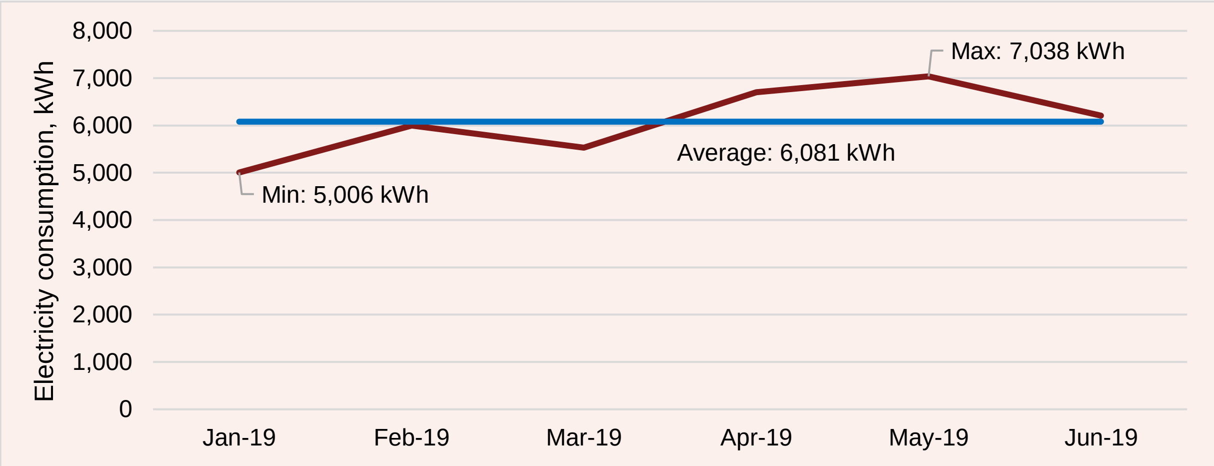


Figure 7 Electricity consumption profile January 2019 – June 2019 (6 months)

Key observations for the period January to June 2019:

- Monthly average consumption of electricity was 6,081 kWh (varying between 5,006 to 7,0038)
- Average electricity tariff (excluding fixed NAC) was SDB 5.71 per kWh (US$ 0.71 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.58 per kWh (US¢ 32.2 per kWh)

Average monthly electricity consumption of Kwaibala Pump Station is 6,081 kWh

A sample electricity bill of Kwaibala pump station is presented in **Figure 8**.

3.3. Specific energy consumption

The daily water transfer from the source to the reservoir using transfer pump was 571.2 m^3 and the daily electrical energy consumption was 194.2 kWh. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 6 months data, which was 202.7 kWh. The specific energy consumption is presented in **Table 6**.

Table 6 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	571.2
Daily electricity consumption	kWh	194.2
Specific energy consumption	**kWh/m³**	**0.340**

Solomon Islands Electricity Authority
trading as SOLOMON POWER

INVOICE / STATEMENT

Customer

SIWA- Auki Kwaibala Pump Station
P O Box 1407
Auki

Date	15/June/2019
Customer Number	20028
Customer Type	**COMMERCIAL**
Customer Category	**C5**

Location: Auki kwaibala Pump Station
Kwaibala Riverside

Previous Month

Balance at Previous Account Date	$82,653.50
Balance Prior to 15 Jun 19	$82,653.50

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$34,949.48	$42,332.58	$40,320.92	$0.00	$117,602.98

Month 15/June/2019

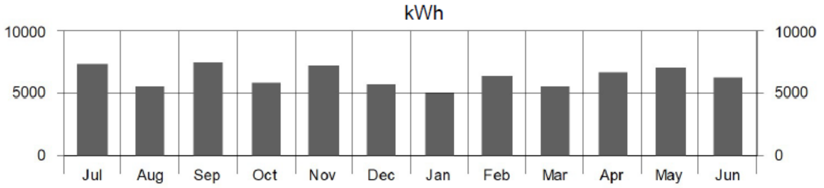
Readings from 15/May/2019 to 15/Jun/2019 **Days** 31

Usage

	Meter no.	Previous	Present	Multi	Units
1	21605996	75,508	81,714	1	6,206

Total **6,206.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 75853 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	C5	Days	31	1,662.40		1,662.40
Fuel	C1	kWh	6,206.00	2.2100	1.0000	13,715.26
Non-Fuel	C1	kWh	250.00	4.2000	1.0000	1,050.00
	C2	kWh	350.00	3.7800	1.0000	1,323.00
	C3	kWh	700.00	3.4800	1.0000	2,436.00
	C4	kWh	1,200.00	3.1300	1.0000	3,756.00
	C5	kWh	3,706.00	2.9700	1.0000	11,006.82
			6,206.00			19,571.82

TOTAL THIS PERIOD	**$34,949.48**
TOTAL DUE	**$117,602.98**
FINAL DATE FOR PAYMENT:	30/June/2019

No further notices will be issued. Unpaid accounts will have supply disconnected.
Previous month balances are payable immediately.

Figure 8 Sample electricity bill of Kwaibala pump station

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with two transfer pumps. These are vertical end-suction centrifugal pumps. Pumps are of Southern Cross make and are driven by individual 11 kW motor. Typically, one pump operates at any given time and other one is standby. During the site visit, only one pump was operational and performance assessment test was conducted on the same.

The performance assessment of transfer pump was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump was operating continuously. However, pump had a level-based control depending of level of water in receiving reservoir. The daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current.

The performance assessment of transfer pump is presented in **Table 7**.

Table 7 Performance assessment of transfer pump 2

Particular	Unit	Pump 2
Operating flow	m^3/h	23.80
Suction head	m	5.00
Discharge head	m	49.50
Total head	m	54.50
Hydraulic power	kW	3.53
Motor input power	kW	8.09
Shaft power	kW	7.24
Pump efficiency	**%**	**48.81**

The operating efficiency of the transfer pumps was 48.81%, which is below par with reference typical efficiency of similar rating pumps. The actual duty point could not be plotted as the pump curve was not available. The total daily water pumped by transfer pumps was 571 m^3.

The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 8**.

Table 8 Transfer pumps motor performance

Parameter	Unit	Motor 2
Voltage	V	409.00
Current	I	14.10
Power factor	-	0.810
Power input	kW	8.09
Motor Efficiency	%	89.5
Power shaft	kW	7.24
Motor loading	**%**	**65.83**

4.1.2. Energy conservation measure

Two options were considered for energy conservation at Kwaibala transfer pumps.

OPTION – A: Considering water flow rate as 25 m3/h (the present measured flow)

The flow rate of transfer pump was 23.8 m3/h, which is substantially lower than the design flow rate 45.0 m3/h. This resulted in lower pump operating efficiency, 48.81%. Suspected reason for drop is flow rate is damaged impeller. Replacing impeller is expected to improve the flow rate, but as the pump is around a decade old, we have recommended replacement of pump with a vertical centrifugal multistate pump with IE4 rated motor to achieve higher efficiency.

The technical specification of proposed pump is as follows (detailed specification is presented in **Appendix A**):

- Make and model: Grundfos CRN 20-6
- Design flow rate: 21 m3/h (Pump operating parameter 26)
- Design head: 70 m (Pump operating parameter 55)
- Pump Best Eficiency: 75% (At system operating point 70%)
- Motor rating and efficiency: IE4, 91.70 %

OPTION – B: Considering water flow rate as design flow of transfer pumps i.e. 45 m3/h

For the same pump considering the parameters as described in Option A, we propose a different pump with rating same as the design rating of existing pump i.e. 45 m3/h, with vertical centrifugal multistate pump with IE4 rated motor to achieve higher energy efficiency.

The technical specification of proposed pump is as follows (detailed specification is presented in **Appendix A**):

- Make and model: Grundfos CRN 45-3
- Design flow rate: 45 m3/h (Pump operating parameter 50)
- Design head: 59 m (Pump operating parameter 55)
- Pump Best Eficiency: 77% (At system operating point 75%)
- Motor rating and efficiency: IE4, 92.6 %

The efficiency improvement and corresponding energy saving estimation is presented in **Table 9**.

Table 9 Transfer pump: Energy saving estimation

Particular	Unit	Value	
		Option A	Option B
Operating flow	m^3/h	25	50
Overall head	m	55	55
Hydraulic power	kW	3.90	7.49
Pump design efficiency	%	70	75

Particular	Unit	Value	
		Option A	Option B
Shaft power required	kW	5.57	9.99
Standard motor size	kW	7.50	11
IE4 Motor efficiency	%	91.70	92.6
Overall power input	**kW**	6.07	10.79
Net daily water duty	m^3	571.2	571.2
Total operating hours	h/day	21.97	11.42
Annual energy consumption – proposed	kWh/year	48,679	44,992
Annual energy consumption – existing	kWh/year	70,873	70,873
Annual energy saving	kWh/year	22,194	25,880
Monetary saving	SBD/year	122,649	143,024
	USD/year	**$ 15,331**	**$ 17,878**
Cost of new pump with IE4 motor	USD	$ 14,000	$ 19,000
Freight cost for pump-motor set	USD	$ 500	$ 500
Cost at port in Solomon Islands	USD	14,500	19,500
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost of pump-motor set with IE4 motor	**USD**	$ 18,750	$ 25,000
Simple payback period	**years**	**1.2**	**1.4**
GHG emission reduction potential	**tCO_2/year**	**14.6**	**17.1**

4.2. Electrical system

4.2.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. The logging of total power is shown in **Figure 9**.

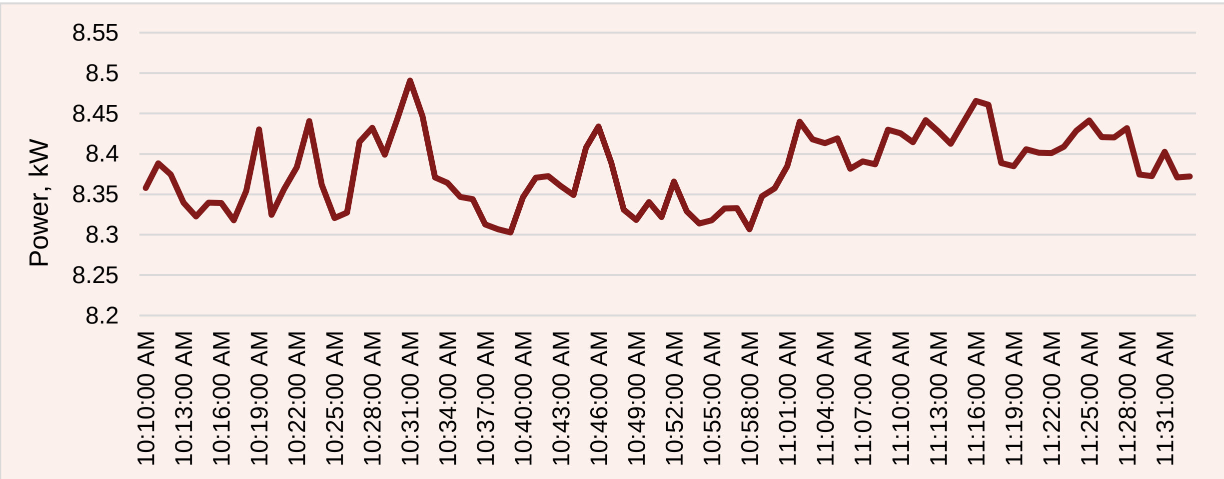


Figure 9 Kwaibala pump station total power log

The power factor (PF) at the main incomer of pump station was varying between 0.700 – 0.860, with an average PF 0.815. The PF variation over 24 hours is presented in **Figure 10**.

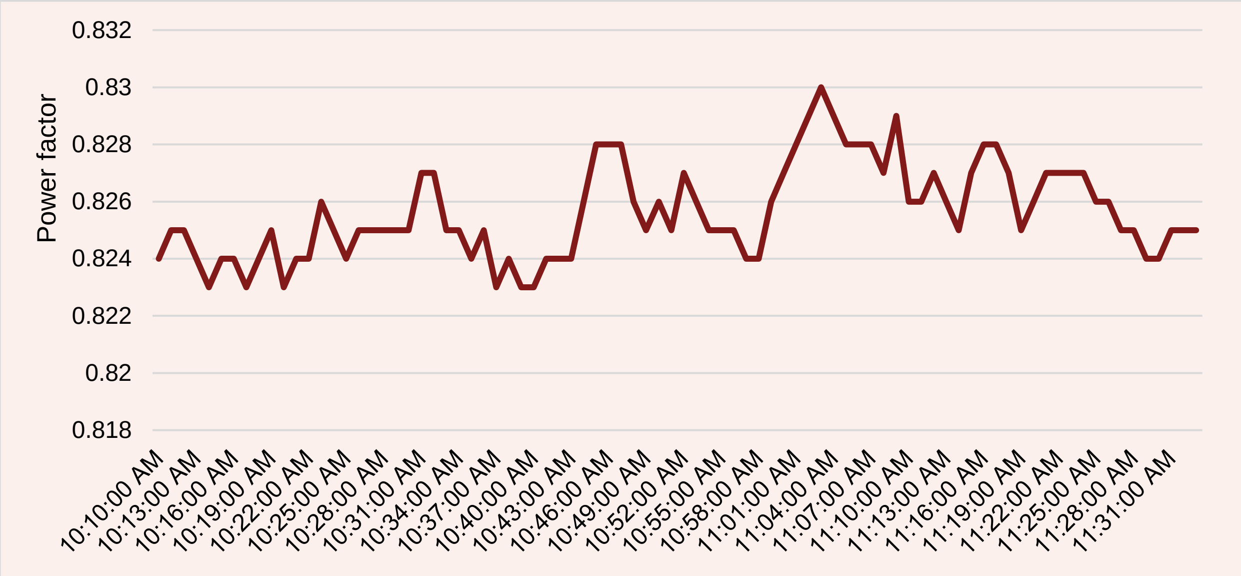


Figure 10 Power factor variation

4.2.2. Automatic Power Factor Correction

The average PF is 0.826 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install a 6 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 2+2+1+0.5+0.5 kVAr.

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 10** and **Table 11**. The pictorial view of APFC panel is presented is **Figure 11**.

Figure 11 APFC panel

Table 10 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.826
Average daily reactive power	kVAr	5.71
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.170
Annual charge for PF	US$/year	$ 733
Capacitor bank requirement	**kVAr**	6
Investment cost	US$	$ 300
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 550
Import duty	%	10

Particular	Unit	Value
GST	%	15
Net landed cost of APFC system	USD	$ 1,313
Simple payback period	**years**	**1.8**

Table 11 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.826
Power factor tariff as % of fuel charge	%	5.00
Annual fuel charge	US$/year	23463
Annual charge for PF	US$/year	$ 1,173
Capacitor bank requirement	**kVAr**	6
Investment cost	US$	$ 300
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 550
Import duty	%	10
GST	%	15
Net landed cost of APFC	USD	$ 1,313
Simple payback period	**years**	**1.1**

4.3. Lighting system

4.3.1. Performance assessment

The pump station was equipped with 6 six feet fluorescent tube lights (FTL) of 36 W rating (T8). 3 fixtures are installed in pump room and 3 fixtures in electrical & diesel set room. The details of the existing system are provided in **Table 12**.

Table 12 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	3	132
FTL T8	Electrical & DG room	36+8	3	132
Total			**6**	**264**

4.3.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 4 LED tube.

Details of the present lighting system are given in **Table 13**. The pictorial view of FTL tube and LED tube is shown in **Figure 12.**

Figure 12 LED tube vs florescent tube

Table 13 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	6	4
Total rating	W	264	84
Operating hours	h/year	250	250
Annual consumption	kWh/year	66	21
Annual saving	kWh/year		45
Monetary saving	SBD/year		254
	USD/year		$ 32
Investment cost	USD		$ 80
Simple payback	**Years**		**2.52**
GHG emission reduction	**tCO_2/year**		**0.03**

The estimated annual energy savings with new LED lighting system is 45 kWh of electricity, effectively equivalents to a monetary savings of US $ 32. The investment requirement is US $ 80. The simple payback period of the recommendation is 2.52 years. Annual reduction in GHG emission is estimated to be 0.03 tCO_2.

5. Self-generation option

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic.

The total available roof area at the Kwaibala pump station is 30 m^2, which corresponds to a potential of 4.0 kWp solar rooftop PV system. However, Kwaibala pump station is located 2 km from Auki city and because of potential security issues and threat of theft, Solomon Water was not interested in installation of renewable energy resources (Solar) in the Kwaibala pump station.

6. Conclusion

6.1. Summary of study

Kwaibala pump station is in Auki city of Malaita province. The pump station is around a decade old. The pump station has a 250 m³ water tank, which receives water from the Kwaibala spring source. The water from the spring source is pumped to the Gallery Tank using two transfer pumps (Currently one of them being operational). The pump station produces 571.2 m³ water daily consuming about 194.2 kWh electrical energy. The existing specific energy consumption is 0.34 kWh per m³. The study has identified recommendations for energy conservation (**Table 14**). These recommendations could save annually about 25925 kWh of electricity. These recommendations have an estimated investment of US $ 25080 and can yield a monetary savings of US $ 17910 per year. The annual energy saving is estimated to be 35.5 % of total energy consumption by the pump station (**Figure 13**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 17.11 tonnes of CO_2.

Table 14 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement of pump with an efficient pump[10]	25,880	$ 17,878	$ 25,000	1.4	17.08
ECM-2	Replacement of FTL with LED lights	45	$ 32	$ 80	2.5	0.03
	Total	**25,925**	**17,910**	**25080**	**1.4**	**17.11**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 15.**

Table 15 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.340 kWh/m³	0.224 kWh/m³
Specific CO_2 emission	0.216 kg CO_2/m³	0.142 kg CO_2/m³

[10] *Considering option 2 with flow rate 45 m³ (Grundfos CRN 45-3)*

6.2. Funding options

The overall investment proposed for the energy conservation measures for Kwaibala pump station is US $ 25,080. The simple payback on this investment is 1.4 years. Solomon Water can fund the project through internal funds. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Kwaibala pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

A collage of select pictures taken during the detailed feasibility study is presented in **Appendix C**.

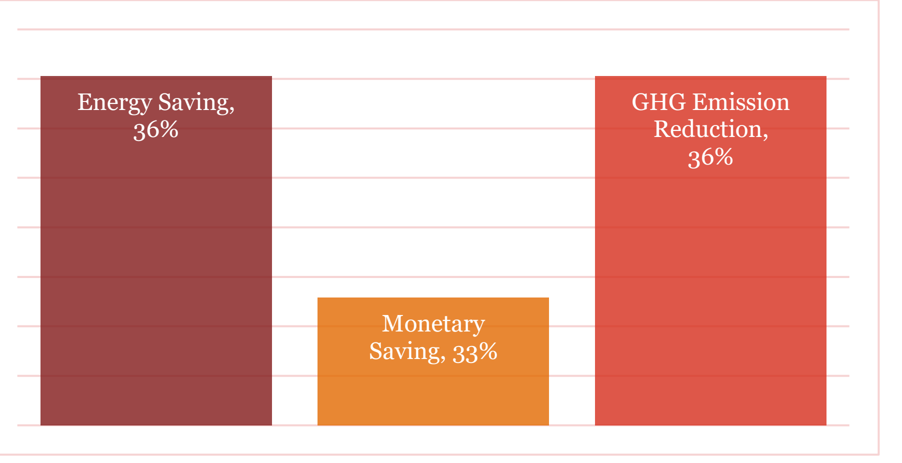


Figure 13 Identified saving potential

Appendix

Appendix A – Proposed pump technical specification

Transfer Pump Grundfos CRN 20-6 (Option 1)

Position	Qty.	Description
	1	**CRN 20-6 A-P-X-V-HQQV**

Product No.: On request

Vertical, multistage centrifugal pump with inlet and outlet ports on same the level (inline). Pump materials in contact with the liquid are in high-grade stainless steel. A cartridge shaft seal ensures high reliability, safe handling, and easy access and service. Power transmission is via a rigid split coupling. Pipe connection is via PJE (Victaulic®) couplings.

The pump is fitted with a 3-phase, fan-cooled asynchronous motor.

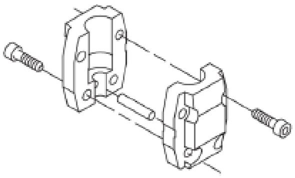
Further product details

Steel, cast iron and aluminium components have an epoxy-based coating made in a cathodic electro-deposition (CED) process. CED is a high-quality dip-painting process where an electrical field around the products ensures deposition of paint particles as a thin, well-controlled layer on the surface. An integral part of the process is a pretreatment. The entire process consists of these elements:

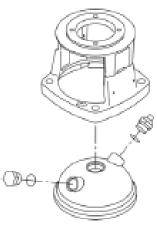
1) Alkaline-based cleaning.
2) Zinc phosphating.
3) Cathodic electro-deposition.
4) Curing to a dry film thickness 18-22 my m.
The colour code for the finished product is NCS 9000/RAL 9005.

Pump

A standard split coupling connects the pump and motor shaft. It is enclosed in the pump head/motor stool by means of two coupling guards.



The pump head and flange for motor mounting is made in one piece (cast iron). The pump head cover is a separate component (stainless steel). The pump head has a combined 1/2" priming plug and vent screw.



The pump is fitted with a balanced O-ring seal unit with a rigid torque-transmission system. This seal type is assembled in a cartridge unit which makes replacement safe and easy. Due to the balancing, this seal type is suitable for high-pressure applications. The cartridge construction also protects the pump shaft from possible wear from a dynamic O-ring between pump shaft and shaft seal.

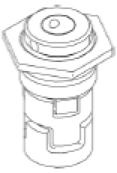
Primary seal:

- Rotating seal ring material: silicon carbide (SiC)
- Stationary seat material: silicon carbide (SiC)

This material pairing is used where higher corrosion resistance is required. The high hardness of this material pairing offers good resistance against abrasive particles.

Secondary seal material: FKM (fluorocarbon rubber)

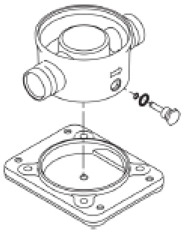
FKM has excellent resistance to oils and chemicals. Above 90 °C, FKM should only be used in media without water.



The shaft seal is screwed into the pump head.

The chambers and impellers are made of stainless-steel sheet. The chambers are provided with a PTFE neck ring offering improved sealing and high efficiency. The impellers have smooth surfaces, and the shape of the blades ensure a high efficiency.

The pump has a stainless-steel base mounted on a separate base plate. The base and base plate are kept in position by the tension of the staybolts which hold the pump together. The outlet side of the base has a drain plug. The pump is secured to the foundation by four bolts through the base plate. The base is prepared for connection by means of PJE (Victualic®) couplings.



Motor

The motor is a totally enclosed, fan-cooled motor with principal dimensions to IEC and DIN standards. The motor is flange-mounted with free-hole flange (FF).

Motor-mounting designation in accordance with IEC 60034-7: IM B 5 (Code I) / IM 3001 (Code II).

Electrical tolerances comply with IEC 60034.

The motor efficiency is classified as IE3 in accordance with IEC 60034-30-1.

The motor has thermistors (PTC sensors) in the windings in accordance with DIN 44081/DIN 44082. The protection reacts to both slow- and quick-rising temperatures, e.g. constant overload and stalled conditions.

Thermal switches must be connected to an external control circuit in a way which ensures that the automatic reset cannot cause accidents. The motors must be connected to a motor-protective circuit breaker according to local regulations.

The motor can be connected to a variable speed drive for adjustment of pump performance to any duty point. Grundfos CUE offers a range of variable speed drives. Please find more information in Grundfos Product Center.

Technical data

Controls:

Frequency converter:	NONE

Liquid:

Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temperature during operation:	20 °C
Density:	998.2 kg/m³

Technical:

Rated flow:	21 m³/h
Rated head:	70.4 m
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQV

Position	Qty.	Description	
		Approvals on nameplate:	CE, EAC
		Curve tolerance:	ISO9906:2012 3B
		Materials:	
		Base:	Stainless steel EN 1.4408 AISI 316
		Impeller:	Stainless steel EN 1.4401 AISI 316
		Bearing:	SIC
		Installation:	
		Maximum ambient temperature:	60 °C
		Maximum operating pressure:	25 bar
		Max pressure at stated temp:	25 bar / 90 °C 25 bar / -20 °C
		Type of connection:	PJE
		Size of inlet connection:	DN 50 2 inch
		Size of outlet connection:	DN 50 2 inch
		Pressure rating for pipe connection:	PN 50
		Flange size for motor:	FF265
		Electrical data:	
		Motor standard:	IEC
		Motor type:	132SB
		IE Efficiency class:	IE3
		Rated power - P2:	7.5 kW
		Power (P2) required by pump:	7.5 kW
		Mains frequency:	50 Hz
		Rated voltage:	3 x 380-415D/660-690Y V
		Rated current:	14,4-14,0/8,30-8,10 A
		Starting current:	780-910 %
		Cos phi - power factor:	0.88-0.82
		Rated speed:	2910-2920 rpm
		Efficiency:	IE3 90,1%
		Motor efficiency at full load:	90.1-90.4 %
		Motor efficiency at 3/4 load:	90.8 %
		Motor efficiency at 1/2 load:	90.8 %
		Number of poles:	2
		Enclosure class (IEC 34-5):	55 Dust/Jetting
		Insulation class (IEC 85):	F
		Others:	
		Minimum efficiency index, MEI ≥:	0.7
		Net weight:	94 kg
		Gross weight:	116 kg
		Shipping volume:	0.285 m³

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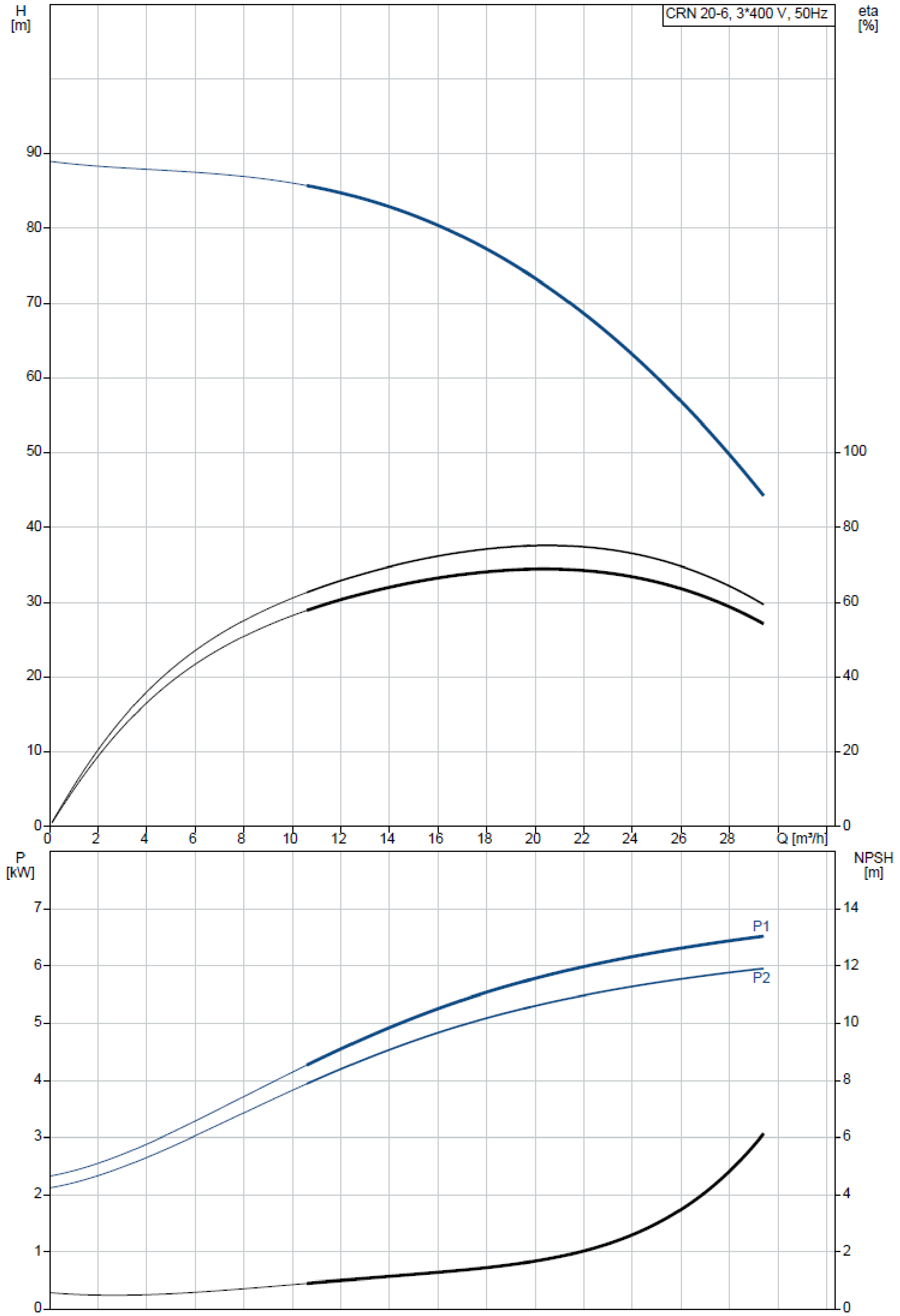
On request CRN 20-6 A-P-X-V-HQQV 50 Hz



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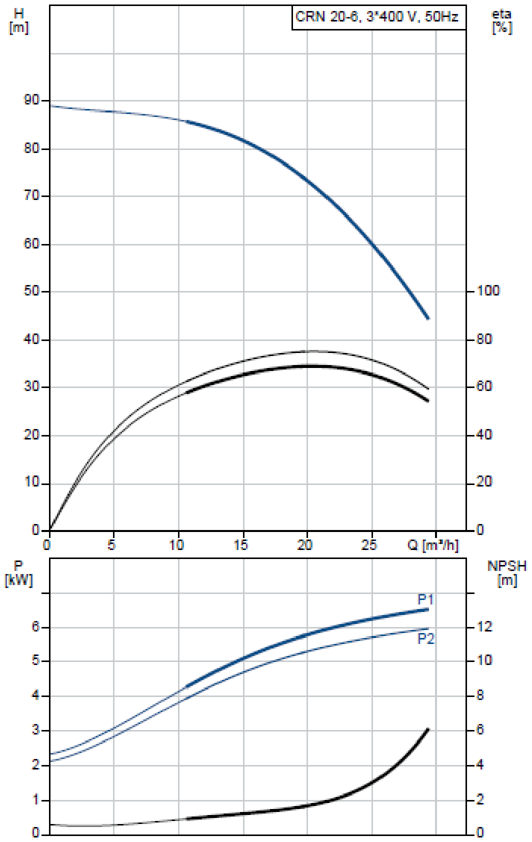
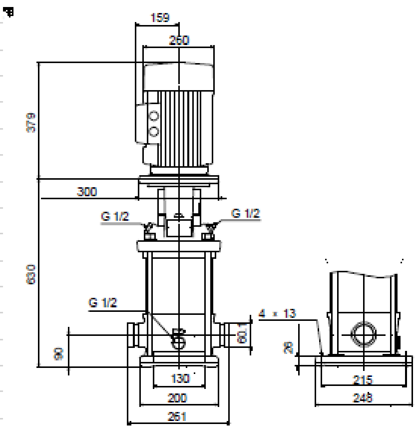
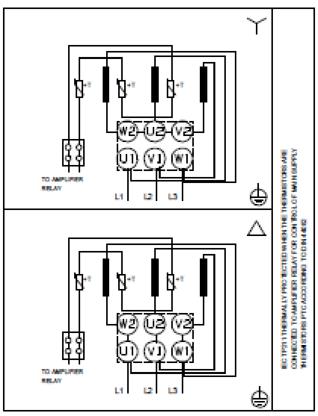
Description	Value
General information:	
Product name:	CRN 20-6 A-P-X-V-HQQV
Product No:	On request
EAN number:	On request
Technical:	
Rated flow:	21 m³/h
Rated head:	70.4 m
Stages:	6
Impellers:	6
Number of reduced-diameter impellers:	0
Low NPSH:	N
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQV
Approvals on nameplate:	CE, EAC
Curve tolerance:	ISO9906:2012 3B
Pump version:	A
Model:	A
Materials:	
Base:	Stainless steel
	EN 1.4408
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Material code:	X
Code for rubber:	V
Bearing:	SIC
Installation:	
Maximum ambient temperature:	60 °C
Maximum operating pressure:	25 bar
Max pressure at stated temp:	25 bar / 90 °C
	25 bar / -20 °C
Type of connection:	PJE
Size of inlet connection:	DN 50
	2 inch
Size of outlet connection:	DN 50
	2 inch
Pressure rating for pipe connection:	PN 50
Flange size for motor:	FF265
Connect code:	P
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temperature during operation:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor standard:	IEC
Motor type:	132SB
IE Efficiency class:	IE3
Rated power - P2:	7.5 kW
Power (P2) required by pump:	7.5 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-415D/660-690Y V
Rated current:	14,4-14,0/8,30-8,10 A
Starting current:	780-910 %
Cos phi - power factor:	0.88-0.82
Rated speed:	2910-2920 rpm
Efficiency:	IE3 90,1%
Motor efficiency at full load:	90.1-90.4 %
Motor efficiency at 3/4 load:	90.8 %
Motor efficiency at 1/2 load:	90.8 %
Number of poles:	2







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Transfer Pump Grundfos CRN 45-3 (Option 2)

Position	Qty.	Description
	1	**CRN 45-3 A-F-A-V-HQQV**

Product No.: On request

Vertical, multistage centrifugal pump with inlet and outlet ports on same the level (inline). Pump materials in contact with the liquid are in high-grade stainless steel. A cartridge shaft seal ensures high reliability, safe handling, and easy access and service. Power transmission is via a rigid split coupling. Pipe connection is via DIN flanges.

The pump is fitted with a 3-phase, fan-cooled asynchronous motor.

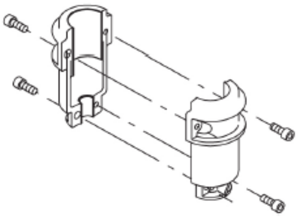
Further product details

Steel, cast iron and aluminium components have an epoxy-based coating made in a cathodic electro-deposition (CED) process. CED is a high-quality dip-painting process where an electrical field around the products ensures deposition of paint particles as a thin, well-controlled layer on the surface. An integral part of the process is a pretreatment. The entire process consists of these elements:

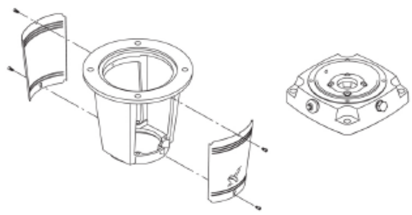
1) Alkaline-based cleaning.
2) Zinc phosphating.
3) Cathodic electro-deposition.
4) Curing to a dry film thickness 18-22 my m.
The colour code for the finished product is NCS 9000/RAL 9005.

Pump

A long split coupling connects the pump and motor shaft. It is enclosed in the motor stool by means of two coupling guards. The long coupling makes it possible to replace the shaft seal without removing the motor from the pump.



The motor stool connects the pump head and motor. The pump head has a combined 1/2" priming plug and vent screw.



The pump is fitted with a balanced O-ring seal unit with a rigid torque-transmission system. This seal type is assembled in a cartridge unit which makes replacement safe and easy. Due to the balancing, this seal type is suitable for high-pressure applications. The cartridge construction also protects the pump shaft from possible wear from a dynamic O-ring between pump shaft and shaft seal.

Primary seal:
- Rotating seal ring material: silicon carbide (SiC)
- Stationary seat material: silicon carbide (SiC)

This material pairing is used where higher corrosion resistance is required. The high hardness of this material pairing offers good resistance against abrasive particles.

Secondary seal material: FKM (fluorocarbon rubber)

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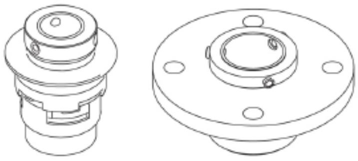
Position	Qty.	Description

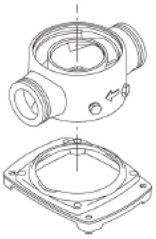
FKM has excellent resistance to oils and chemicals. Above 90 °C, FKM should only be used in media without water.



The shaft seal is retained in the pump head by a cover and screws. It can be replaced without removing the motor.

The chambers and impellers are made of stainless-steel sheet. The chambers are provided with a PTFE neck ring offering improved sealing and high efficiency. The impellers have smooth surfaces, and the shape of the blades ensure a high efficiency.

The pump has a stainless-steel base mounted on a separate base plate. The base and base plate are kept in position by the tension of the staybolts which hold the pump together. Both the inlet and the outlet side of the base have two pressure gauge tappings. The pump is secured to the foundation by four bolts through the base plate. The flanges are fastened to the base by means of locking rings.



Motor

The motor is a totally enclosed, fan-cooled motor with principal dimensions to IEC and DIN standards. The motor is flange-mounted with free-hole flange (FF).

Motor-mounting designation in accordance with IEC 60034-7: IM B 5 (Code I) / IM 3001 (Code II).

Electrical tolerances comply with IEC 60034.

The motor efficiency is classified as IE3 in accordance with IEC 60034-30-1.

The motor has thermistors (PTC sensors) in the windings in accordance with DIN 44081/DIN 44082. The protection reacts to both slow- and quick-rising temperatures, e.g. constant overload and stalled conditions.

Thermal switches must be connected to an external control circuit in a way which ensures that the automatic reset cannot cause accidents. The motors must be connected to a motor-protective circuit breaker according to local regulations.

The motor can be connected to a variable speed drive for adjustment of pump performance to any duty point. Grundfos CUE offers a range of variable speed drives. Please find more information in Grundfos Product Center.

Technical data

Controls:
Frequency converter: NONE

Liquid:
Pumped liquid: Water
Liquid temperature range: -20 .. 90 °C
Liquid temperature during operation: 20 °C
Density: 998.2 kg/m³

Technical:
Rated flow: 45 m³/h
Rated head: 59.4 m
Pump orientation: Vertical
Shaft seal arrangement: Single

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Position	Qty.	Description	
		Code for shaft seal:	HQQV
		Approvals on nameplate:	CE, EAC
		Curve tolerance:	ISO9906:2012 3B
		Materials:	
		Base:	Stainless steel EN 1.4408 AISI 316
		Impeller:	Stainless steel EN 1.4401 AISI 316
		Bearing:	SIC
		Support bearing:	Graflon
		Installation:	
		Maximum ambient temperature:	60 °C
		Maximum operating pressure:	16 bar
		Max pressure at stated temp:	16 bar / 90 °C 16 bar / -20 °C
		Type of connection:	DIN
		Size of inlet connection:	DN 80
		Size of outlet connection:	DN 80
		Pressure rating for pipe connection:	PN 40
		Flange size for motor:	FF300
		Electrical data:	
		Motor standard:	IEC
		Motor type:	160MB
		IE Efficiency class:	IE3
		Rated power - P2:	11 kW
		Power (P2) required by pump:	11 kW
		Mains frequency:	50 Hz
		Rated voltage:	3 x 380-415D/660-690Y V
		Rated current:	20,8-19,8/12,0-11,8 A
		Starting current:	660-780 %
		Cos phi - power factor:	0.88-0.84
		Rated speed:	2940-2950 rpm
		Efficiency:	IE3 91,2%
		Motor efficiency at full load:	91.2-91.2 %
		Motor efficiency at 3/4 load:	91.8 %
		Motor efficiency at 1/2 load:	91.3 %
		Number of poles:	2
		Enclosure class (IEC 34-5):	55 Dust/Jetting
		Insulation class (IEC 85):	F
		Others:	
		Minimum efficiency index, MEI ≥:	0.7
		Net weight:	164 kg
		Gross weight:	197 kg
		Shipping volume:	0.495 m³

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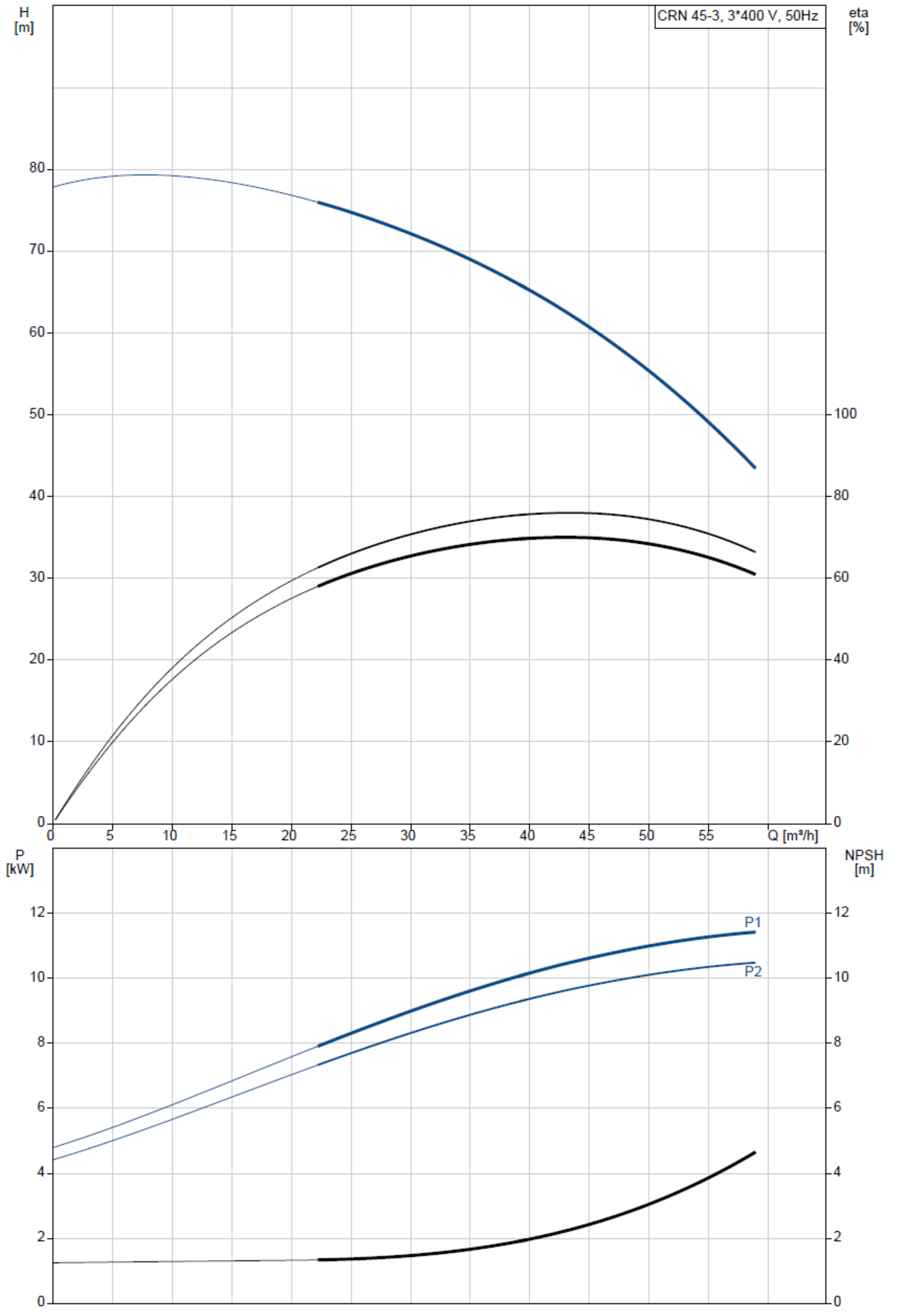
On request CRN 45-3 A-F-A-V-HQQV 50 Hz



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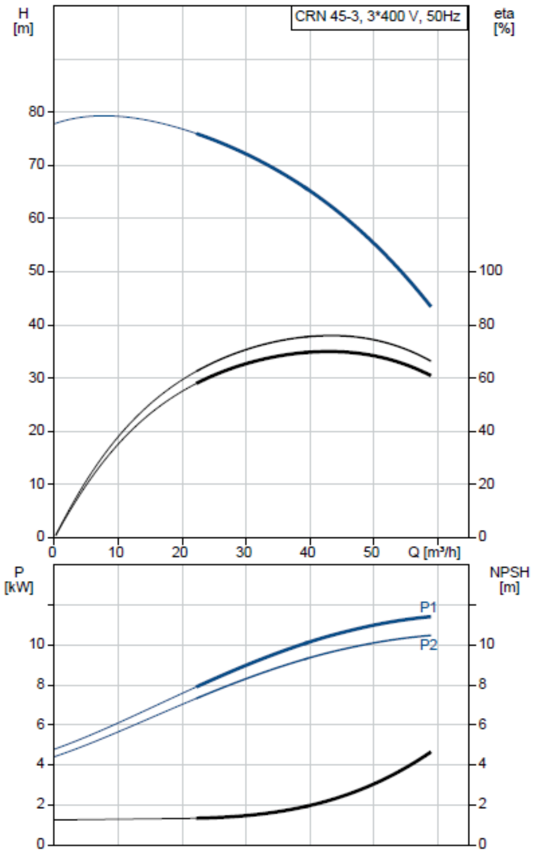
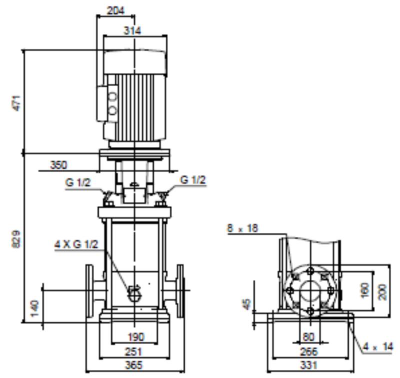
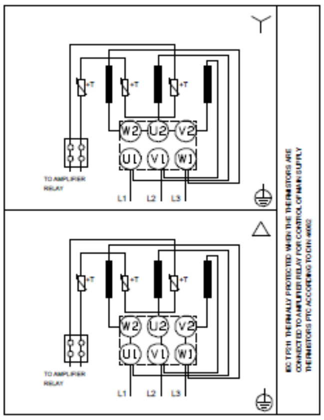
Description	Value
General information:	
Product name:	CRN 45-3 A-F-A-V-HQQV
Product No:	On request
EAN number:	On request
Technical:	
Rated flow:	45 m³/h
Rated head:	59.4 m
Stages:	3
Impellers:	3
Number of reduced-diameter impellers:	0
Low NPSH:	N
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQV
Approvals on nameplate:	CE, EAC
Curve tolerance:	ISO9906:2012 3B
Pump version:	A
Model:	B
Materials:	
Base:	Stainless steel
	EN 1.4408
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Material code:	A
Code for rubber:	V
Bearing:	SIC
Support bearing:	Graflon
Installation:	
Maximum ambient temperature:	60 °C
Maximum operating pressure:	16 bar
Max pressure at stated temp:	16 bar / 90 °C
	16 bar / -20 °C
Type of connection:	DIN
Size of inlet connection:	DN 80
Size of outlet connection:	DN 80
Pressure rating for pipe connection:	PN 40
Flange size for motor:	FF300
Connect code:	F
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temperature during operation:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor standard:	IEC
Motor type:	160MB
IE Efficiency class:	IE3
Rated power - P2:	11 kW
Power (P2) required by pump:	11 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-415D/660-690Y V
Rated current:	20,8-19,8/12,0-11,8 A
Starting current:	660-780 %
Cos phi - power factor:	0.88-0.84
Rated speed:	2940-2950 rpm
Efficiency:	IE3 91,2%
Motor efficiency at full load:	91.2-91.2 %
Motor efficiency at 3/4 load:	91.8 %
Motor efficiency at 1/2 load:	91.3 %
Number of poles:	2
Enclosure class (IEC 34-5):	55 Dust/Jetting







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Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
9/9/2019	10:10:00 AM	50.02	405.0	407.9	409.3	14.3	13.8	14.9	8.36	0.824
9/9/2019	10:11:00 AM	50.02	405.1	407.9	409.5	14.3	13.8	14.9	8.39	0.825
9/9/2019	10:12:00 AM	50.02	405.3	407.9	408.4	14.3	14	14.7	8.37	0.825
9/9/2019	10:13:00 AM	50.01	405.8	407.8	408.4	14.4	13.9	14.5	8.34	0.824
9/9/2019	10:14:00 AM	50.01	406.0	407.9	408.6	14.4	13.9	14.5	8.32	0.823
9/9/2019	10:15:00 AM	50.02	405.6	407.7	408.8	14.4	13.8	14.7	8.34	0.824
9/9/2019	10:16:00 AM	50.01	405.3	407.8	408.2	14.3	13.9	14.6	8.34	0.824
9/9/2019	10:17:00 AM	50.02	405.6	408.6	408.4	14.2	14	14.6	8.32	0.823
9/9/2019	10:18:00 AM	50.01	405.5	408.5	408.6	14.2	14	14.7	8.35	0.824
9/9/2019	10:19:00 AM	50.02	405.3	408.3	409.1	14.4	14	14.9	8.43	0.825
9/9/2019	10:20:00 AM	50.01	405.9	408.0	409.1	14.4	13.8	14.6	8.32	0.823
9/9/2019	10:21:00 AM	50.02	405.8	407.9	408.7	14.4	13.9	14.6	8.36	0.824
9/9/2019	10:22:00 AM	50.02	405.6	408.1	408.8	14.4	14	14.7	8.38	0.824
9/9/2019	10:23:00 AM	50.02	405.7	408.1	408.6	14.5	14.1	14.8	8.44	0.826
9/9/2019	10:24:00 AM	50.01	404.9	406.4	408.8	14.5	13.6	14.8	8.36	0.825
9/9/2019	10:25:00 AM	50.02	404.8	406.5	408.8	14.5	13.6	14.8	8.32	0.824
9/9/2019	10:26:00 AM	50.02	404.8	406.5	408.3	14.5	13.7	14.7	8.33	0.825
9/9/2019	10:27:00 AM	50.02	405.8	408.5	408.4	14.4	14.1	14.7	8.41	0.825
9/9/2019	10:28:00 AM	50.02	406.0	408.7	408.5	14.4	14.2	14.7	8.43	0.825
9/9/2019	10:29:00 AM	50.02	406.0	407.6	409.2	14.6	13.8	14.8	8.40	0.825
9/9/2019	10:30:00 AM	50.02	405.9	408.4	409.1	14.4	14	14.8	8.44	0.825
9/9/2019	10:31:00 AM	50.01	405.6	408.2	408.2	14.5	14.2	14.8	8.49	0.827

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
9/9/2019	10:32:00 AM	50.02	405.2	408.5	407.6	14.3	14.3	14.7	8.45	0.827
9/9/2019	10:33:00 AM	50.01	405.4	408.6	407.9	14.2	14.2	14.6	8.37	0.825
9/9/2019	10:34:00 AM	50.02	405.4	408.7	408.3	14.2	14.1	14.7	8.36	0.825
9/9/2019	10:35:00 AM	50.01	405.2	408.8	407.7	14.1	14.3	14.6	8.35	0.824
9/9/2019	10:36:00 AM	50.02	404.5	408.7	407.6	14	14.2	14.7	8.34	0.825
9/9/2019	10:37:00 AM	50.01	405.8	408.6	408.4	14.2	14	14.5	8.31	0.823
9/9/2019	10:38:00 AM	50.02	405.4	408.4	407.3	14.2	14.2	14.4	8.31	0.824
9/9/2019	10:39:00 AM	50.02	406.0	408.4	408.0	14.3	14	14.4	8.30	0.823
9/9/2019	10:40:00 AM	50.02	406.2	408.2	408.8	14.4	13.9	14.6	8.35	0.823
9/9/2019	10:41:00 AM	50.02	406.2	408.4	408.9	14.4	14	14.6	8.37	0.824
9/9/2019	10:42:00 AM	50.01	405.6	408.6	409.0	14.2	14	14.8	8.37	0.824
9/9/2019	10:43:00 AM	50.01	405.5	408.3	408.0	14.3	14.1	14.6	8.36	0.824
9/9/2019	10:44:00 AM	50.01	404.6	407.4	407.0	14.2	14.1	14.5	8.35	0.826
9/9/2019	10:45:00 AM	50.01	404.3	407.0	405.8	14.3	14.4	14.5	8.41	0.828
9/9/2019	10:46:00 AM	50.02	404.3	407.0	407.1	14.4	14.1	14.7	8.43	0.828
9/9/2019	10:47:00 AM	50.01	404.2	405.7	407.1	14.6	13.9	14.7	8.39	0.828
9/9/2019	10:48:00 AM	50.02	404.0	406.0	407.7	14.4	13.7	14.8	8.33	0.826
9/9/2019	10:49:00 AM	50.01	404.0	407.0	407.3	14.2	13.9	14.7	8.32	0.825
9/9/2019	10:50:00 AM	50.02	403.8	407.1	407.2	14.2	14	14.7	8.34	0.826
9/9/2019	10:51:00 AM	50.01	404.4	407.6	407.6	14.1	14	14.7	8.32	0.825
9/9/2019	10:52:00 AM	50.01	404.0	407.0	406.7	14.2	14.1	14.6	8.37	0.827
9/9/2019	10:53:00 AM	50.02	404.2	407.1	407.2	14.2	14	14.6	8.33	0.826
9/9/2019	10:54:00 AM	50.02	404.6	407.2	407.5	14.3	13.9	14.6	8.31	0.825
9/9/2019	10:55:00 AM	50.01	404.6	407.4	407.6	14.2	14	14.6	8.32	0.825

Appendix C – Photographs taken during the study

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Detailed Feasibility Report
Skyline Pump Station

Prepared for
UNIDO – CTCN

Under the project
Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious “technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan”.

The study team is indebted to Mr. Ian Gooden, Chief Executive Officer, Solomon Island Water Authority for showing keen interest in the study and thankful to the progressive management of Solomon Water for their wholehearted support and cooperation for the study and preparation of Detailed Feasibility Report. It is well worthy to mention that the efforts being taken, and the enthusiasm shown by all the personnel towards energy efficiency was admirable. A special thanks to Mr. Mark Waite (Strategic Projects Management Advisor), Mr. Shaun Kies-Ryan (Hydrogeologist), Mr. Noel Orudiana (Project Manager) and Mr. Danny Titiri (Electrical and Mechanical Team Lead) for coordinating the field visits. We would like to thank all the staff for support including technicians, electricians i.e. Mr. Livingston, Mr. Sam and Mr. Moffat.

PwC is grateful to Mr. Hudson Kauhiona, Director Climate Change for his committed support from Ministry of Environment, Climate Change, Disaster Management and Meteorology for executing the technical assistance.

Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Skyline pump station is in Mbokonavera area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Skyline JICA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. However, at present only two bore pumps are operated at a time. This is to avoid unsustainable depletion of boreholes. Details of Skyline pump station is presented below.

Name of the pump station	Skyline
No. of transfer pumps	3 (1 Run + 2 Standby)
No. of bore-hole pumps	4
Monthly electricity consumption	32432 kWh (average of last 12 months)
Monthly water production	34430 m^3 (based on onsite measurement)
Name and details of contact person	Livingston Kute, Plumber +677-7459172 Danny Titiri, Electrical and Mechanical Team Lead dtitiri@solomonwater.com.sb, +677-8876857
Annual working days	365

A detailed feasibility study of Skyline pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Skyline pump station is in Mbokonavera area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m3 water receiver tank, which receives water from four boreholes. The water from receiving tanks is pumped to Skyline JICA reservoir using three transfer pumps. The pump station produces 1132 m3 water daily consuming about 1078.7 kWh electrical energy. The existing specific energy consumption is 0.953 kWh per m^3. The study has identified four recommendations for energy conservation (Table). These recommendations could save annually about 78,244 kWh of electricity. These recommendations have an estimated investment of US $ 29,313 and can yield a monetary savings of US $ 53,597 per year. The annual energy saving is estimated to be 20.1% of total energy consumption by the pump station (Figure). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 51.64 tonnes of CO2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Installation of VFD on transfer pumps	4,514	$ 3,092	$ 7,195	2.3	2.98
ECM-2	Replacement of borepump-1 with efficient pump	30181	$ 20,674	$ 9,375	0.5	19.92
ECM-3	Replacement of borepump-4 with efficient pump	43348	$ 29,694	$ 12,504	0.4	28.61
ECM-4	Replacement of FTL with LED lights	201	$ 137	$ 240	1.7	0.13
	Total	**78244**	**$ 53,597**	**$ 29,313**	**0.5**	**51.64**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.953 kWh/m^3	0.657 kWh/m^3
Specific CO_2 emission	0.622 kg CO_2/m^3	0.434 kg CO_2/m^3

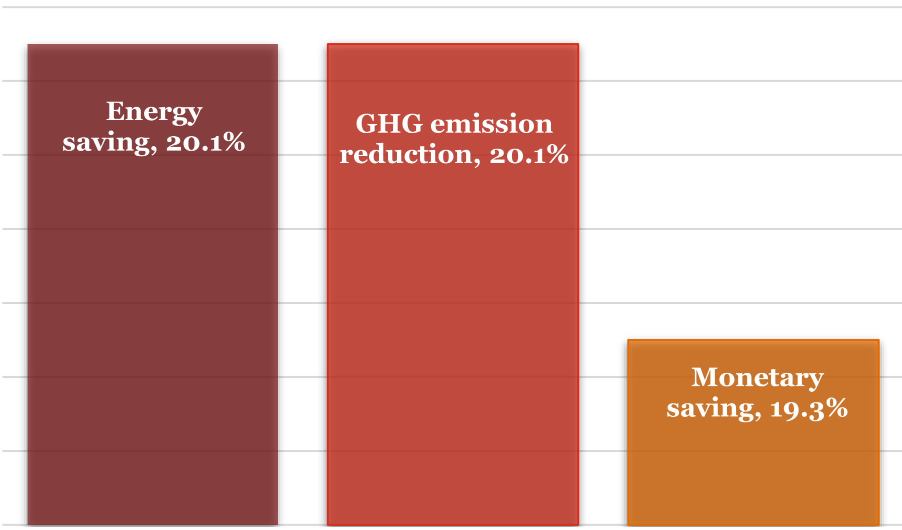
On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

Funding options

The overall investment proposed for four energy conservation measures for Skyline pump station is US$ 29,313. The simple payback on this investment is 6 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 6 months, which can be followed by VFD on transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Skyline pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Identified saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m^3	1,000 liters
1 USD	8 SBD

* *Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[1] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

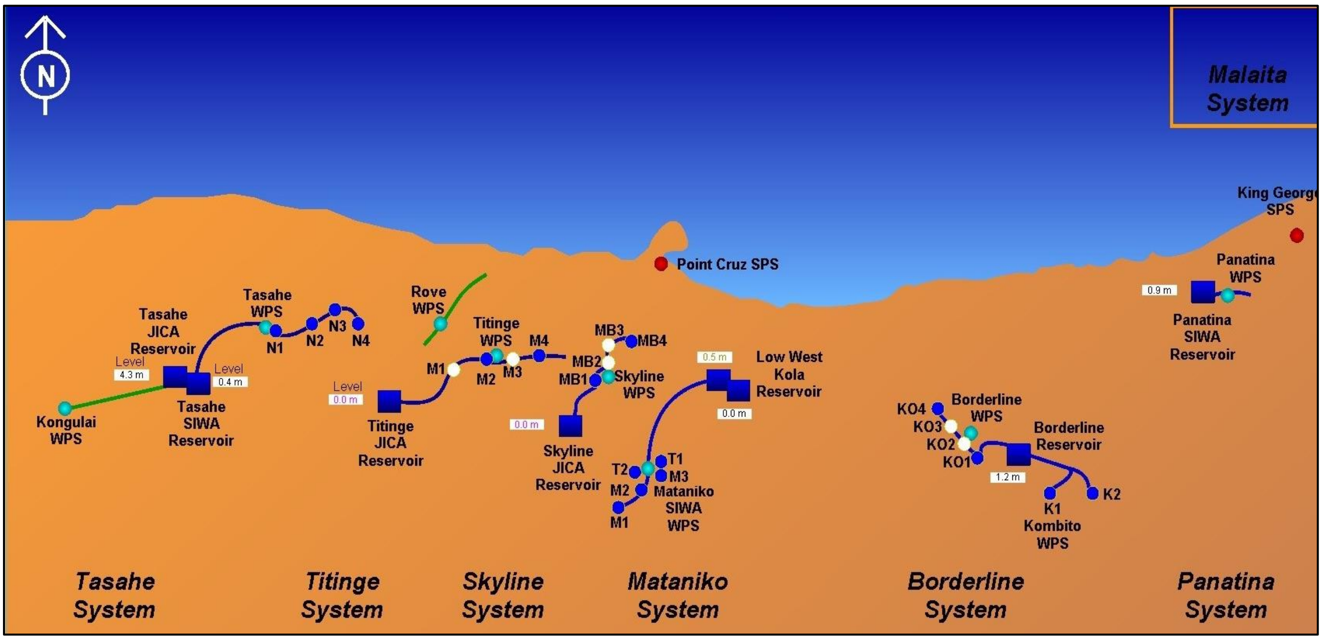


Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[1]

[1] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[2]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

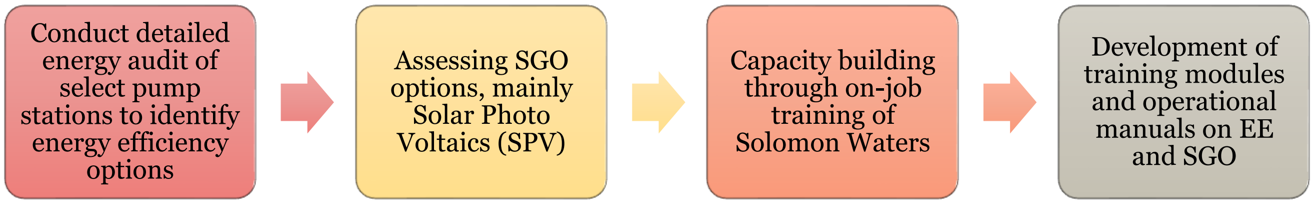


Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[2] *Response Plan, CTCN request ID: 2017000039*

Assessment of Energy Efficiency and RE options

- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options

Capacity building through on-job training for Solomon Water

- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation

Detail assessments of shortlisted EE and SGO options for Solomon Water

- Technical analysis
- Financial analysis

Monitoring of impact

- Monitoring and evaluation of Impacts
- Report on Gender co-benefits

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

Environmental Benefits

- Enhanced energy efficiency
- Improved energy security
- Lower dependence on imported fuels
- Contribution towards climate change mitigation

Economic Benefits

- Reduced operating (energy) cost for Solomon Water
- Increased investments in energy efficiency and renewable energy

Social Benefits

- Skill enhancement of Solomon Water professionals on EE and RE
- Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

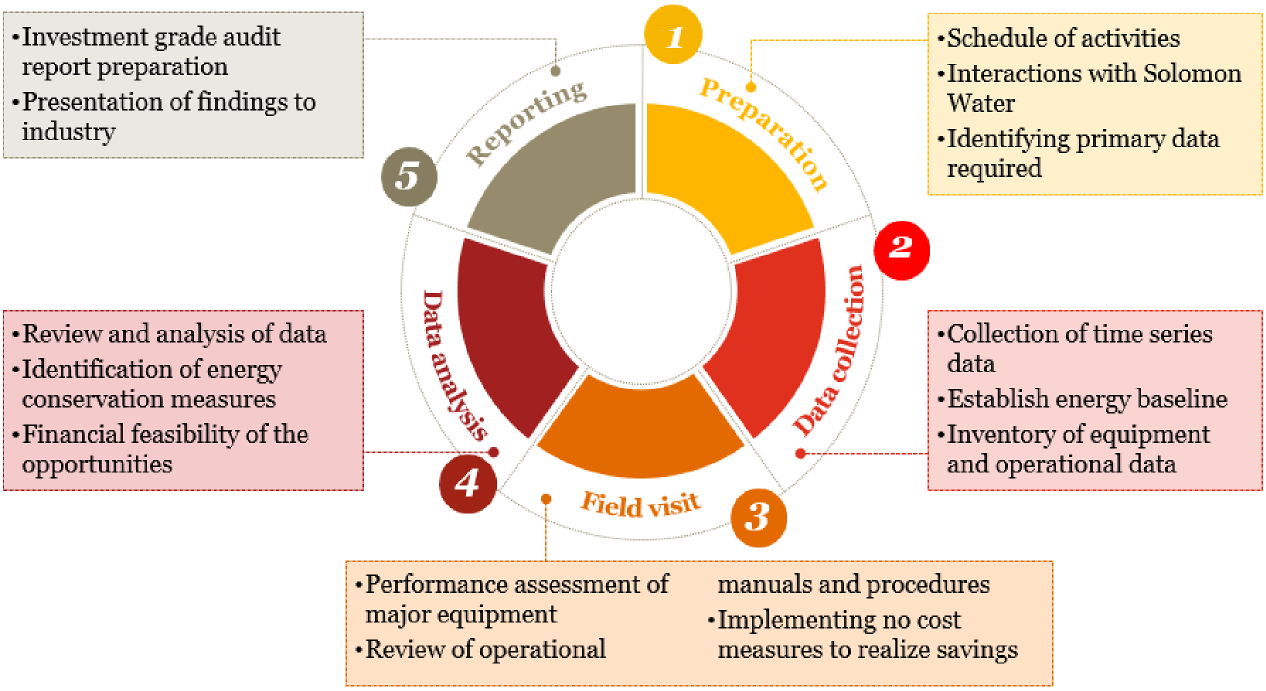


Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Skyline pump station

2.1. About Skyline pump station

Skyline pump station is in Mbokonavera area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m³ water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Skyline JICA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. However, at present only two bore pumps are operated at a time. This is to avoid unsustainable depletion of boreholes. The overview of Skyline pump station as seen in Solomon Water SCADA system is shown in **Figure 6**.

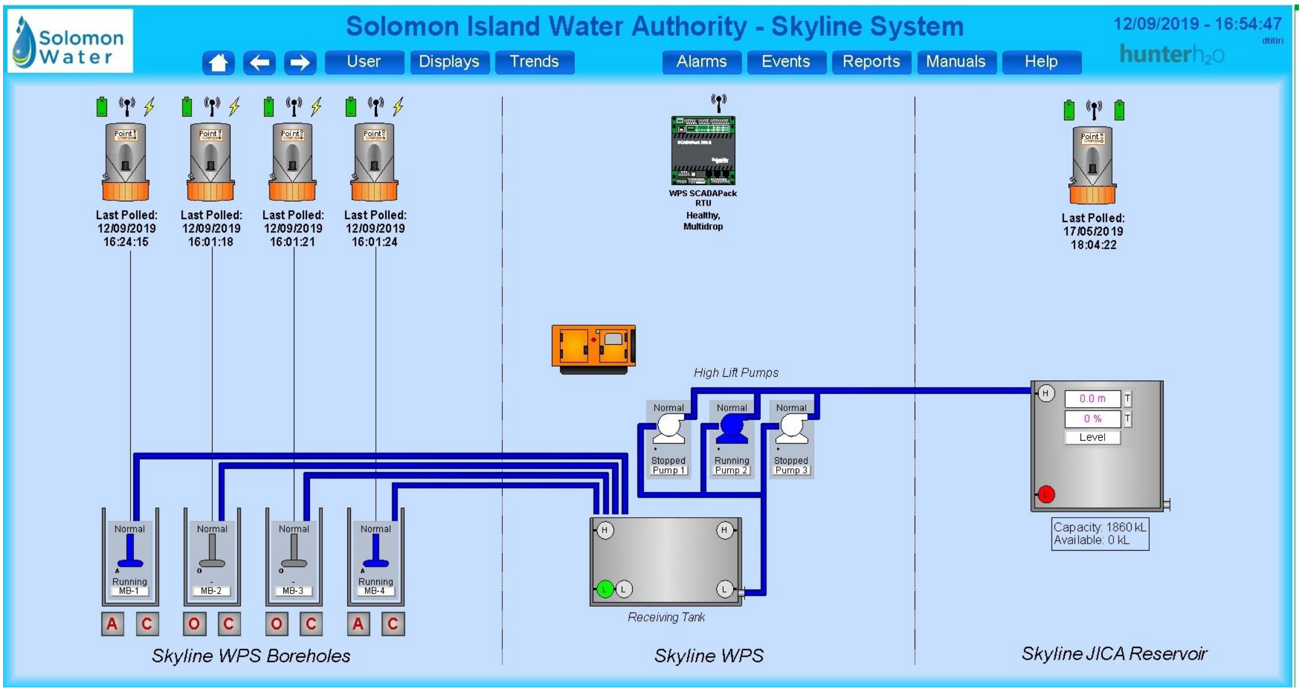


Figure 6 Skyline pump station overview - SCADA system

2.2. Transfer pumps

The Skyline pump station is equipped with three vertical multi-stage centrifugal pumps. These three pumps are connected to operate in parallel. Pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Skyline JICA reservoir. Only one transfer pump operates at any given time, with remaining two as standby. Design details of the transfer pumps and its corresponding motor is presented in **Table 2** and **Table 3** respectively. The pictorial view of transfer pumps is presented in **Figure 7**.

Table 2 Design details of transfer pumps

Particular	Unit	Pump #1, #2, #3
Make	-	Grundfos
Model	-	CRN 64-4-1 AFGV-HQQV
Design flow	m³/h	64.0
Design head	m	83.9
Max. head	m	109.3
Impeller type	-	Stainless Steel

Particular	Unit	Pump #1, #2, #3
Pump speed	rpm	2947
Recommended motor rating	kW	22.0
Max. pressure	bar	16.0
Pump efficiency	%	79.0

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor #1, #2, #3
Make	-	Grundfos
Power	kW	22.0
Voltage	V	415.0
Current	I	39.5
Power Factor	-	0.90
Motor speed	rpm	2950
Frequency	Hz	50.0
Rating	-	IE3
Efficiency	%	92.7

Figure 7 Skyline transfer pumps

2.3. Borehole pumps

The skyline pump station receives water from four borehole pumps. Water is extracted using submersible centrifugal pumps. As the pumps were underground, name plates could not be checked physically. The design details were collected from records available at Solomon Water maintenance office. Initially, the system was designed for 24 x 7 operation of four bore pumps. However, at present only two bore pumps are operated.

The design details of bore pumps is presented in **Table 4** and schematic view of Skyline bore-field is presented in **Figure 8**.

Table 4 Design details of borehole pumps

Particular	Unit	MB-1	MB-2	MB-3	MB-4
Make	-	Grundfos	Grundfos	Grundfos	Grundfos
Model	-	SP46-10	SP30-12	SP46-10	SP30-16
Design flow	m³/h	40.7	21.6	43.2	29.5
Design head	m	90.8	102.2	90.4	126.2
Pump depth	m	93	85	63	96
Pump efficiency	%	74.0	74.4	74.5	72.1

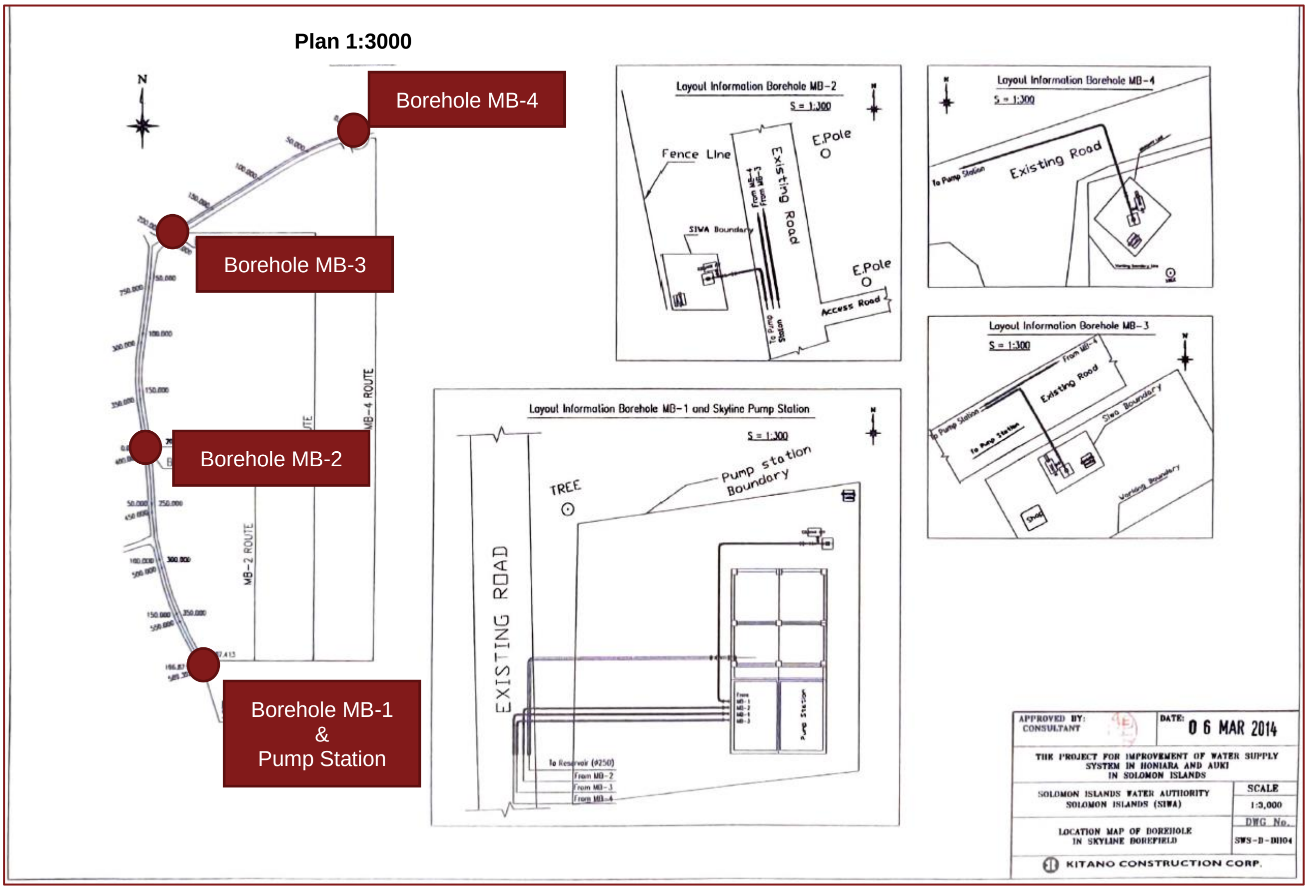


Figure 8 Location of boreholes in Skyline bore-field

3. Energy consumption analysis

3.1. Energy source and tariff details

Skyline pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Skyline pump station is under Industrial I3 type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff for last 12 months was captured during feasibility study and same is presented in **Table 5**.

Table 5 Electricity tariff details – Last 12 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)			NAC (SBD/month)[3]
		I1[4]	I2[5]	I3[6]	
Aug-18	2.85	3.68	3.16	2.81	3,175.72
Sep-18	2.85	3.7	3.18	2.83	3,199.91
Oct-18	2.71	3.71	3.19	2.84	3,204.42
Nov-18	2.83	3.72	3.2	2.85	3,218.49
Dec-18	2.81	3.75	3.23	2.87	3,242.95
Jan-19	2.77	3.77	3.24	2.89	3,258.18
Feb-19	2.49	3.11	2.68	2.38	2,690.01
Mar-19	2.71	3.79	3.26	2.9	3,277.82
Apr-19	2.53	3.61	3.11	2.77	3121.85
May-19	2.64	3.85	3.31	2.95	3328.04
Jun-19	2.21	3.85	3.31	2.95	3,324.80
Jul-19	2.38	3.84	3.3	2.94	3,316.60
Average	**2.65**	**3.70**	**3.18**	**2.83**	**3,196.57**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 18 months for Skyline pump station was analyzed. The average electricity tariff and consumption for last 12 months was evaluated. These 12-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 12 months (August 2018 to July 2019) was 389,189 kWh. The bill amount corresponding to this consumption was SBD 2.217 million i.e. USD 277,191.

The electricity consumption along with monthly energy charges is presented in **Table 6**. Variation of electricity consumption is presented in **Figure 9**.

[3] I3 connection electricity consumption>6000 kWh
[4] First 1300 units of the monthly consumption
[5] Next 4700 units of the monthly consumption
[6] Remaining consumption of the month

Table 6 Electricity consumption details

Month	Consumption	NAC (SBD)	Fuel charge (SBD)	Non-fuel charge			Total (SBD)
	kWh			I1	I2	I3	
Aug-18	20,680	3175.72	58938	4784	14852	41251	123001
Sep-18	43,680	3199.91	124488	4810	14946	106634	254078
Oct-18	43,960	3204.42	119132	4823	14993	107806	249958
Nov-18	38,120	3218.49	107880	4836	15040	91542	222516
Dec-18	29,360	3242.95	82502	4875	15181	67043	172844
Jan-19	6,480	3258.18	17950	4901	15228	1387	42724
Feb-19	24,760	2690.01	61652	4043	12596	44649	125630
Mar-19	31,760	3277.82	86070	4927	15322	74704	184300
Apr-19	37149	3121.85	93987	4693	14617	100606	217025
May-19	39,200	3328.04	103488	5005	15557	97940	225318
Jun-19	38,280	3324.80	84599	5005	15557	95226	203712
Jul-19	35,760	3316.60	85109	4992	15510	87494	196422
Average	**32,432**	**3,197**	**85,483**	**4,808**	**14,950**	**76,357**	**184,794**
Annual	**389,189**	**38,359**	**1,025,793**	**57,694**	**179,399**	**916,284**	**2,217,528**

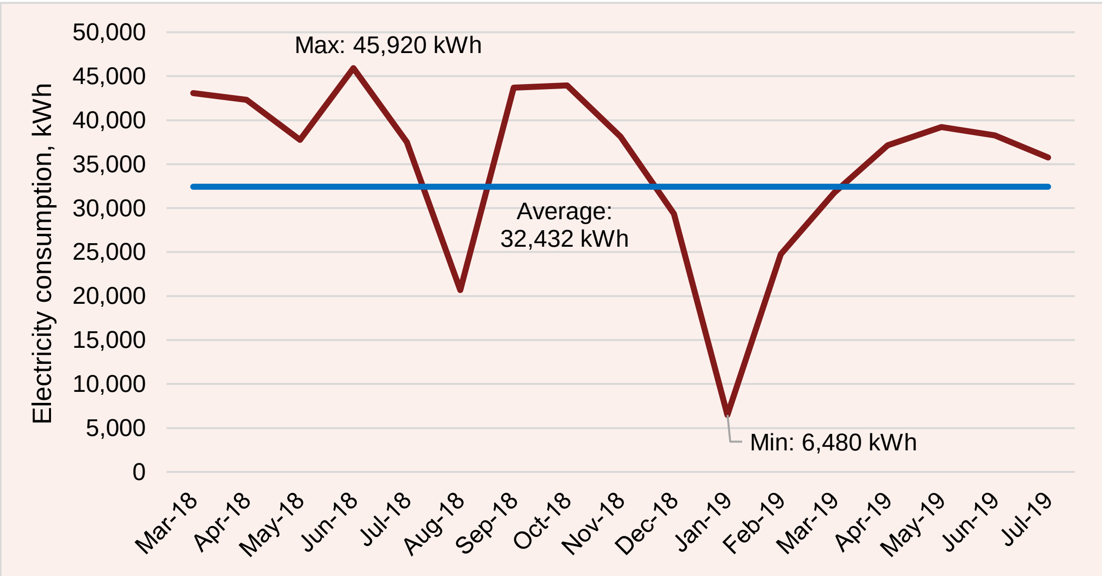


Figure 9 Electricity consumption profile March 2018 – July 2019 (18 months)

Key observations for the period August 2018 to July 2019:

- Monthly average consumption of electricity was 32,432 kWh (varying between 6,480 to 43,960)
- Average electricity tariff (excluding fixed NAC) was SDB 5.60 per kWh (US$ 0.70 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.65 per kWh (US¢ 33.1 per kWh)

Average monthly electricity consumption of Skyline Pump Station is 32,432 kWh

A sample electricity bill of Skyline pump station is presented in **Figure 10**.

Solomon Islands Electricity Authority trading as SOLOMON POWER

INVOICE / STATEMENT

Customer

SIWA-Skyline Pump Station
P O Box 1407
Honiara

Date	06/April/2018
Customer Number	06157
Customer Type	**INDUSTRIAL**
Customer Category	**I3**

Location: Skyline Pump Station
Skyline

Previous Month

Balance at Previous Account Date	$226,829.73
Payment Received to 16 Apr Thank you	($226,829.73)
Balance Prior to 6 Apr 18	$0.00

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$230,107.85	$0.00	$0.00	$0.00	$230,107.85

Month 06/April/2018

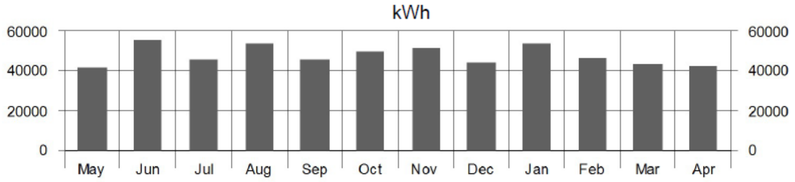
Readings from 6/Mar/2018 to 6/Apr/2018 **Days** 31

Usage

	Meter no.	Previous	Present	Multi	Units
1	21201343	36,091	37,149	40	42,320

Total **42,320.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 571760 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	I3	Days	31	3,121.85		3,121.85
Fuel	I1	kWh	42,320.00	2.5300	1.0000	107,069.60
Non-Fuel	I1	kWh	1,300.00	3.6100	1.0000	4,693.00
	I2	kWh	4,700.00	3.1100	1.0000	14,617.00
	I3	kWh	36,320.00	2.7700	1.0000	100,606.40
			42,320.00			119,916.40

TOTAL THIS PERIOD	**$230,107.85**
TOTAL DUE	**$230,107.85**
FINAL DATE FOR PAYMENT:	21/April/2018

No further notices will be issued. Unpaid accounts will have supply disconnected. Previous month balances are payable immediately.

Figure 10 Sample electricity bill of Skyline pump station

The total electricity consumption in the pump station can be categorized in four parts: (a) transfer pumps, (b) borehole pumps, (c) lighting system and (d) electrical system losses and miscellaneous. The average consumption by each category is presented in **Figure 11**.

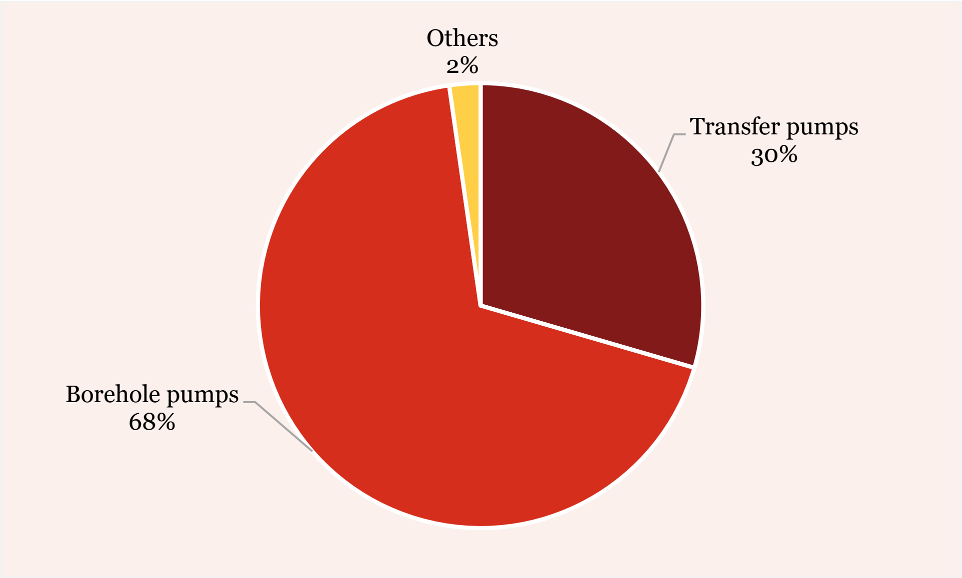


Figure 11 Electricity consumption share

3.3. Specific energy consumption

The daily water production from the bore-fields was 1131.9 m^3 and the daily total energy consumption was 1078.7 kWh of electricity. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 12 months data, which was 1081 kWh. The specific energy consumption is presented in **Table 7**.

Table 7 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	1131.94
Daily electricity consumption	kWh	1078.69
Specific energy consumption	**kWh/m^3**	**0.953**

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with three transfer pumps. These are multistage vertical centrifugal pumps with stainless steel impeller. Pumps are of Grundfos make and are driven by individual 22 kW motor. Typically, one pump operates at any given time and other two are standby. During the site visit pump 1 and 2 were in operating condition and performance assessment test was conducted on both separately. However, the soft starter of pump 3 had some issue and it was not in operation, thus performance assessment could not be conducted.

The performance assessment of transfer pumps was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump was operating intermittently i.e. operating in ON-OFF mode. This was based on level switch control installed in receiver tank. The daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. **Figure 12** shows (a) three-phase power analyser connected to main incomer of Skyline pump station and (b) water flow measurement using non-intrusive ultrasonic water flow meter.

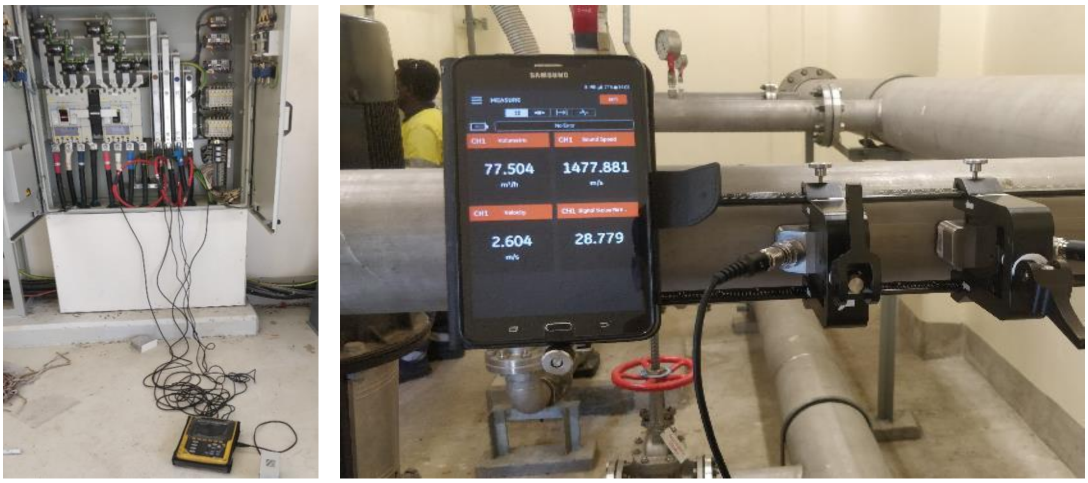


Figure 12 Power and water flow measurement photographs

The measured data such as operating hours and flow are verified using system data available at Solomon Water. The performance assessment of transfer pump 1 and 2 is presented in **Table 8**.

Table 8 Performance assessment of transfer pumps 1 and 2

Particular	Unit	Pump 1	Pump 2
Operating flow	m^3/h	78.80	78.60
Suction head	m	-2.0	-2.0
Discharge head	m	62.0	62.0
Total head	m	60.0	60.0
Hydraulic power	kW	12.88	12.85
Motor input power	kW	21.14	21.11
Shaft power	kW	19.60	19.57
Pump efficiency	**%**	**65.74**	**65.66**

The operating efficiency of the transfer pumps were about 65%, which is 14% less than design rating. The main reason for drop in efficiency was actual system duty point being away from best efficiency point of pump. The actual duty point, and best efficiency point of pump 1 and 2 are depicted in **Figure 13** and **Figure 14**.

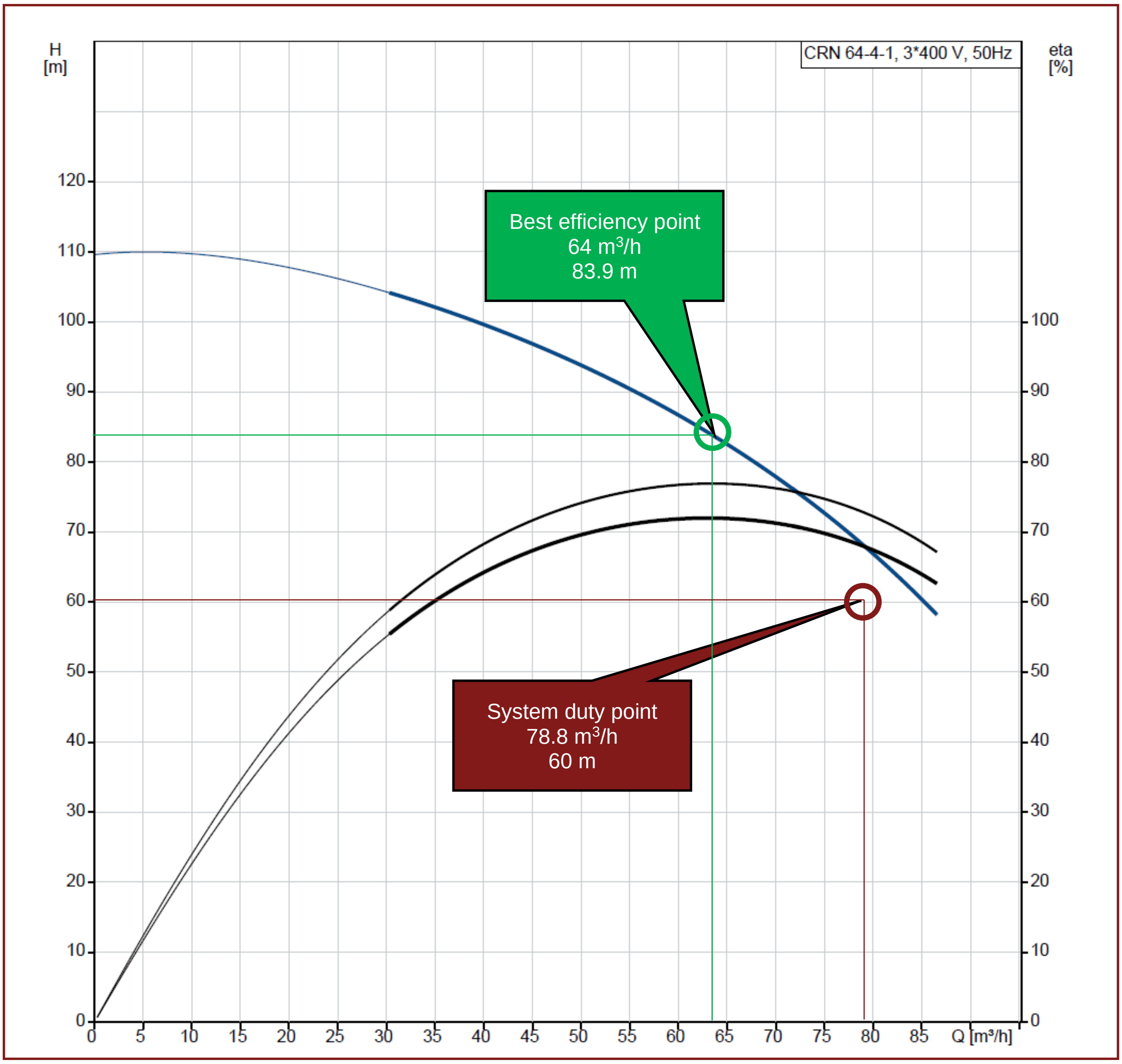


Figure 13 Transfer pump-1 duty point vs design

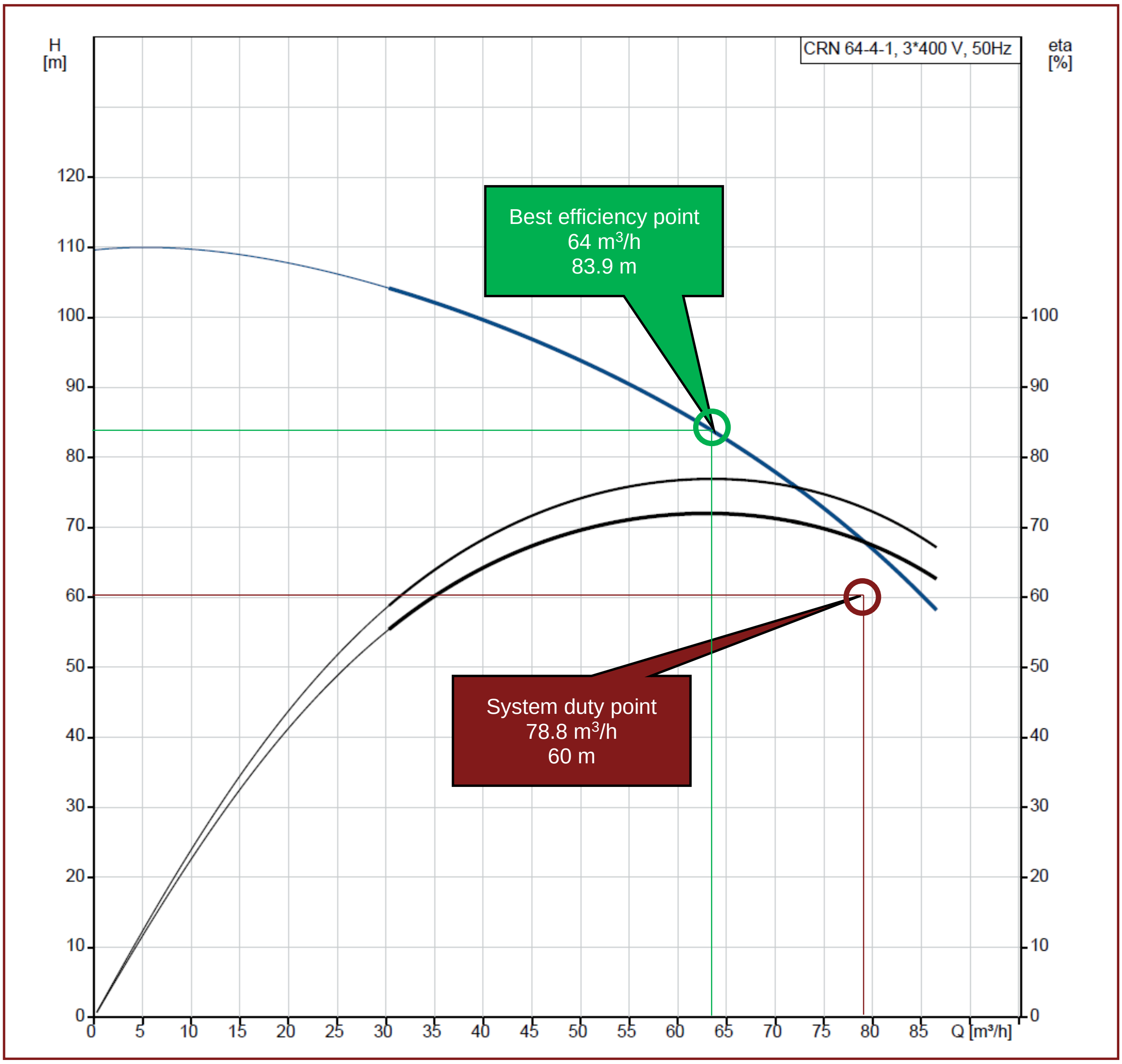


Figure 14 Transfer pump-2 duty point vs design

The operating hours of the transfer pumps was recorded using power log taken by three-phase power analyser and it was 14.4 hours per day. The operating hours is equally divided among two transfer pumps. The total daily water pumped by transfer pumps was 1132 m3. The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 9**.

Table 9 Transfer pumps motor performance

Particular	Unit	Motor 1	Motor 2
Voltage	V	418.50	418.90
Current	I	33.60	33.80
Power factor	-	0.868	0.861
Power input	kW	21.14	21.11
Motor Efficiency	%	92.7	92.7
Power shaft	kW	19.60	19.57
Motor loading	**%**	**89.08**	**88.97**

4.1.2. Energy conservation measure

The transfer pump installed is the nearest best pump available for the ststem duty requirements. However, the efficiency of operation can be inproved by installing a variable frequency drive (VFD) on the pump and operating at a lower efficiency to meet the system requirements. The motor is rated at 50 Hz and operates at 2950 rpm. By installing a VFD and operating the motor at 43.27 Hz the speed of shaft can be brought down to 2596 rpm, thus delivering 56.3 m^3/h flow at 65 m head, which close to system requirments. The flow, head and power are estimated using pump affinity laws. VFD generally has internal losses of about 2%. In saving estimation is conservative and VFD internal loss is taken as 5%.

The duty point calculation with VFD is presented in **Table 10** and saving estimation is shown in **Table 11**.

Table 10 Duty point estimation with VFD

Parameter	Unit	Design	Present	Proposed
F – Frequency	Hz	50.00	50.00	43.27
N – Speed	Rpm	2950	2950	2596
Q – Flow	m^3/h	64.0	78.8	56.3
H – Head	m	83.9	60.0	65.0
P – Power	kW	20.0	21.1	14.3

Table 11 Energy saving estimation - VFD on transfer pumps

Particular	Unit		Value
Net daily water duty	m^3		1132.0
Total operating hours	h/day		20.10
Daily energy consumption	kWh/day		287
Annual energy consumption	kWh/year		104883
Existing consumption	kWh/year		109396
Annual energy saving	kWh/year		4514
Monetary saving	SBD/year		24735
	USD/year	**$**	**3,092**
Cost of 2 VFDs	USD	$	5,006
Freight cost for 2 VFDs	USD	$	250
Cost at port in Solomon Islands	USD	$	5,256
Import duty	%		10
GST on imported goods	%		15
Net landed cost of 2 VFDs	**USD**	**$**	**7,195**
Simple payback period	**years**		**2.3**
GHG emission reduction potential	**tCO_2/year**		**2.98**

The annual energy saving by installing VFD on transfer pumps is 4514 kWh equivalent to monetary saving of US $ 3092. The investment required for installation of two VFDs is US $ 5006. The freight cost of shipping from Australia is US $ 250. Overall landed cost in Honiara inclusive of all applicable duties is US $ 7195. The simple payback period of the recommendation is 2.3 years. The GHG emission reduction potential of the recommendation is 2.98 tCO_2 equivalent.

4.2. Borehole pumps

4.2.1. Performance assessment

The Skyline pump station has four borehole pumps. At the time of study two boreholes were operational. Performance was assessed for these two bore-pumps. The power measurement was taken using three-phase power analyser, flow was measured using ultrasonic water flow meter, head was measured using a water depth measurement instrument available with Solomon Water (Shaun, Hydrogeologist) and head from borehole surface level to receiver tank is measured using digital pressure meter.

The duty-point and best efficiency point of bore-hole pump 1 and 4 are depicted in **Figure 15** and **Figure 15**. The performance assessment of borehole pump 1 and 4 is presented in **Table 12**.

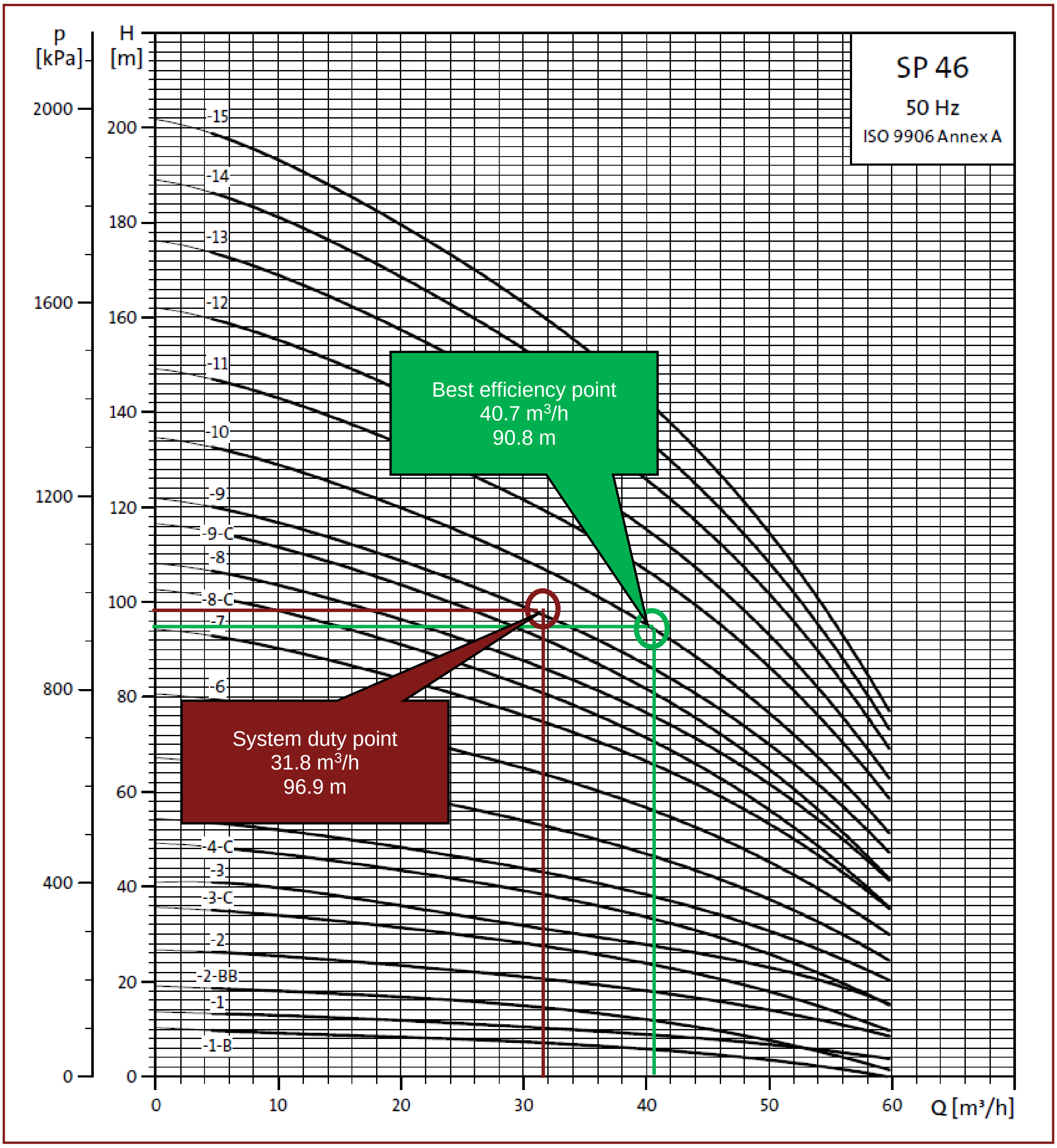


Figure 15 Bore-hole pump-1 duty point vs design

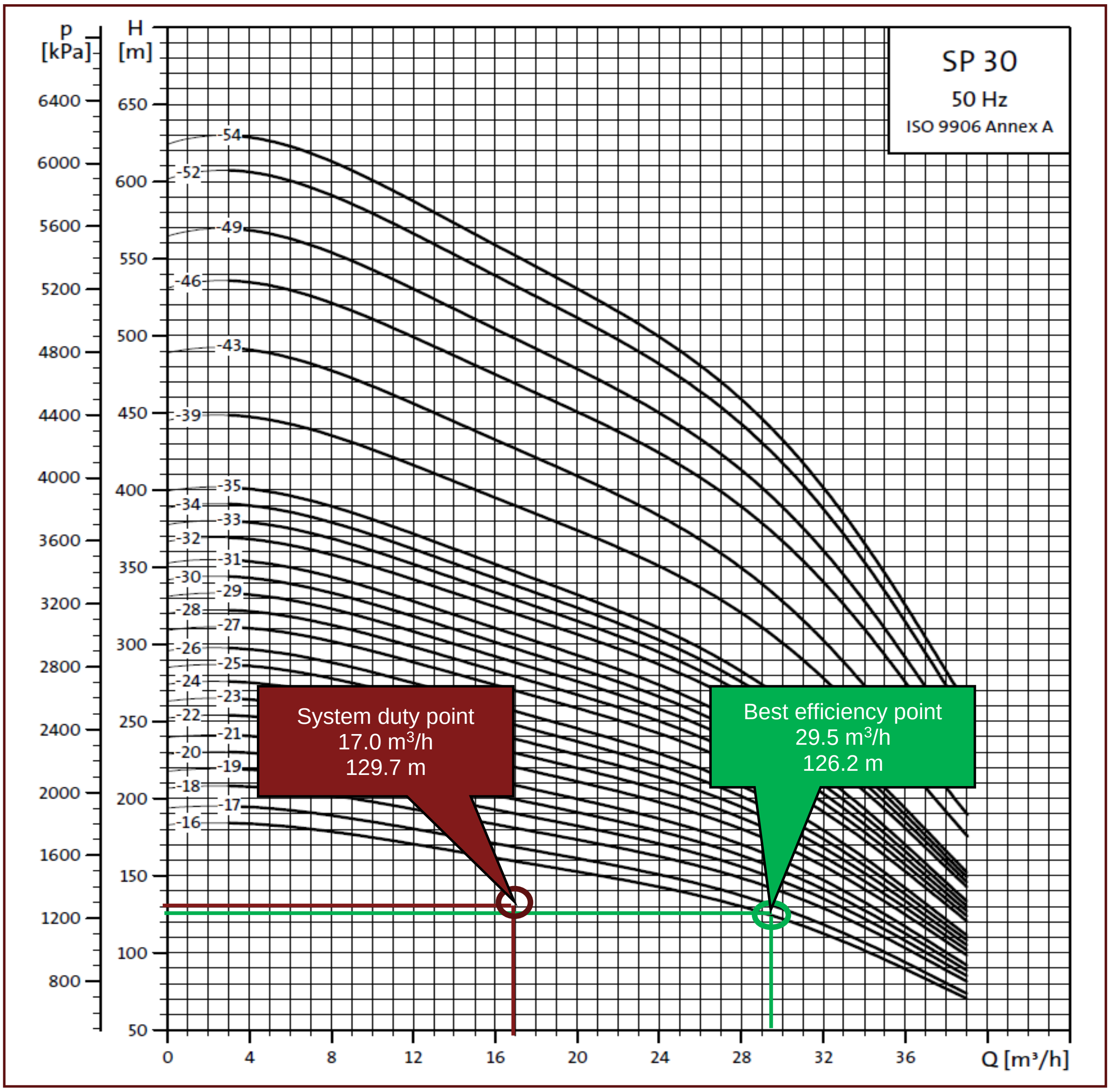


Figure 16 Bore-hole pump-4 duty point vs design

The valve on the discharge pipe coming out of well was throttled, leading to a head of 10.6 and 35.7 m respectively for MB-1 and MB-4, which is close to the actual head estimated from this point till reservoir. The reason for higher head for MB-4 as compared to bore pump 1 is physical distance and elevation from pump station. Hence, throttling has marginal effect on system head. However, for better understanding, it is recommented to carry out detailed study to identify affect after unthrottling on head and pump operation.

Table 12 Performance assessment of borehole pump 1 and 4

Particular	Unit	Bore-pump 1	Bore-pump 4
Operating flow	m^3/h	31.80	17.00
Well depth to water level	m	86.30	94.00
Head from surface to receiver tank	m	10.60	35.70
Total head	m	96.90	129.70
Hydraulic power	kW	8.40	6.01
Motor power	kW	16.95	14.89
Pump efficiency	**%**	**60.03**	**48.90**

The flow of bore-pump-1 was less than design as the operating head was higher than the design head. The drop in flow rate much higher than what the pump curve indicates, this could be result of slightly worn impeller due to ageing and erosion due to dirt in suction water.

The flow of bore-pump-4 was less than design despite the operating head being lower than the design head. The drop in flow rate could be result of slightly worn impeller due to ageing, erosion due to dirt in suction water or clogging of suction inlet screen.

The operating hours of the bore-hole pumps was taken from the SCADA system. The measured flow rate of water was then converted to arrive at daily water production from borefields, same is presented in **Table 13**.

Table 13 Production from bore-fields

Bore-field	Flow rate (m^3/h)	Operating hours (h)	Daily production (m^3)
Bore-pump 1 (MB-1)	31.8	23.3	740.9
Bore-pump 2 (MB-2)	0.0	0.0	0.0
Bore-pump 3 (MB-3)	0.0	0.0	0.0
Bore-pump 4 (MB-4)	17.0	23.0	391.0
Total			**1131.9**

4.2.2. Energy conservation measure

The bore-pumps were operating away from pumps best efficiency duty point. It is recommended to properly size the submersible pump for specific requirement of the bore-pump. **It is suggested that before replacement of the bore-pumps the water inlet screens in the bore-hole must should be cleaned**. In addition, we propose Solomon Water to have a regular half-yearly or yearly maintenance program to ensure efficient extraction of water from bore-field. The submersible pump specification of the existing bore pump, system duty-point and recommended pump is presented in **Table 14**. ***Based on recommendation from Hydrogeologist, the bore pump 4 is not running and bore pump 3 would meet the demand of 579 m³ per day.***

Table 14 Technical specification of existing pump, system duty point and recommended pump

Particular	Unit	Existing Pump	System duty point	Proposed pump
Bore-hole pump MB-1				
Model	-	Grundfos SP 46-10	-	Grundfos SP 46-11
Flow rate	m^3/h	40.7	31.8	44.3
Total head	m	90.8	96.9	100.0

Bore pump 3 recommendation is for 24.1 m³ per hour at a head of 125 meters. The proposed submersible pump as replacement for bore pumps is capable of handling head variation of ± 5 m, without substantial difference in discharge head. Detailed technical specification of the recommended pump is provided in **Appendix A –** . ***The energy saving is estimated considering the sustainable daily water production for the bore field shared by Solomon Water Hydrogeologist***. Detailed saving estimation is presented in **Table 15**. The bore pump 3 will also require a variable frequency drive (VFD) to run pump at optimum duty point.

The annual energy saving by replacing two borehole pumps is 78514 kWh equivalent to monetary saving of US $ 50,368. The investment required for installation of two pumps and one VFD is US $ 16,003. The freight cost of shipping from Australia is US $ 500. Overall landed cost in Honiara inclusive of all applicable duties is US $ 21,879. The simple payback period of the recommendation is five months. The GHG emission reduction potential of the recommendation is 48.532 tCO_2 equivalent.

Table 15 Borehole pumps energy saving estimation

Particular	Unit	MB-1	MB-3
Net daily water duty	m^3	717.0	579.0
Proposed pump flow rate	m^3/h	29.90	24.10
Operating hours	h/day	24.0	24.0
Proposed annual energy consumption	kWh/year	107307	120353
Existing annual energy consumption	kWh/year	139534	166639
Annual energy saving	kWh/year	30181	43348
Monetary saving	SBD/year	165393	237548
	USD/year	$ 20,674	$ 29,694
Cost of new bore-pump	USD	$ 6,750	$ 9,253
Freight cost	USD	$ 250	$ 250
Cost at port in Solomon Islands	USD	$ 7,000	$ 9,503
Import duty	%	10	10
GST	%	15	15
Net landed cost of bore-pump	USD	$ 9,375	$ 12,504
Simple payback period	**years**	**0.5**	**0.4**
GHG emission reduction	**tCO_2/year**	**19.92**	**28.61**

4.3. Electrical system

4.3.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel and bore-pumps panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B** – Main incomer sample power log**.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. The logging of total power for 24 hours is shown in **Figure 17**.

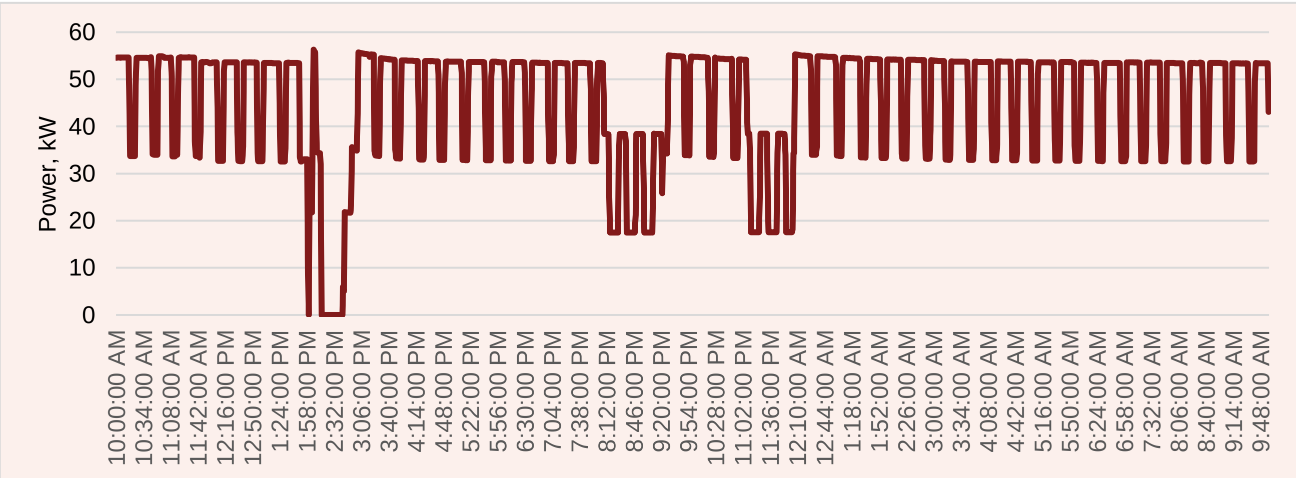


Figure 17 Skyline pump station total power log 24 hours

The power factor (PF) at the main incomer of pump station was varying between 0.761 – 0.837. The PF variation over 24 hours is presented in **Figure 18**.

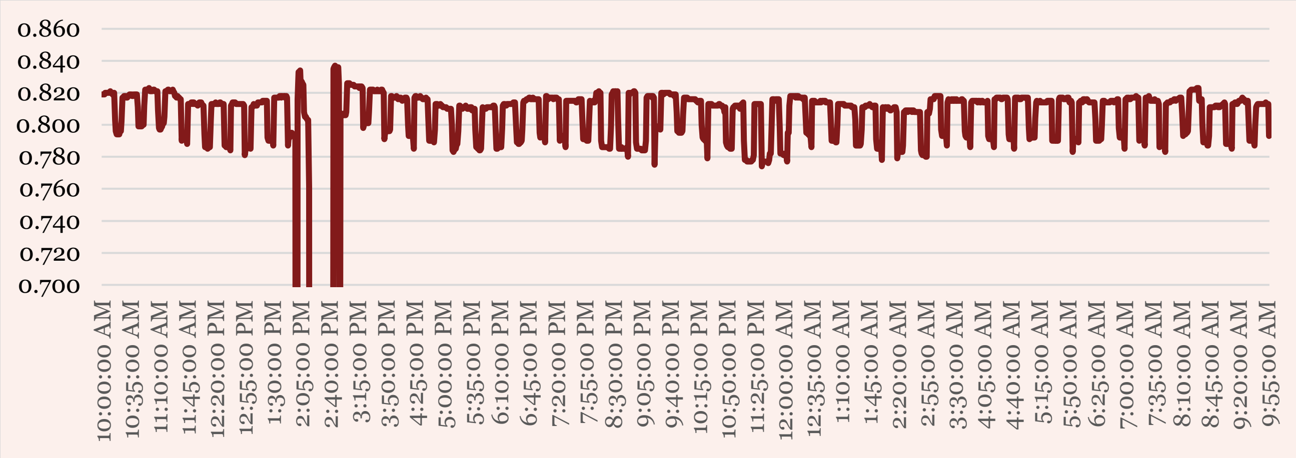


Figure 18 Power factor variation over 24 hours

4.3.2. Automatic Power Factor Correction

The average PF is 0.807 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install a 40 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 20+10+5+2+2+1 kVAr. All the banks recommended are detuned capacitors.

Figure 19 APFC panel

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 16** and

Table 17. The pictorial view of APFC panel is presented is **Figure 19**.

Table 16 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.807
Average daily reactive power	kVAr	33.26
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.17
Annual charge for PF	US$/year	$ 4,269
Capacitor bank requirement	kVAr	40
Investment cost	US$	$ 2,000
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 2,250
Import duty	%	10
GST	%	15
Net landed cost of 40 kVAr APFC	USD	$ 3,438

Simple payback period	**years**	**0.8**

Table 17 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.807
Power factor tariff as % of fuel charge (if PF < 0.90)	%	5.00
Annual fuel charge	US$/year	128224
Annual charge for PF	US$/year	$ 6,411
Capacitor bank requirement	kVAr	40
Investment cost	US$	$ 2,000
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 2,250
Import duty	%	10
GST	%	15
Net landed cost of 40 kVAr APFC	USD	$ 3,438
Simple payback period	**years**	**0.5**

4.4. Lighting system

4.4.1. Performance assessment

The pump station was equipped with 24 six feet fluorescent tube lights (FTL) of 36 W rating (T8). 12 fixtures are installed in pump room and 12 fixtures in electrical & diesel set room. The details of the existing system are provided in **Table 18**.

Table 18 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	12	528
FTL T8	Electrical & DG room	36+8	12	528
Total			**24**	**1056**

4.4.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 6 LED tube pump room and 6 in DG room. Details of the present lighting system are given in **Table 19**. The pictorial view of FTL tube and LED tube is shown in **Figure 20.**

Figure 20 LED tube vs florescent tube

Table 19 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED

Particular	Unit	Existing	Proposed
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	24	12
Total rating	W	1056	252
Operating hours	h/year	250	250
Annual consumption	kWh/year	264	63
Annual saving	kWh/year		201
Monetary saving	SBD/year		1125
	USD/year		$ 137
Investment cost	USD		$ 240
Simple payback	**Years**		**1.75**
GHG emission reduction	**tCO_2/year**		**0.13**

The estimated annual energy savings with new LED lighting system is 201 kWh of electricity, effectively equivalents to a monetary savings of US $ 137. The investment requirement is US $ 240. The simple payback period of the recommendation is 1.8 years. The annual reduction in GHG emission is estimated to be 0.13 tCO_2.

5. Self-generation option

5.1. Renewable energy assessment

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic. Detailed feasibility analysis for solar is presented in this chapter.

5.2. Site description

Skyline pump station is in Mbokonavera area of Honiara city in Guadalcanal province. The pump station is spread across an area of about 530 m². The projected roof area as seen from the top, over the pump house building is about 160 m². The rest of the area is used servicing purpose and one of the bore-hole is situated inside pump house. There are no buildings nearby to cause shading, except for a tree on NW corner outside pump station, which may cause shading on part of building roof for a limited duration during the evening hours. Roof is made of concrete and support installation of solar roof top PV modules.

5.3. Solar resource assessment

The solar data source i.e. Global Horizontal Irradiance (GHI) for Honiara, is derived from a Japan International Cooperation Agency (JICA) report on Pilot Survey for Disseminating SME's Technologies for Introduction of Utility Interactive Grid-Connected Photovoltaic Generation System Possessed in Okinawa Prefecture for Small Island Regions, 2015. These values are an estimation of the solar resource on a horizontal surface. Solar data for Honiara is presented in **Table 20**.

Table 20 Daily Global Horizontal Irradiation at site location

Daily Global Horizontal Irradiation in kWh/m²/day											
Latitude -9.438⁰, Longitude 159.959⁰											
Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

The roof orientation yields optimum results when the tilt angle is equal to the latitude which in this case is 9.4⁰. The sun elevation diagram for the pump station is presented in **Figure 21**.

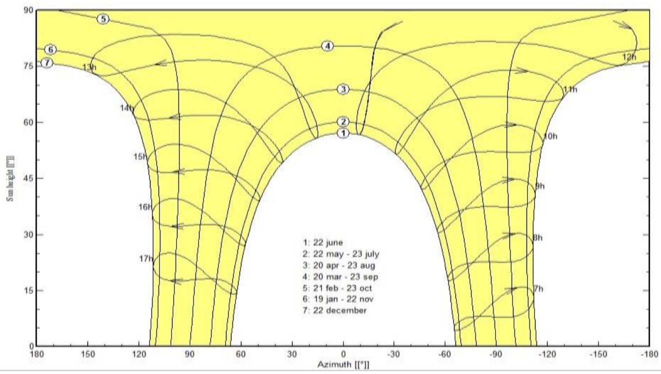


Figure 21 Sun elevation diagram for the site

5.4. System sizing and cost benefit

The effective area available for solar-roof PV installation is 136 m². Capacity for PV systems is measured at Standard Testing Conditions, of 1000 W/m², AM 1.5 and 25°C cell temperature. These conditions may not be the same on site. Site specific capacity varies intermittently with changing irradiance, ambient temperature, wind speed and air mass with respect to time, calendar day and other effects like cloud cover. The Polycrystalline technology generally has efficiency of ~16%. Monocrystalline Silicon technology can achieve ~20% although they are expensive. The power delivered at the interconnection will be further reduced due to inverter efficiency, transformer efficiency, module fouling and cabling losses. The system sizing along with cost benefit considering thin film and monocrystalline technology is presented in **Table 21**. This is considering there is no standby charges fees and the utility i.e. SIEA pays fuel charges to Solomon Water for imported energy to grid which is SBD 2.65 per kWh.

Table 21 Cost benefit of solar roof PV - Thin film and monocrystalline

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m^2	160	160
Utilization area	m^2	136	136
Nominal power	kWp	13.6	21.8
Average global horizontal irradiance	$kWh/m^2/day$	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	20974	33620
Avg fuel charges	SBD/kWh	2.65	2.65
Monetary saving	SBD/year	55547	89038
	USD/year	$ 6,943	$ 11,130
Module cost	USD	$ 12,716	$ 20,346
Supports cost	USD	$ 15,558	$ 15,558
Inverter and wiring cost	USD	$ 4,787	$ 4,787
Transport and mounting cost	USD	$ 18,370	$ 26,755
Cost at port in Solomon Islands	USD	$ 51,431	$ 67,446
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost	USD	$ 64,914	$ 84,933
Simple payback period	**years**	**9.3**	**7.6**

The cost benefit considering present tariff structure is presented in **Table 22**. With present regulation we have considered the standby changes in addition with cost system.

Table 22 Cost benefit of solar roof PV with present tariff

Particular	Unit	Thin-film	Monocrystalline
Nominal power	kWp	13.6	21.8
Annual solar yield	kWh/year	20974	33620
Monetary saving by avoided energy consumption	SBD/year	59392	95202
	USD/year	$ 7,424	$ 11,900
Annual standby charges	USD/year	$ 9,244	$ 14,818
Net landed cost	USD	$ 74,158	$ 99,751
Simple payback period	**years**	10.0	8.4

The detailed analysis for Solar roof PV system sizing was performed on PVSyst software. PVSyst software provides possibility of complex simulation input and output parameters of PV plant and is also commercially to calculate the total production of electricity. As per the PVSyst simulation results, the estimated energy generation for the first year is 21.0 MWh/year, with Specific Energy Yield of 1545 kWh/kW_p/year for thin film technology-based modules. The simulation was run considering monocrystalline cell modules and the estimated energy generation for the first year is 33.6 MWh/year. The detailed results of PVSyst are presented in **Appendix C** – PVSYST simulation results.

5.5. Regulatory framework

The policies, processes and forms for solar system connection to SIEA grid are available in Solar Manual of SIEA. Some of the key highlights are:

- Inverter energy systems that have a continuous rating of no more than 30 kVA for three-phase systems.
- The installation should as a minimum comply with Australian Standards AS3000, AS4777 and AS5033 and all other relevant Australian Standards and Solomon Islands statutory requirements.
- All energy consumed from the grid at the premises will be metered by an import-only meter and billed to the customer under the applicable tariff(s). It is only any 'excess' energy will be exported to the SIEA grid. This energy will be metered but will NOT be paid for by SIEA.

The process for solar grid connection as provided by SIEA is presented in **Figure 22**.

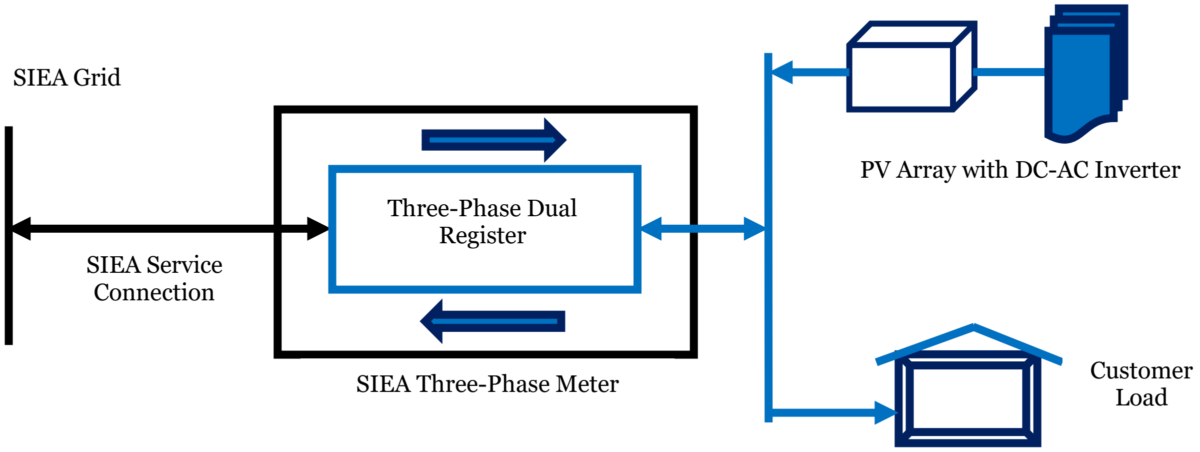


Figure 22 Schematics of solar PV interconnection with SIEA grid

Net metering is a utility billing mechanism that offers a credit to customers who are making excess electricity with their solar panel systems and sending it back to the grid. Solomon Islands at present does not have provision for net metering. However, SIEA is in process of reviewing and restructuring its electricity tariff. It may introduce the net metering option for solar roof top.

*Solar PV option for the pump station is **technically feasible**. But, the financially feasibility is dependent on future SIEA tariff structure. With present tariff structure and regulatory elements, the solar PV is not feasible.*
*The Solomon Water can **take a strategic call** if to invest in solar PV now or to wait for favorable regulatory regime.*

5.6. Other grid-connected solar initiatives in Solomon Islands

The World Bank is implementing a scaling-up of renewable energy project in Solomon Islands in the period 2018 to 2023. The Project intends to improve lifestyle and increase shared prosperity for the low-income household through scaling-up off and on-grid renewable energy projects.

The project is being implemented in four components, which are presented in **Table 23**.

Table 23 Components of WB Scaling-up RE project

Component – 1	Renewable energy hybrid mini-grids – Supply, installation and initial maintenance
Component – 2	Electricity connections in low income areas – Households, micro enterprise and community infrastructure
Component – 3	Grid-connected solar power - Supply, installation and initial maintenance
Component – 4	Enabling environment and project management – including gender related activities, technical assistance and training activities

The third component deals with grid connected solar power. World Bank intendeds to support supply, implementation and initial maintenance of grid-connected solar power projects. The project financing and source of funding for the gird connected solar power is presented in **Table 24**.

Table 24 Project financing and source of funding

Source of Fund	Project financing (US$ million)	Share of financing
International Development Association (IDA) financing credits	3.5	**70%**
IDA financing grant	0.55	**11%**
Trust funds GEF	0.95	**19%**
Total	**5.0**	**100%**

The reason for the solar power project being financially feasible as compared to solar power project proposed at pumps station are as follows:

- About 30% of the total funding for the project is through grant or funds, thus, reducing financing burden
- The remaining cost of project is also in terms of IDA financing credits, which has very low interest charge and repayments been stretched over long term
- The economy of scale, the solar power supported by World Bank is of MW capacity, however, the pump station projects capacity is in kW size
- One component of the World Bank project is on reducing regulatory barriers for solar project while creating the conditions for future replication. (This is in progress)

In case, the solar power project proposed for pump station can be financed through similar mechanism i.e. close to 30% grant/funds, the project finances will improve. Moreover, a further strengthened regulatory regime will be an advantage. The sensitivity analysis of grid connected solar power project with and without grant funding is presented in **Table 25**.

Table 25 Sensitivity analysis - Solar power project with and without grant

Particular	Unit	Without grant	With grant
Solar rooftop plant capacity for Skyline Pump Station	kWp	21.8	21.8
Monetary savings	US $	11130	11130
Investment	US $	84933	59453
Simple payback period	**Years**	**7.6**	**5.3**

6. Conclusion

6.1. Summary of study

Skyline pump station is in Mbokonavera area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four boreholes. The water from receiving tanks is pumped to Skyline JICA reservoir using three transfer pumps. The pump station produces 1132 m^3 water daily consuming about 1078.7 kWh electrical energy. The existing specific energy consumption is 0.953 kWh per m^3. The study has identified four recommendations for energy conservation (**Table 26**). These recommendations could save annually about 78,244 kWh of electricity. These recommendations have an estimated investment of US $ 29,313 and can yield a monetary savings of US $ 53,597 per year. The annual energy saving is estimated to be 20.1% of total energy consumption by the pump station (**Figure 23**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 51.64 tonnes of CO_2.

Table 26 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Installation of VFD on transfer pumps	4,514	$ 3,092	$ 7,195	2.3	2.98
ECM-2	Replacement of borepump-1 with efficient pump	30,181	$ 20,674	$ 9,375	0.5	19.92
ECM-3	Replacement of borepump-4 with efficient pump	43,348	$ 29,694	$ 12,504	0.4	28.61
ECM-4	Replacement of FTL with LED lights	201	$ 137	$ 240	1.7	0.13
	Total	**78,244**	**$ 53,597**	**$ 29,313**	**0.5**	**51.64**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 27**.

Table 27 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.953 kWh/m^3	0.657 kWh/m^3
Specific CO_2 emission	0.622 kg CO_2/m^3	0.434 kg CO_2/m^3

On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

6.2. Funding options

The overall investment proposed for four energy conservation measures for Skyline pump station is US$ 29,313. The simple payback on this investment is 6 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 6 months, which can be followed by VFD on transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Skyline pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

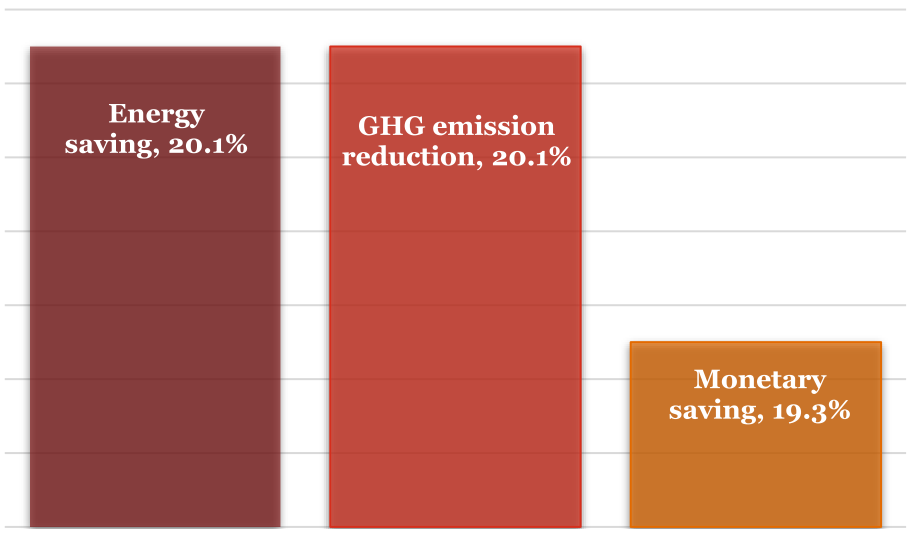


Figure 23 Identified saving potential

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

A collage of select pictures taken during the detailed feasibility study is presented in **Appendix D**.

Appendix

Appendix A – Borehole pump technical specification

Borehole pump MB-1

GRUNDFOS

Company name:
Created by:
Phone:

Date: 05/02/2020

Qty.	Description
1	**SP 30-12**

Note! Product picture may differ from actual product

Product No.: 13B03612

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 18.5 kW MS6000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	3450 rpm
Rated flow:	36 m³/h
Rated head:	130 m
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP3

Company name:
Created by:
Phone:

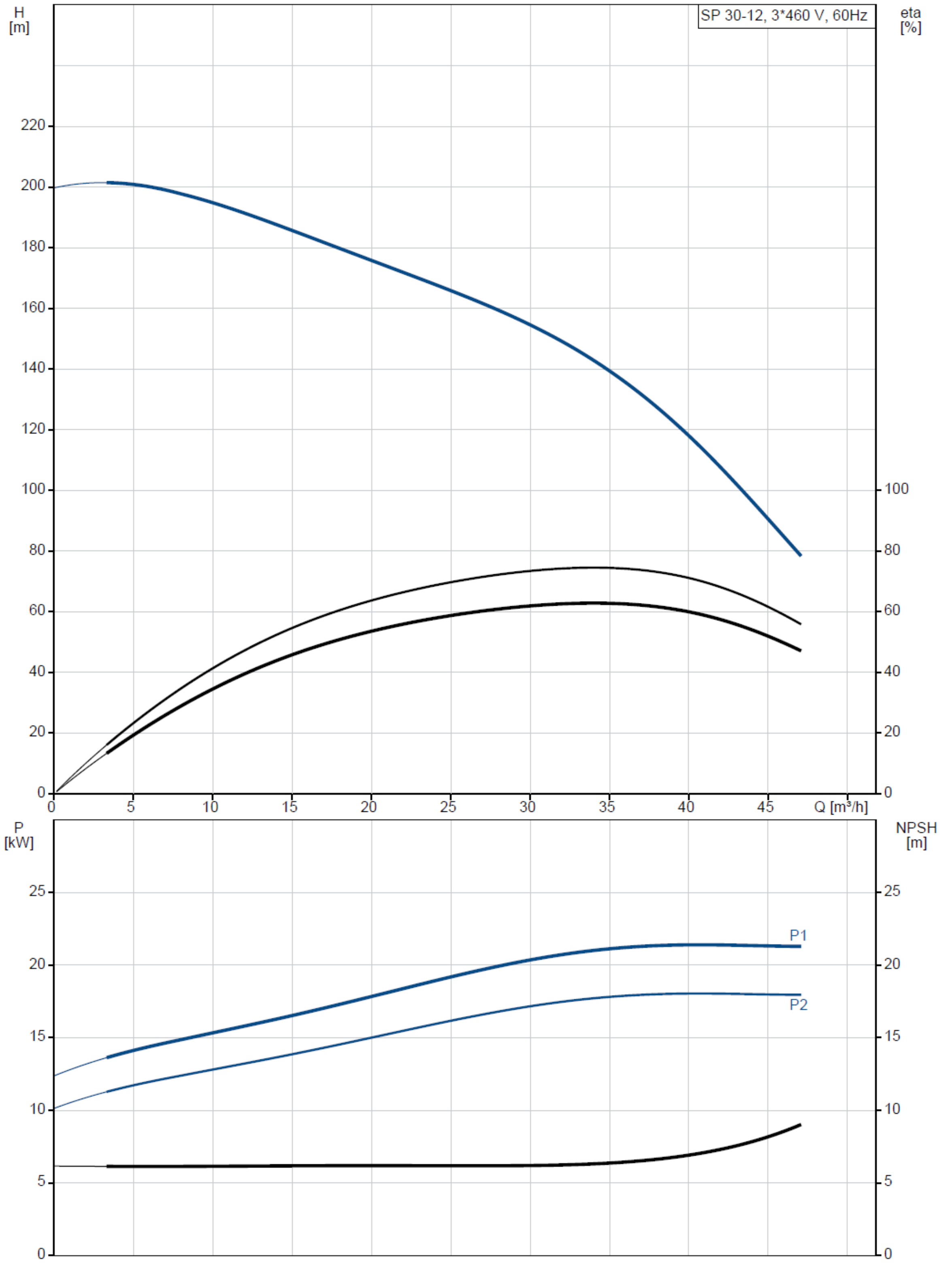
Date: 05/02/2020

Qty.	Description	
	Motor diameter:	6 inch
	Electrical data:	
	Motor type:	MS6000
	Rated power - P2:	18.5 kW
	Power (P2) required by pump:	18.5 kW
	Mains frequency:	60 Hz
	Rated voltage:	3 x 440-460-480 V
	Service factor:	1.15
	Rated current:	41.0-40.0-39.5 A
	Starting current:	540-590-620 %
	Cos phi - power factor:	0.85-0.83-0.80
	Rated speed:	3460-3480-3490 rpm
	Start. method:	direct-on-line
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	78195517
	Others:	
	Minimum efficiency index, MEI ≥:	0.50
	ErP status:	EuP Standalone/Prod.
	Net weight:	88.5 kg
	Gross weight:	123 kg
	Shipping volume:	0.264 m^3

Company name:
Created by:
Phone:

Date: 05/02/2020

13B03612 SP 30-12

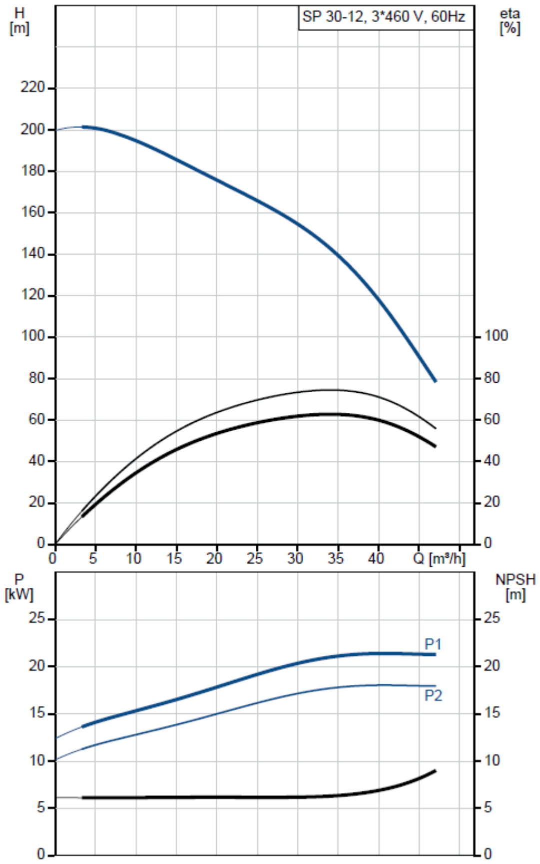


GRUNDFOS

Company name:
Created by:
Phone:

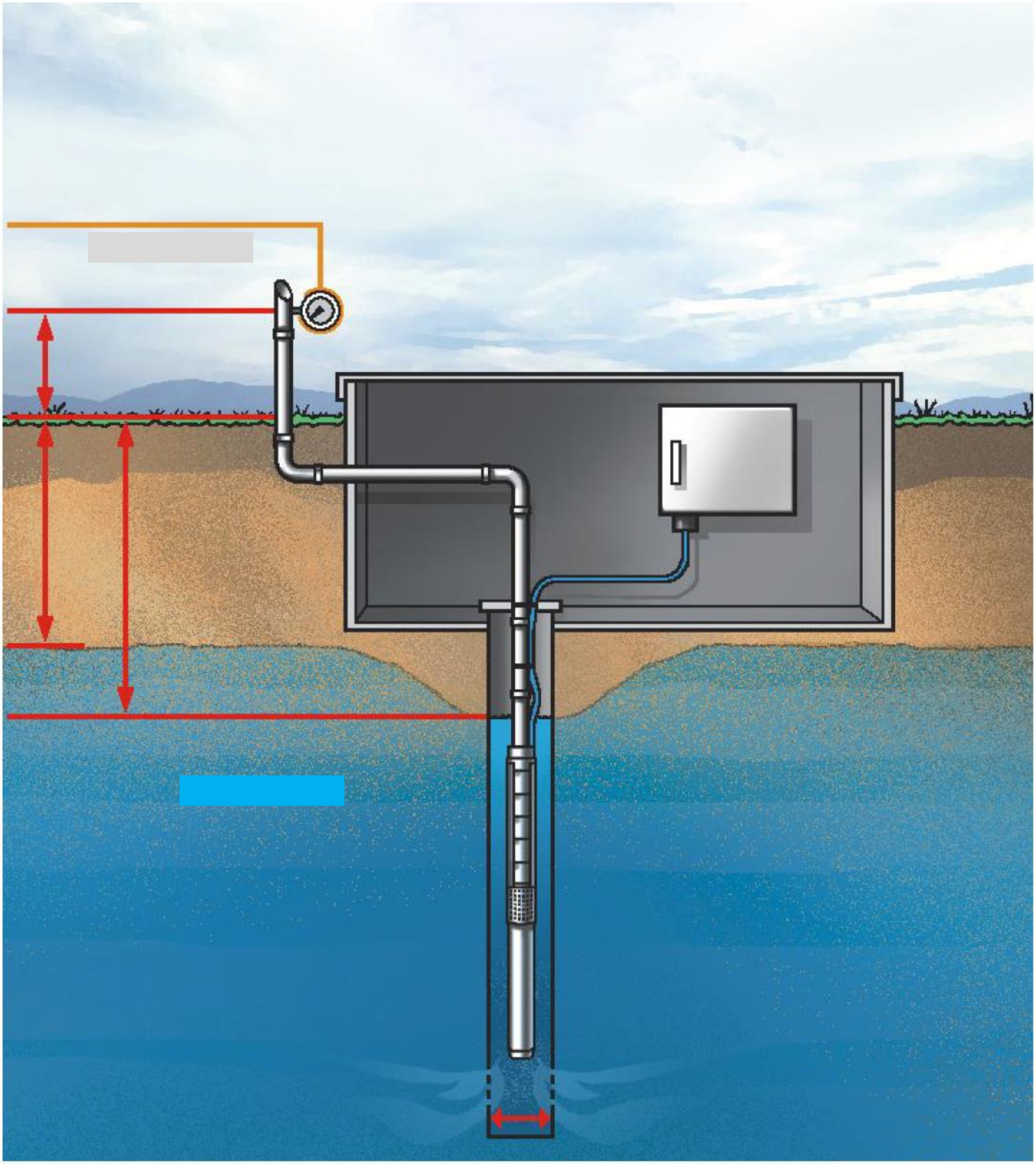
Date: 05/02/2020

Description	Value
General information:	
Product name:	SP 30-12
Product No:	13B03612
EAN number:	5700391417573
	5700391417573
Technical:	
Pump speed on which pump data are based:	3450 rpm
Rated flow:	36 m³/h
Rated head:	130 m
Stages:	12
Impeller reduc.:	NONE
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP3
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS6000
Applic. motor:	GRUNDFOS
Rated power - P2:	18.5 kW
Power (P2) required by pump:	18.5 kW
Mains frequency:	60 Hz
Rated voltage:	3 x 440-460-480 V
Service factor:	1.15
Rated current:	41.0-40.0-39.5 A
Starting current:	540-590-620 %
Cos phi - power factor:	0.85-0.83-0.80
Rated speed:	3460-3480-3490 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	78195517
Others:	
Minimum efficiency index, MEI ≥:	0.50



Company name:
Created by:
Phone:

Date: 16/10/2019



Borehole pump MB-4

GRUNDFOS

Company name:
Created by:
Phone:

Date: 05/02/2020

Qty.	**Description**
1	**SP 30-14**

Note! Product picture may differ from actual product

Product No.: 13A16914

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 13 kW MS6000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for star-delta starting (Y/D).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Rated flow:	30 m³/h
Rated head:	108 m
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP3

GRUNDFOS

Company name:
Created by:
Phone:

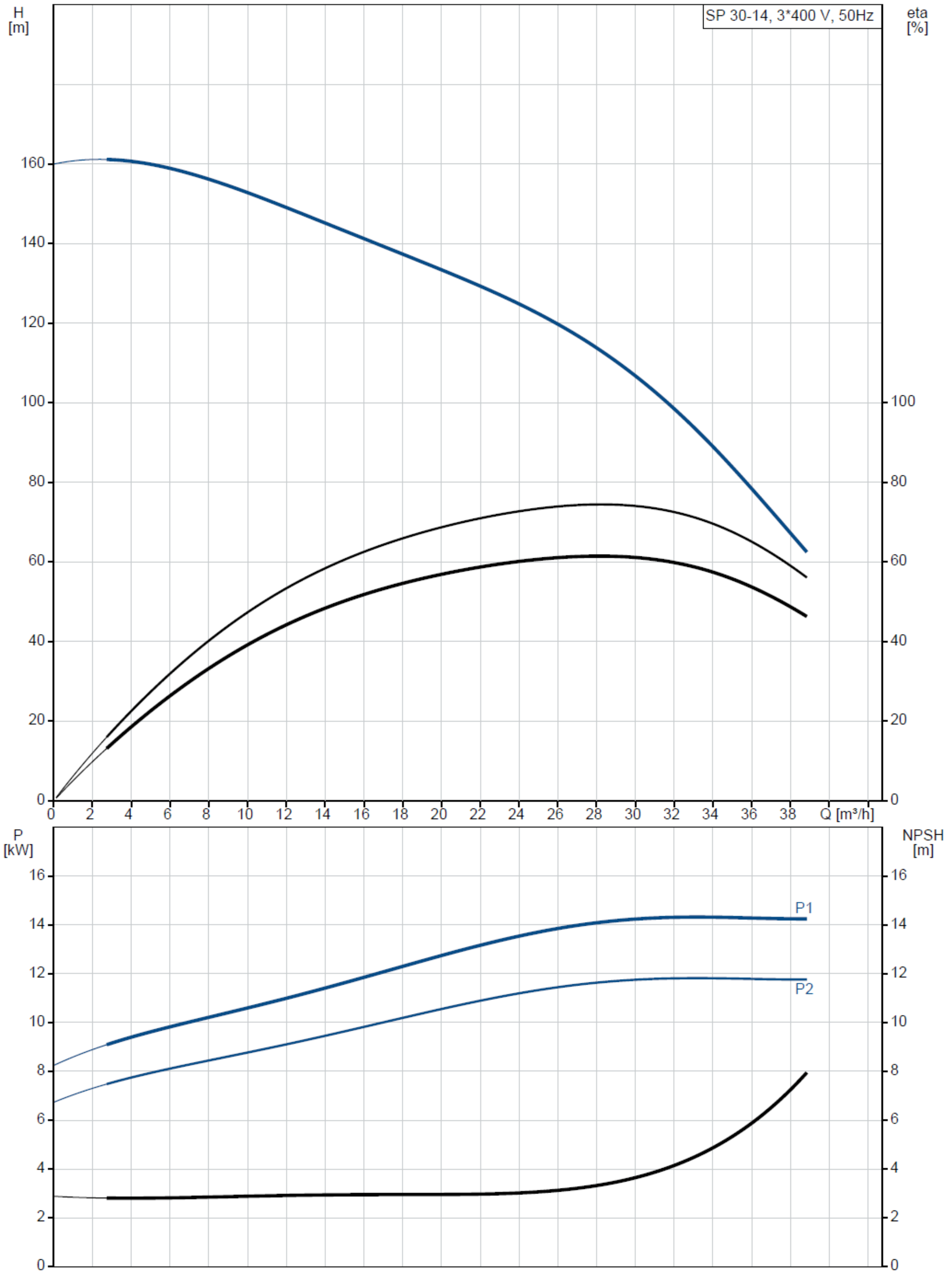
Date: 05/02/2020

Qty.	Description	
	Motor diameter:	6 inch
	Electrical data:	
	Motor type:	MS6000
	Rated power - P2:	13 kW
	Power (P2) required by pump:	13 kW
	Mains frequency:	50 Hz
	Rated voltage:	3 x 380-400-415 V
	Rated current:	30.0-29.0-29.0 A
	Starting current:	490-540-560 %
	Cos phi - power factor:	0.85-0.82-0.79
	Rated speed:	2850-2870-2880 rpm
	Start. method:	star/delta
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	78695515
	Others:	
	Minimum efficiency index, MEI ≥:	0.50
	ErP status:	EuP Standalone/Prod.
	Net weight:	82.7 kg
	Gross weight:	118 kg
	Shipping volume:	0.295 m^3

Company name:
Created by:
Phone:

Date: 05/02/2020

13A16914 SP 30-14 50 Hz

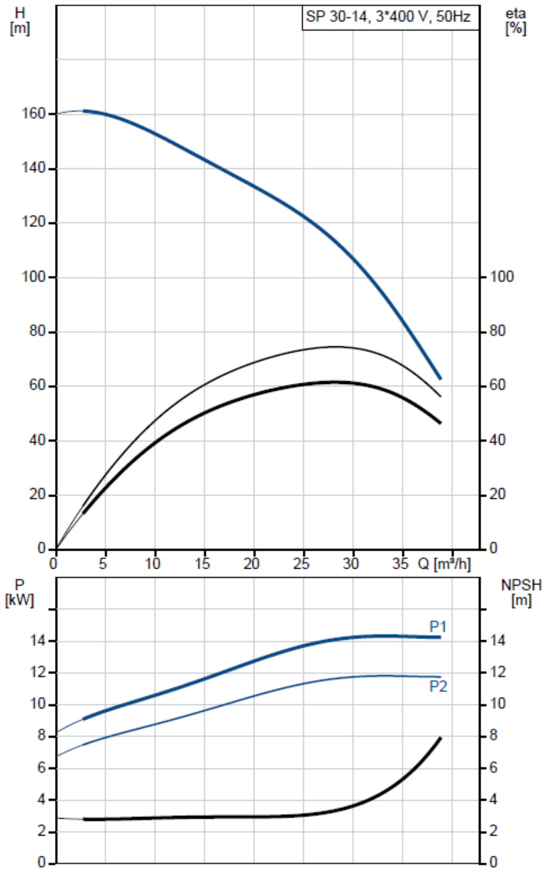


GRUNDFOS

Company name:
Created by:
Phone:

Date: 05/02/2020

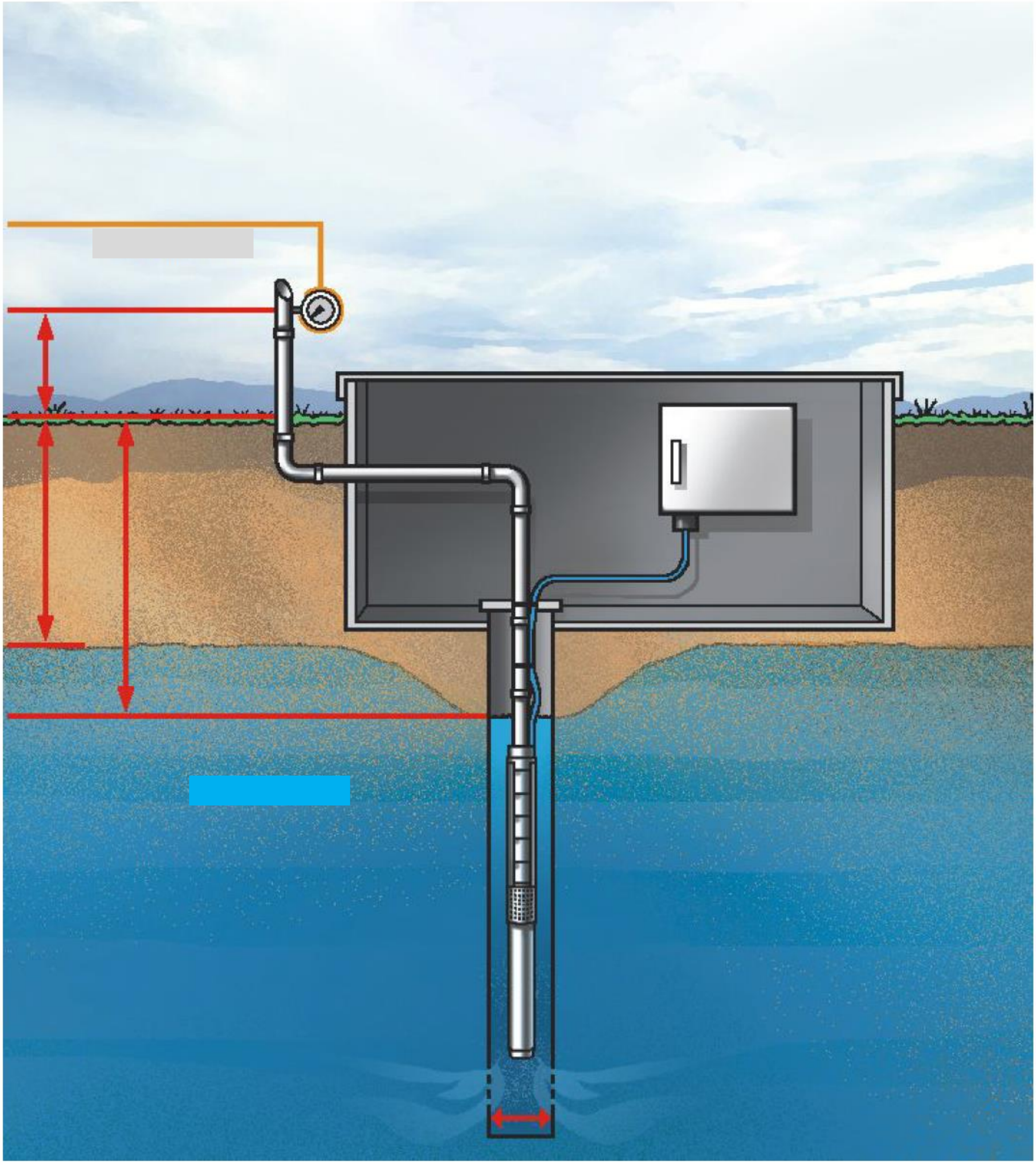
Description	Value
General information:	
Product name:	SP 30-14
Product No:	13A16914
EAN number:	5700390384258
	5700390384258
Technical:	
Pump speed on which pump data are based:	2900 rpm
Rated flow:	30 m³/h
Rated head:	108 m
Stages:	14
Impeller reduc.:	NONE
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP3
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS6000
Applic. motor:	GRUNDFOS
Rated power - P2:	13 kW
Power (P2) required by pump:	13 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-400-415 V
Rated current:	30.0-29.0-29.0 A
Starting current:	490-540-560 %
Cos phi - power factor:	0.85-0.82-0.79
Rated speed:	2850-2870-2880 rpm
Start. method:	star/delta
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	78695515
Others:	
Minimum efficiency index, MEI ≥:	0.50
ErP status:	EuP Standalone/Prod.



GRUNDFOS

Company name:
Created by:
Phone:

Date: 16/10/2019



Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
9/5/2019	10:00:00 AM	50	415.7	416.6	416.2	95.6	90.9	90.4	54.59	0.819
9/5/2019	10:01:00 AM	50	415.9	416.8	416.5	95.7	90.8	90.6	54.62	0.819
9/5/2019	10:02:00 AM	50	415.8	416.7	416.5	95.7	90.6	90.7	54.62	0.819
9/5/2019	10:03:00 AM	50	415.8	416.4	416.4	96	90.5	90.6	54.62	0.819
9/5/2019	10:04:00 AM	50	415.4	416.1	416	95.8	90.6	90.6	54.61	0.82
9/5/2019	10:05:00 AM	50	415.2	416	415.8	95.8	90.7	90.5	54.59	0.82
9/5/2019	10:06:00 AM	50	415.6	416.3	415.8	95.8	91	90.2	54.62	0.82
9/5/2019	10:07:00 AM	50	415.6	416.3	415.9	95.8	90.8	90.3	54.60	0.82
9/5/2019	10:08:00 AM	50	415.5	416.4	416.1	95.7	90.7	90.6	54.61	0.82
9/5/2019	10:09:00 AM	50	415.2	416.3	416.2	95.5	90.6	90.9	54.62	0.82
9/5/2019	10:10:00 AM	50	414.9	416	415.9	95.5	90.6	90.9	54.60	0.821
9/5/2019	10:11:00 AM	50	415.1	415.9	416	95.8	90.3	90.9	54.61	0.82
9/5/2019	10:12:00 AM	50	415.6	416.4	416.4	95.9	90.4	90.7	54.63	0.82
9/5/2019	10:13:00 AM	50.01	415.9	416.4	416.5	96.1	90.4	90.6	54.64	0.819
9/5/2019	10:14:00 AM	50	415.7	416.2	416.4	96.1	90.3	90.7	54.61	0.82
9/5/2019	10:15:00 AM	50	415.5	416	416.4	96.1	90.1	90.8	54.61	0.82
9/5/2019	10:16:00 AM	50	415.9	416.5	416.8	85.9	80	80.7	47.71	0.803
9/5/2019	10:17:00 AM	50	417.5	418.3	418.4	62.4	56	56.8	33.71	0.796
9/5/2019	10:18:00 AM	50	418.3	419.1	419.1	62.4	56.1	56.9	33.74	0.794
9/5/2019	10:19:00 AM	50	418.4	418.9	418.9	62.5	56.1	56.7	33.73	0.794
9/5/2019	10:20:00 AM	50.01	418.4	418.9	418.9	62.5	56.1	56.7	33.74	0.794
9/5/2019	10:21:00 AM	50	418.5	418.9	419	62.5	56.1	56.7	33.74	0.794
9/5/2019	10:22:00 AM	50	417.8	418.2	418.4	62.5	56	56.7	33.72	0.796

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
9/5/2019	10:23:00 AM	50	417.6	418.2	418.1	62.4	56.1	56.7	33.72	0.796
9/5/2019	10:24:00 AM	50	416.3	416.8	416.6	88.2	82.7	82.2	48.69	0.802
9/5/2019	10:25:00 AM	50	415.9	416.3	416	96.6	91.1	89.9	54.56	0.817
9/5/2019	10:26:00 AM	50	415.8	416	416	96.8	90.9	90	54.57	0.817
9/5/2019	10:27:00 AM	50	415.7	415.8	415.8	96.8	90.9	89.9	54.58	0.818
9/5/2019	10:28:00 AM	50	415.3	415.5	415.8	96.7	90.6	90.3	54.55	0.818
9/5/2019	10:29:00 AM	50	415.2	415.6	415.8	96.6	90.7	90.4	54.57	0.818
9/5/2019	10:30:00 AM	50	415.7	416	416.3	96.7	90.6	90.4	54.58	0.817
9/5/2019	10:31:00 AM	50	415.8	416.1	416.2	96.6	90.8	90.2	54.57	0.817
9/5/2019	10:32:00 AM	50.01	415.6	416.2	416.3	96.4	90.8	90.4	54.58	0.818
9/5/2019	10:33:00 AM	50	415.2	415.9	416.2	96.3	90.6	90.7	54.57	0.818
9/5/2019	10:34:00 AM	50	414.6	415.3	415.7	96.3	90.4	90.8	54.54	0.819
9/5/2019	10:35:00 AM	50	414.6	415.2	415.4	96.3	90.6	90.6	54.54	0.819
9/5/2019	10:36:00 AM	50.01	414.9	415.8	415.5	96.1	91	90.4	54.56	0.819
9/5/2019	10:37:00 AM	50.01	415.2	415.9	415.7	96.2	91.1	90.3	54.57	0.818
9/5/2019	10:38:00 AM	50.01	415.3	416	415.8	96.2	91	90.4	54.57	0.818
9/5/2019	10:39:00 AM	49.99	415	415.7	415.5	96.1	90.9	90.4	54.53	0.819
9/5/2019	10:40:00 AM	50	414.5	415.4	415.3	96	90.9	90.5	54.52	0.819
9/5/2019	10:41:00 AM	50	414.7	415.7	415.5	95.9	90.9	90.6	54.53	0.819
9/5/2019	10:42:00 AM	50	415.1	415.8	415.6	96.1	91	90.3	54.53	0.818
9/5/2019	10:43:00 AM	50	415	415.7	415.4	96.3	91.4	90.4	54.69	0.819
9/5/2019	10:44:00 AM	50	415.2	416	415.7	92.1	86.9	86.4	51.69	0.811
9/5/2019	10:45:00 AM	50	417.2	417.8	417.4	62.7	56.7	57.2	34.10	0.799
9/5/2019	10:46:00 AM	50	417	417.6	417.2	62.7	56.7	57.1	34.05	0.8

Appendix C – PVSYST simulation results

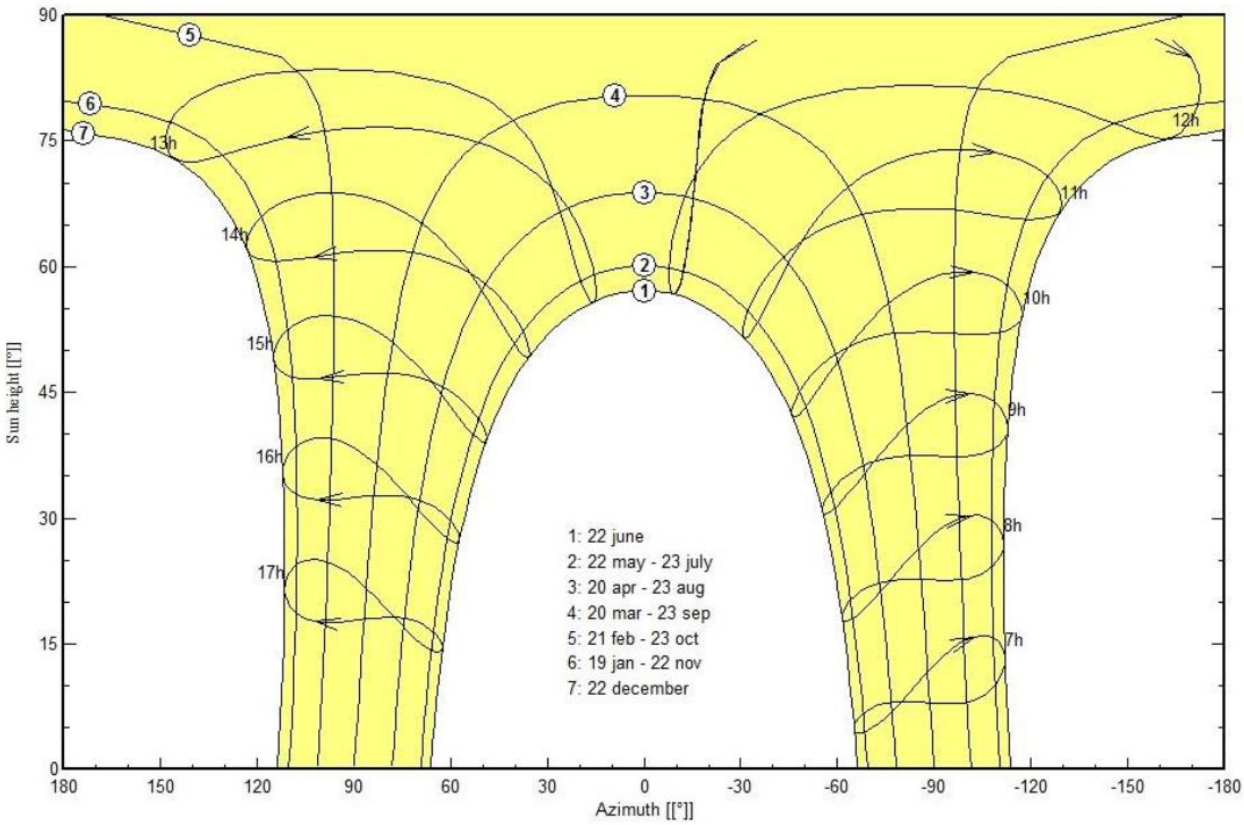
Definition of Geographical Site

Geographical Site	**Honiara**	Country	**Solomon Islands**
	File New.SIT of 01/10/19 12h40		
Situation	Latitude: -9.45° S		Longitude: 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10 m

Monthly Meteo values

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m² day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m² day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

Solar paths at Honiara, (Lat. -9.4517° S, long. 159.9612° E, alt. 10 m) - Legal Time



Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt: 10°		Azimuth 0°

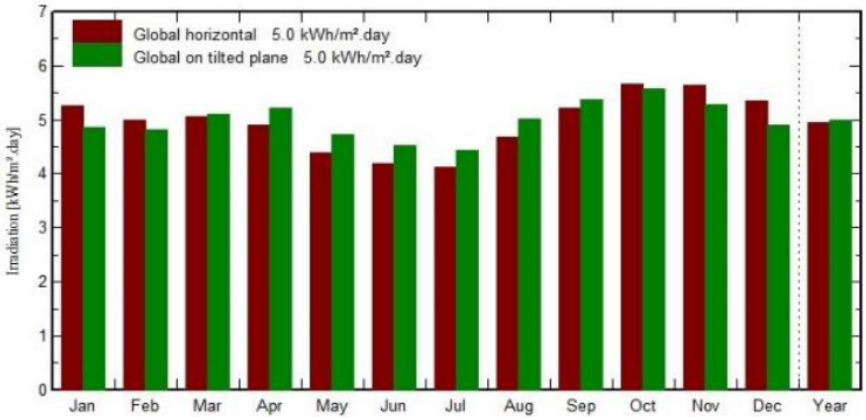
PV Installation main features

Module Type	Standard
Technology	Thin film
Mounting method	Flat roof
Back ventilation properties	Free Standing

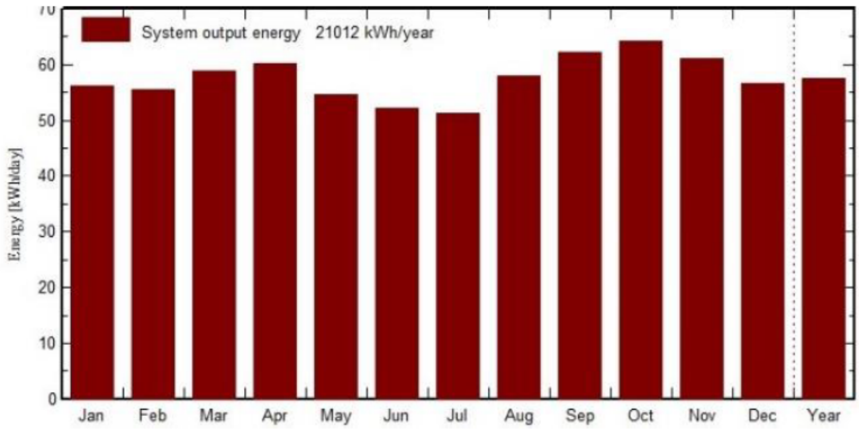
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	13.6 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	21.0 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	56.16	1741
Feb	4.99	4.81	55.58	1556
Mar	5.05	5.10	58.93	1827
Apr	4.91	5.21	60.18	1806
May	4.39	4.72	54.53	1690
June	4.19	4.52	52.16	1565
Jul	4.12	4.43	51.22	1588
Aug	4.67	5.02	58.03	1799
Sept	5.21	5.38	62.09	1863
Oct	5.67	5.57	64.29	1993
Nov	5.64	5.28	61.02	1831
Dec	5.35	4.90	56.59	1754
Year	4.95	4.98	57.57	21012

Grid System Pre-sizing			
Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt:10°		Azimuth: 0°

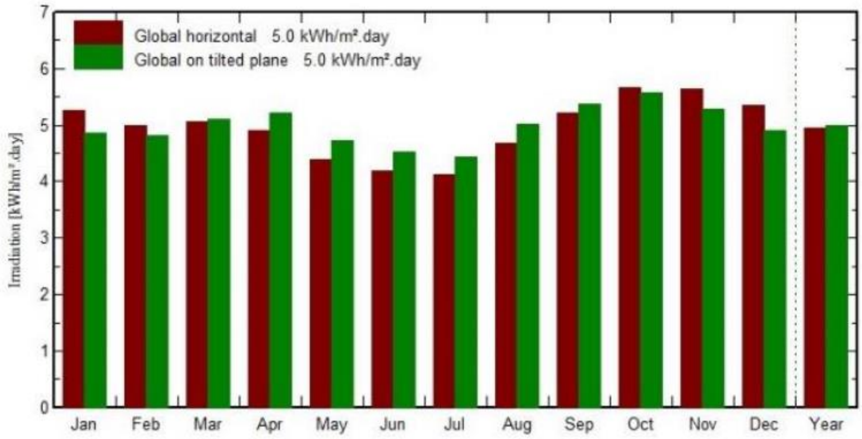
PV Installation main features

Module Type	Standard
Technology	Monocrystalline cell
Mounting method	Flat roof
Back ventilation properties	Free Standing

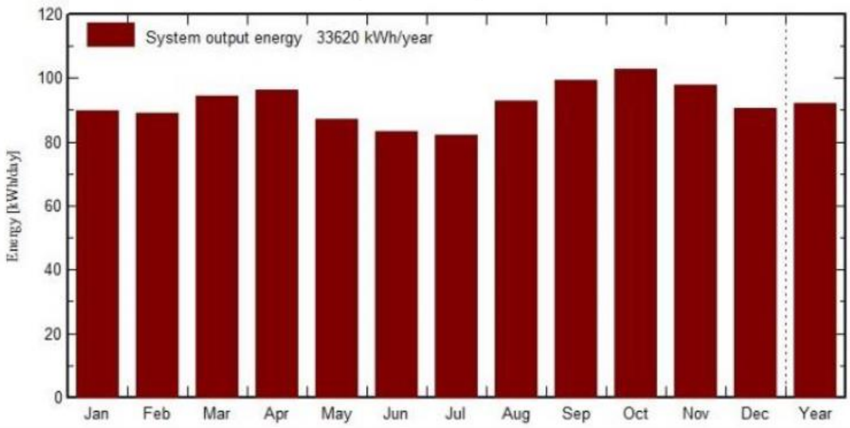
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	21.8 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	33.6 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	89.85	2785
Feb	4.99	4.81	88.93	2490
Mar	5.05	5.10	94.29	2923
Apr	4.91	5.21	96.29	2889
May	4.39	4.72	87.25	2705
June	4.19	4.52	83.45	2504
Jul	4.12	4.43	81.95	2540
Aug	4.67	5.02	92.86	2879
Sept	5.21	5.38	99.34	2980
Oct	5.67	5.57	102.9	3189
Nov	5.64	5.28	97.63	2929
Dec	5.35	4.90	90.55	2807
Year	4.95	4.98	92.11	33620

Appendix D – Photographs taken during the study

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Detailed Feasibility Report
Tasahe Pump Station

Prepared for
UNIDO – CTCN

Under the project
Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious "technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan".

The study team is indebted to Mr. Ian Gooden, Chief Executive Officer, Solomon Island Water Authority for showing keen interest in the study and thankful to the progressive management of Solomon Water for their wholehearted support and cooperation for the study and preparation of Detailed Feasibility Report. It is well worthy to mention that the efforts being taken, and the enthusiasm shown by all the personnel towards energy efficiency was admirable. A special thanks to Mr. Mark Waite (Strategic Projects Management Advisor), Mr. Shaun Kies-Ryan (Hydrogeologist), Mr. Noel Orudiana (Project Manager) and Mr. Danny Titiri (Electrical and Mechanical Team Lead) for coordinating the field visits. We would like to thank all the staff for support including technicians, electricians i.e. Mr. Livingston, Mr. Sam and Mr. Moffat.

PwC is grateful to Mr. Hudson Kauhiona, Director Climate Change for his committed support from Ministry of Environment, Climate Change, Disaster Management and Meteorology for executing the technical assistance.

Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Tasahe pump station is in Tasahe area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Tasahe JICA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. At the time of study all the four bore-pumps were operational, and two transfer pumps were running in parallel. Details of Tasahe pump station is presented below.

Name of the pump station	Tasahe
No. of transfer pumps	3 (2 Run + 1 Standby)
No. of bore-hole pumps	4 (All 4 Operational)
Monthly electricity consumption	66383 kWh (average of last 12 months)
Monthly water production	98122 m^3 (based on onsite measurement)
Name and details of contact person	Livingston Kute, Plumber +677-7459172 Danny Titiri, Electrical and Mechanical Team Lead dtitiri@solomonwater.com.sb, +677-8876857
Annual working days	365

A detailed feasibility study of Tasahe pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Tasahe pump station is in Tasahe area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m3 water receiver tank, which receives water from four boreholes. The water from receiving tanks is pumped to Tasahe JICA reservoir using three transfer pumps. The pump station produces 3225.9 m3 water daily consuming about 2213 kWh electrical energy. The existing specific energy consumption is 0.686 kWh per m3. The study has identified three recommendations for energy conservation (Table). These recommendations could save annually about 60,273 kWh of electricity. These recommendations have an estimated investment of US $ 16,396 and can yield a monetary savings of US $ 41,287 per year. The annual energy saving is estimated to be 7.6% of total energy consumption by the pump station (Figure). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 39.78 tonnes of CO2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement of borepump-2 with efficient pump	36,725	$ 25,157	$ 8,250	0.3	24.24
ECM-2	Replacement of borepump-4 with efficient pump	23,347	$ 15,993	$ 7,906	0.5	15.41
ECM-3	Replacement of FTL with LED lights	201	$ 138	$ 240	1.7	0.13
	Total	**60,273**	**$ 41,287**	**$ 16,396**	**0.4**	**39.78**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.686 kWh/m^3	0.625 kWh/m^3
Specific CO_2 emission	0.447 kg CO_2/m^3	0.413 kg CO_2/m^3

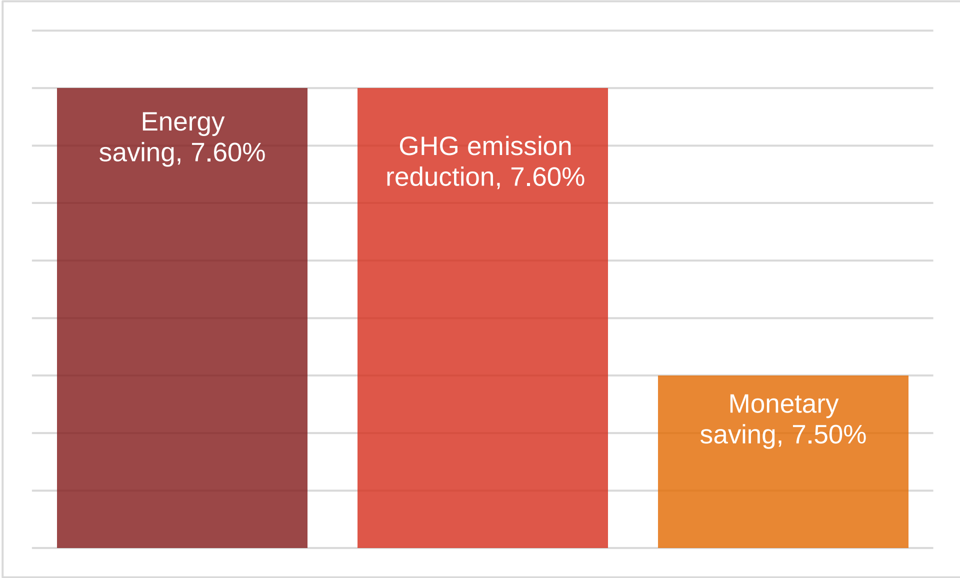
On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

Funding options

The overall investment proposed for four energy conservation measures for Tasahe pump station is US$ 16,396. The simple payback on this investment is 5 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 5 months. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Tasahe pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Identified saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m³	1,000 liters
1 USD	8 SBD

** Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[1] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

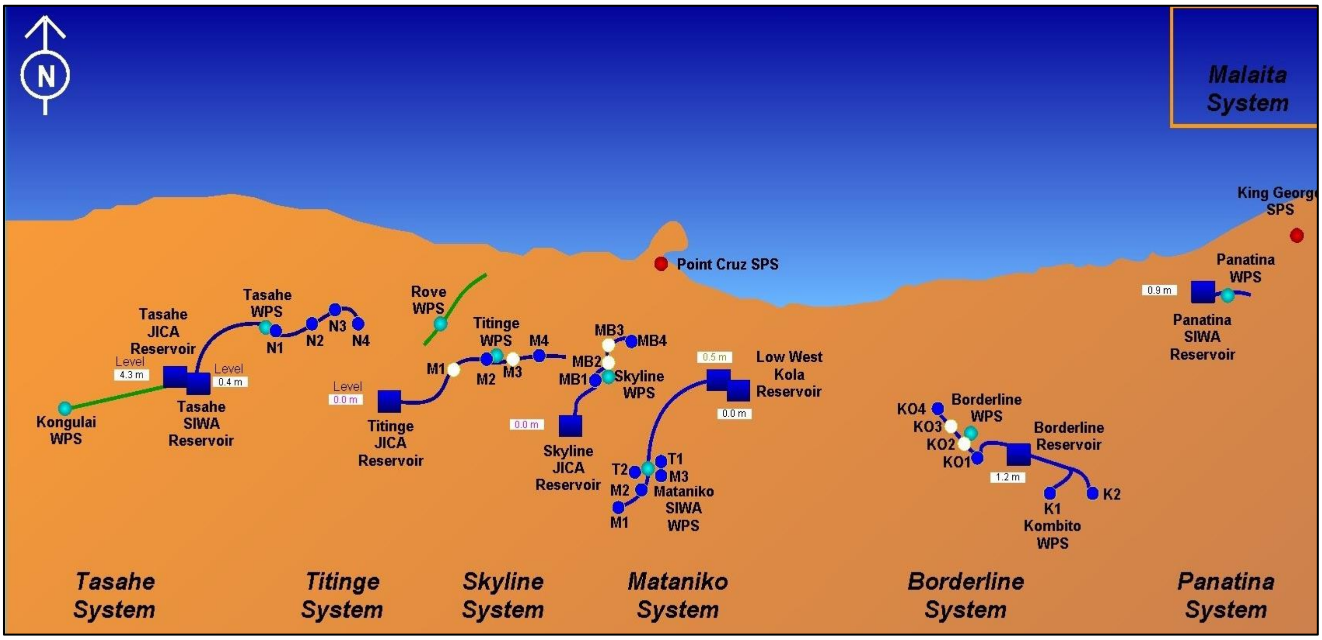

Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[1]

[1] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[2]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

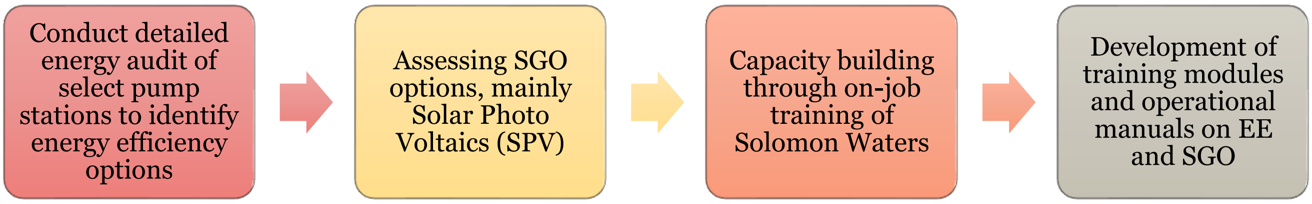

Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[2] *Response Plan, CTCN request ID: 2017000039*

Assessment of Energy Efficiency and RE options

- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options

Capacity building through on-job training for Solomon Water

- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation

Detail assessments of shortlisted EE and SGO options for Solomon Water

- Technical analysis
- Financial analysis

Monitoring of impact

- Monitoring and evaluation of Impacts
- Report on Gender co-benefits

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

Environmental Benefits

- Enhanced energy efficiency
- Improved energy security
- Lower dependence on imported fuels
- Contribution towards climate change mitigation

Economic Benefits

- Reduced operating (energy) cost for Solomon Water
- Increased investments in energy efficiency and renewable energy

Social Benefits

- Skill enhancement of Solomon Water professionals on EE and RE
- Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

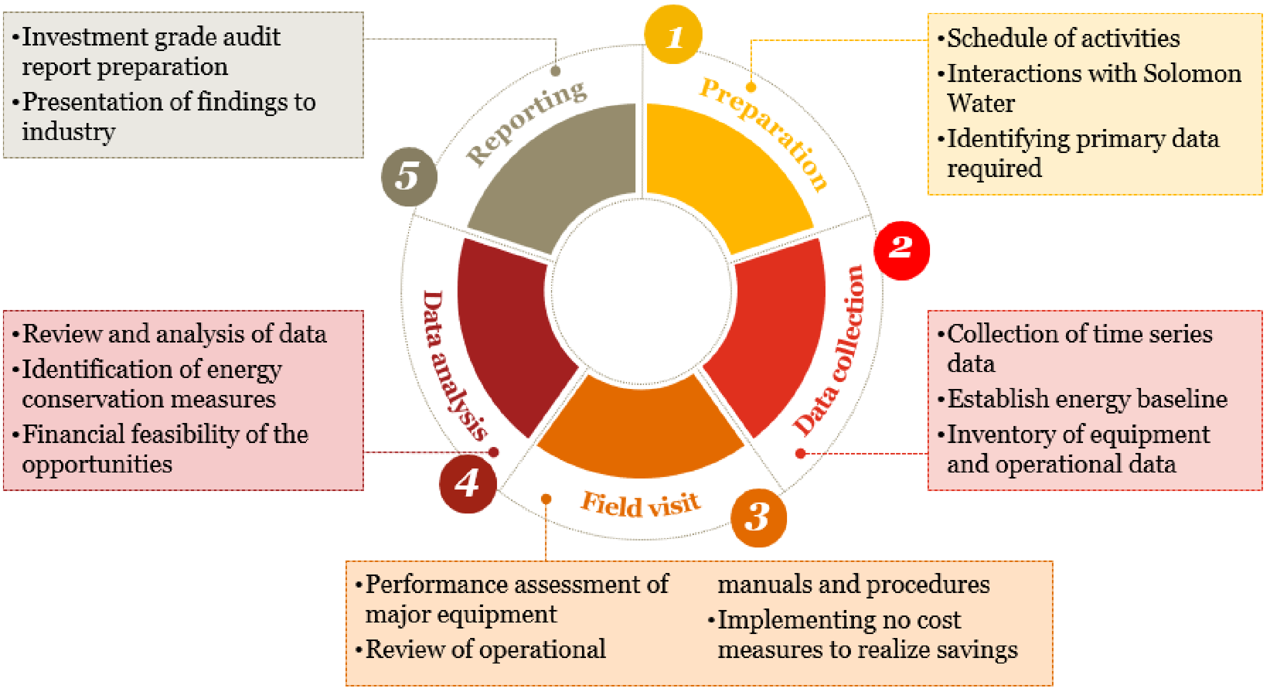

Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Tasahe pump station

2.1. About Tasahe pump station

Tasahe pump station is in Tasahe area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Tasahe JICA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. At the time of study all the four bore-pumps were operational, and two transfer pumps were running in parallel. The overview of Tasahe pump station as seen in Solomon Water SCADA system is shown in **Figure 6**.

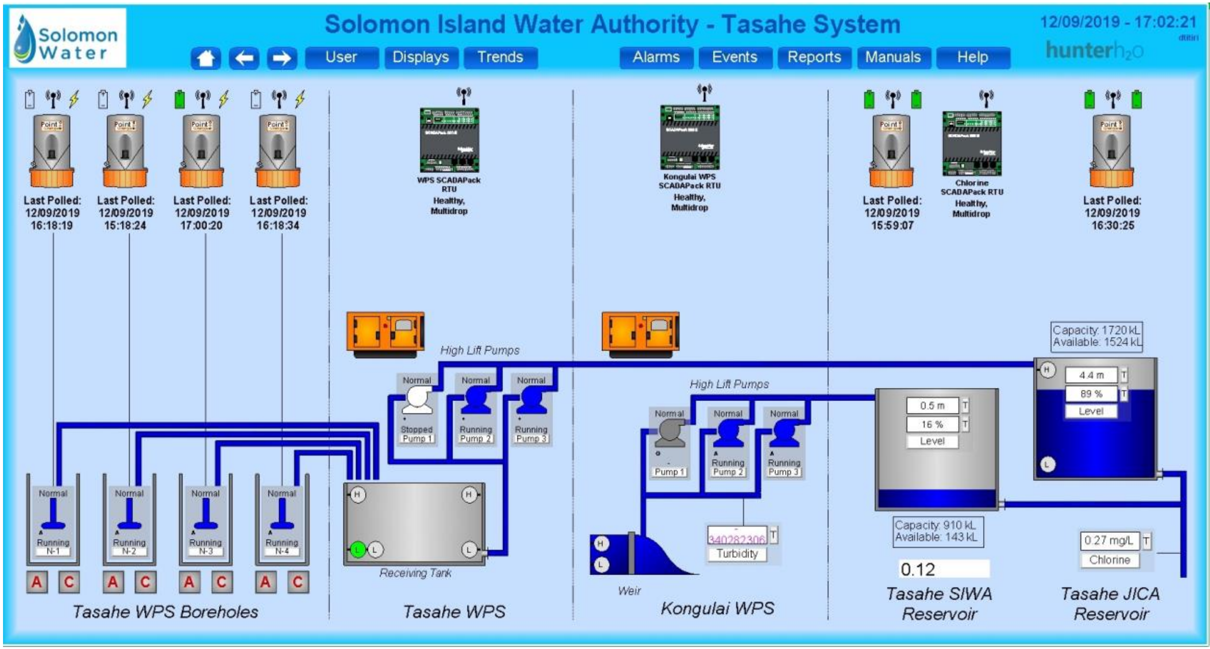

Figure 6 Tasahe pump station overview - SCADA system

2.2. Transfer pumps

The Tasahe pump station is equipped with three vertical multi-stage centrifugal pumps. These three pumps are connected to operate in parallel. Pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Tasahe JICA reservoir. Two transfer pump operates at any given time, with third one as standby. Design details of the transfer pumps and its corresponding motor is presented in **Table 2** and **Table 3** respectively. The pictorial view of transfer pumps is presented in **Figure 7**.

Table 2 Design details of transfer pumps

Particular	Unit	Pump #1, #2, #3
Make	-	Grundfos
Model	-	CRN 64-5-1 AFGV-HQQV
Design flow	m^3/h	64.0
Design head	m	108.5
Max. head	m	139.2
Impeller type	-	Stainless Steel
Pump speed	rpm	2951

Particular	Unit	Pump #1, #2, #3
Recommended motor rating	kW	30.0
Max. pressure	bar	16.0
Pump efficiency	%	77.0

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor #1, #2, #3
Make	-	Groundfos
Power	kW	30
Voltage	V	400.0
Current	I	51.5
Power Factor	-	0.88
Motor speed	rpm	2962
Frequency	Hz	50.0
Rating	-	IE2
Efficiency	%	92.0

Figure 7 Tasahe transfer pumps

2.3. Borehole pumps

The Tasahe pump station receives water from four borehole pumps. Water is extracted using submersible centrifugal pumps. As the pumps were underground, name plates could not be checked physically. The design details were collected from records available at Solomon Water maintenance office. Initially, the system was designed for 24 x 7 operation of four bore pumps. All four bore-pumps were operational during testing.

The design details of bore pumps is presented in **Table 4** and schematic view of Tasahe bore-field is presented in **Figure 8**.

Table 4 Design details of borehole pumps

Particular	Unit	N-1	N-2	N-3	N-4
Make	-	Grundfos	Grundfos	Grundfos	Grundfos
Model	-	SP46-6	SP46-8C	SP46-7	SP30-13
Design flow	m^3/h	50.0	39.5	41.5	29.0
Design head	m	45.1	71.3	65.1	100.2
Pump depth	m	40	54	40	77
Pump efficiency	%	74.5	74.5	70.0	74.5

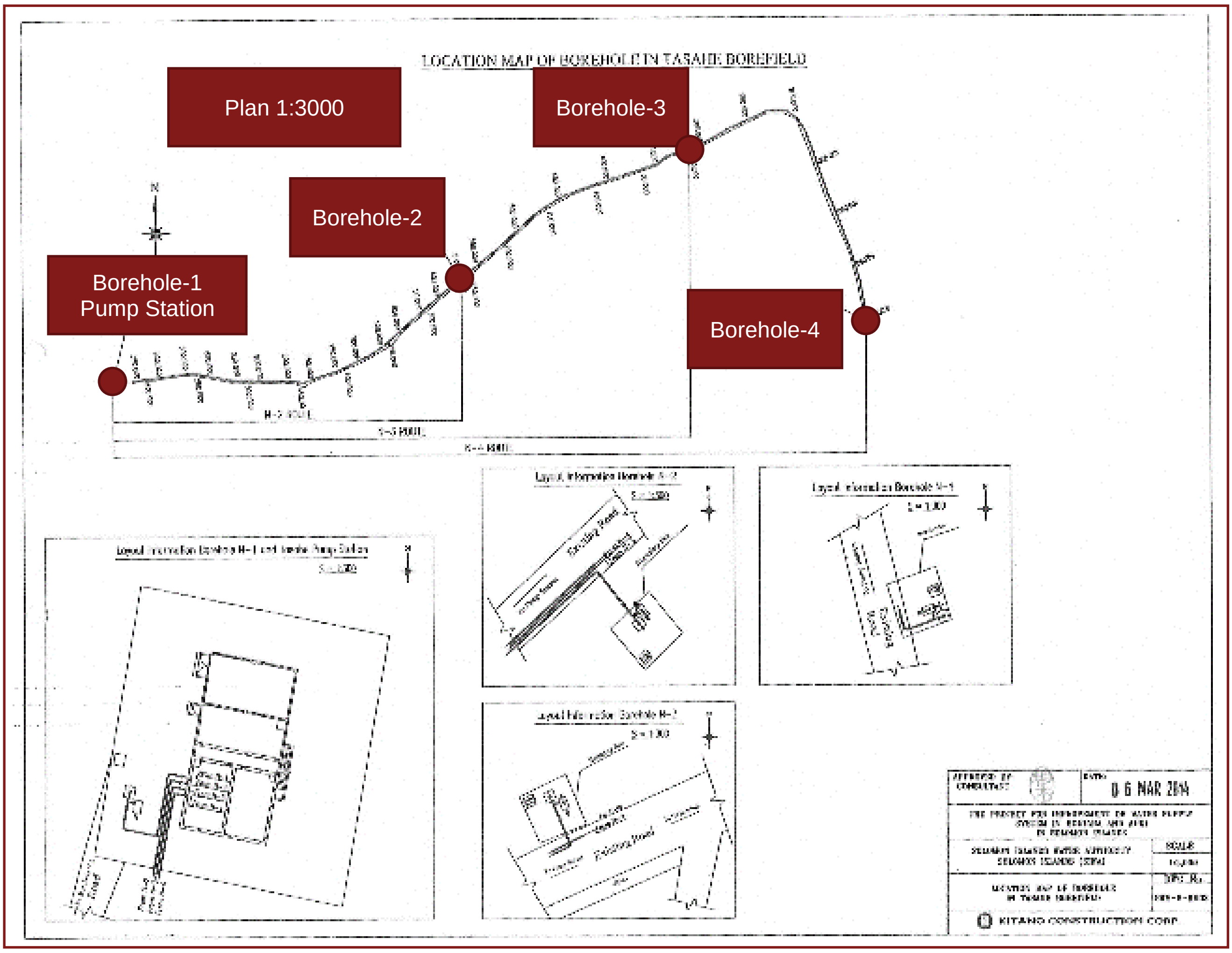

Figure 8 Location of boreholes in Tasahe bore-field

3. Energy consumption analysis

3.1. Energy source and tariff details

Tasahe pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Tasahe pump station is under Industrial I3 type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff for last 12 months was captured during feasibility study and same is presented in **Table 5**.

Table 5 Electricity tariff details – Last 12 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)			NAC (SBD/month)[3]
		I1[4]	I2[5]	I3[6]	
Aug-18	2.85	3.68	3.16	2.81	3,175.72
Sep-18	2.85	3.7	3.18	2.83	3,199.91
Oct-18	2.71	3.71	3.19	2.84	3,204.42
Nov-18	2.83	3.72	3.2	2.85	3,218.49
Dec-18	2.81	3.75	3.23	2.87	3,242.95
Jan-19	2.77	3.77	3.24	2.89	3,258.18
Feb-19	2.49	3.11	2.68	2.38	2,690.01
Mar-19	2.71	3.79	3.26	2.90	3,277.82
Apr-19	2.53	3.61	3.11	2.77	3121.85
May-19	2.64	3.85	3.31	2.95	3328.04
Jun-19	2.21	3.85	3.31	2.95	3,324.80
Jul-19	2.38	3.84	3.3	2.94	3,316.60
Average	**2.65**	**3.70**	**3.18**	**2.83**	**3,196.57**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 18 months for Tasahe pump station was analyzed. The average electricity tariff and consumption for last 12 months was evaluated. These 12-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 12 months (August 2018 to July 2019) was 796,600 kWh. The bill amount corresponding to this consumption was SBD 4.43 million i.e. USD 554,140.

The electricity consumption along with monthly energy charges is presented in **Table 6**. Variation of electricity consumption is presented in **Figure 9**.

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[3] I3 connection electricity consumption>6000 kWh
[4] First 1300 units of the monthly consumption
[5] Next 4700 units of the monthly consumption
[6] Remaining consumption of the month

Table 6 Electricity consumption details

Month	Consumption kWh	NAC (SBD)	Fuel charge (SBD)	Non-fuel charge I1	Non-fuel charge I2	Non-fuel charge I3	Total (SBD)
Aug-18	33,840	3,176	96,444	4,784	14,852	78,230	**197,486**
Sep-18	69,360	3,200	197,676	4,810	14,946	179,309	**399,941**
Oct-18	69,280	3,204	187,749	4,823	14,993	179,715	**390,484**
Nov-18	72,440	3,218	205,005	4,836	15,040	189,354	**417,454**
Dec-18	69,960	3,243	196,588	4,875	15,181	183,565	**403,452**
Jan-19	74,040	3,258	205,091	4,901	15,228	196,636	**425,114**
Feb-19	67,280	2,690	167,527	4,043	12,596	145,846	**332,703**
Mar-19	61,800	3,278	167,478	4,927	15,322	161,820	**352,825**
Apr-19	72,480	3,122	183,374	4,693	14,617	184,150	**389,956**
May-19	71,400	3,328	188,496	5,005	15,557	192,930	**405,316**
Jun-19	66,760	3,325	147,540	5,005	15,557	179,242	**350,668**
Jul-19	67,960	3,317	161,745	4,992	15,510	182,162	**367,726**
Average	**66,383**	**3,197**	**175,393**	**4,808**	**14,950**	**171,080**	**369,427**
Annual	**796,600**	**38,359**	**2,104,712**	**57,694**	**179,399**	**2,052,960**	**4,433,124**

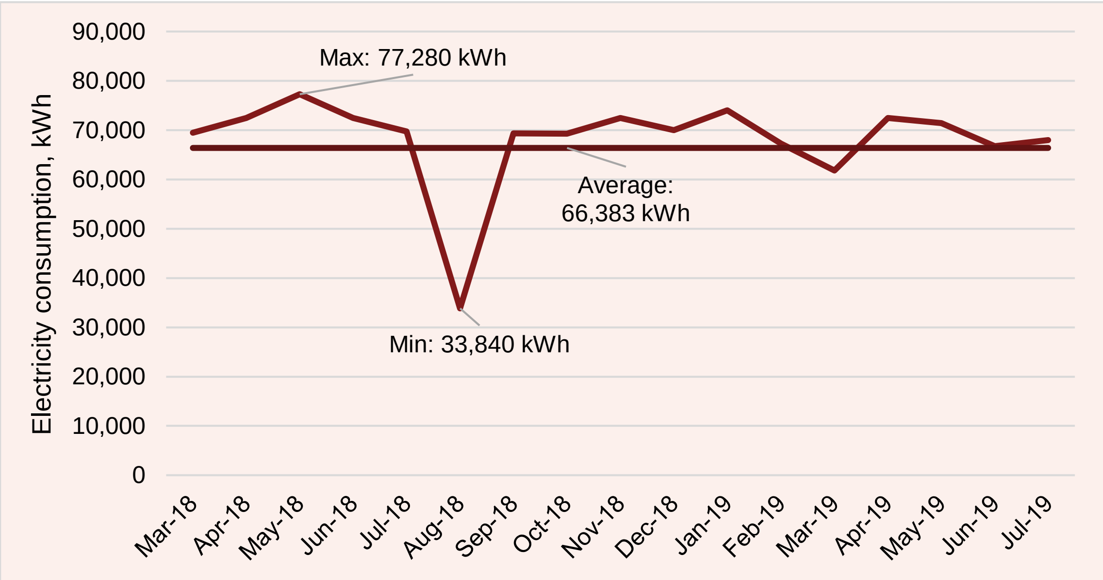


Figure 9 Electricity consumption profile March 2018 – July 2019 (18 months)

Key observations for the period August 2018 to July 2019:

- Monthly average consumption of electricity was 66,383 kWh (varying between 33,840 to 77,280)
- Average electricity tariff (excluding fixed NAC) was SDB 5.58 per kWh (US$ 0.70 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.65 per kWh (US¢ 33.1 per kWh)

Average monthly electricity consumption of Tasahe Pump Station is 66,383 kWh

A sample electricity bill of Tasahe pump station is presented in **Figure 10**.

Solomon Islands Electricity Authority
trading as SOLOMON POWER

INVOICE / STATEMENT

Customer	SIWA-Tasahe Pump Station P O Box 1407 Honiara	Date	06/January/2019
		Customer Number	17071
		Customer Type	**INDUSTRIAL**
		Customer Category	**I3**

Location: Tasahe Pump Station
Tasahe

Previous Month

Balance at Previous Account Date	$820,905.44
Payment Received to 19 Dec Thank you	($417,453.69)
Balance Prior to 6 Jan 19	$403,451.75

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$425,113.58	$403,451.75	$0.00	$0.00	$828,565.33

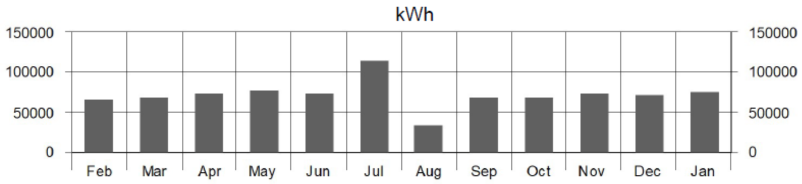
Month 06/January/2019

Readings from 6/Dec/2018 to 6/Jan/2019 **Days** 31

Usage	**Meter no.**	**Previous**	**Present**	**Multi**	**Units**
1	217039036	7,872	9,723	40	74,040

Total **74,040.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 863160 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	I3	Days	31	3,258.18		3,258.18
Fuel	I1	kWh	74,040.00	2.7700	1.0000	205,090.80
Non-Fuel	I1	kWh	1,300.00	3.7700	1.0000	4,901.00
	I2	kWh	4,700.00	3.2400	1.0000	15,228.00
	I3	kWh	68,040.00	2.8900	1.0000	196,635.60
			74,040.00			216,764.60

TOTAL THIS PERIOD	**$425,113.58**
TOTAL DUE	**$828,565.33**
FINAL DATE FOR PAYMENT:	21/January/2019

No further notices will be issued. Unpaid accounts will have supply disconnected.
Previous month balances are payable immediately.

Figure 10 Sample electricity bill of Tasahe pump station

The total electricity consumption in the pump station can be categorized in four parts: (a) transfer pumps, (b) borehole pumps, (c) lighting system and (d) electrical system losses and miscellaneous. The average consumption by each category is presented in **Figure 11**.

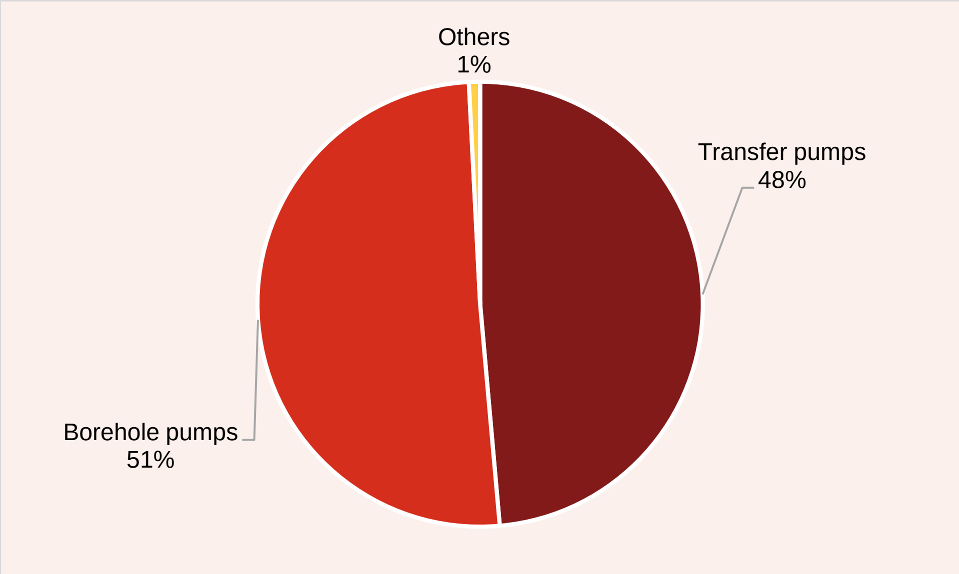


Figure 11 Electricity consumption share

3.3. Specific energy consumption

The daily water production from the bore-fields was 3225.9 m^3 and the daily electrical energy consumption was 2213 kWh. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 12 months data, which was 2188 kWh. The specific energy consumption is presented in **Table 7**.

Table 7 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	3225.9
Daily electricity consumption	kWh	2213
Specific energy consumption	**kWh/m^3**	**0.686**

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with three transfer pumps. These are multistage vertical centrifugal pumps with stainless steel impeller. Pumps are of Grundfos make and are driven by individual 30 kW motor. Typically, two pump operates in parallel at any given time and other one is standby. During the site visit all pumps were operational and performance assessment test was conducted on pumps individually and in combination of pump1+2, pump 2+3 and pump 3+1 separately.

The performance assessment of transfer pumps was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump was operating intermittently i.e. operating in ON-OFF mode. This was based on level switch control installed in receiver tank. The daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current.

The measured data such as operating hours and flow are verified using system data available at Solomon Water. The performance assessment of transfer pumps is presented in **Table 8**.

Table 8 Performance assessment of transfer pumps 1, 2 and 3

Particular	Unit	Pump 1	Pump 2	Pump 3
Operating flow	m^3/h	79.10	77.90	78.10
Suction head	m	-2.00	-2.00	-2.00
Discharge head	m	89.00	91.00	91.00
Total head	m	87.0	89.0	89.0
Hydraulic power	kW	18.75	18.89	18.94
Motor input power	kW	25.83	26.02	26.12
Shaft power	kW	23.77	23.94	24.03
Pump efficiency	**%**	**78.90**	**78.92**	**78.81**

The operating efficiency of the transfer pumps 1, 2 and 3 were 78.9, 78.9 and 78.8% respectively, which is satisfactory and at par with the design efficiency of the pump. The reason of higher efficiency than name plate can be attributed to different duty point and nominal error in measurement. The actual duty point and best efficiency point of pump 1, 2 and 3 are depicted in **Figure 13, Figure 12** and **Figure 14.**

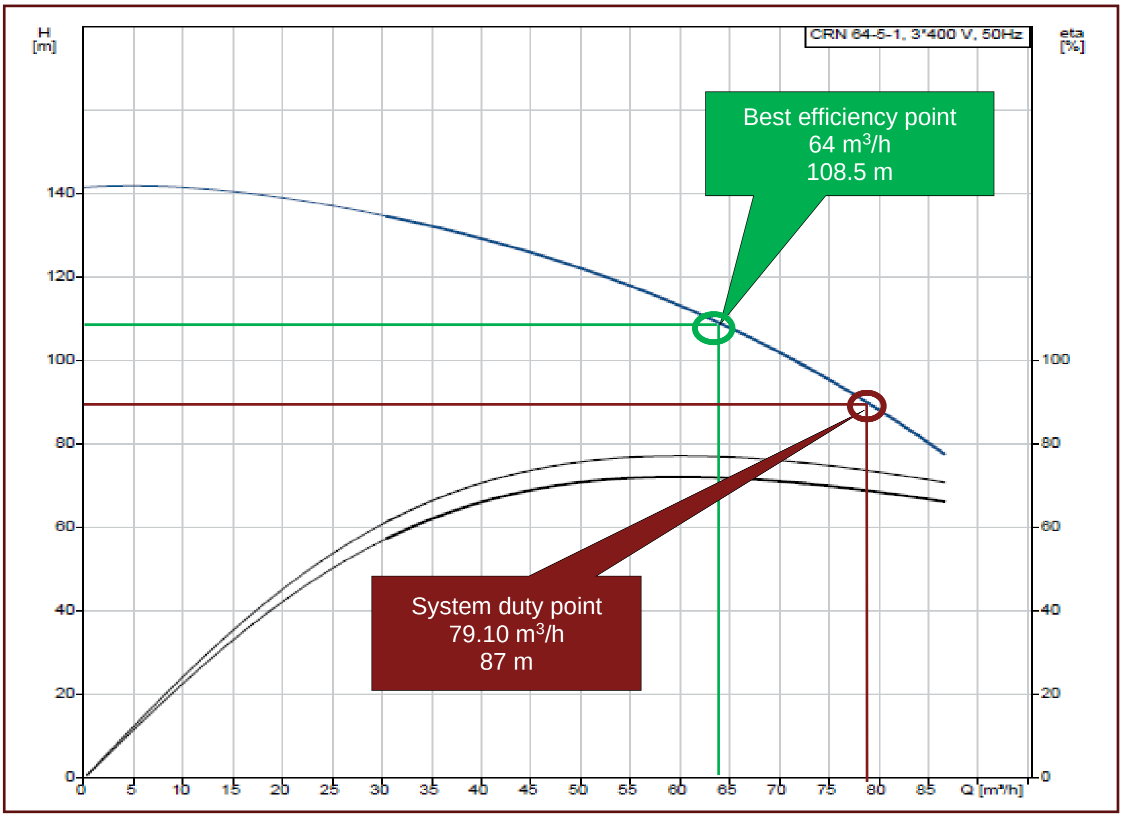


Figure 13 Transfer pump-1 duty point vs design

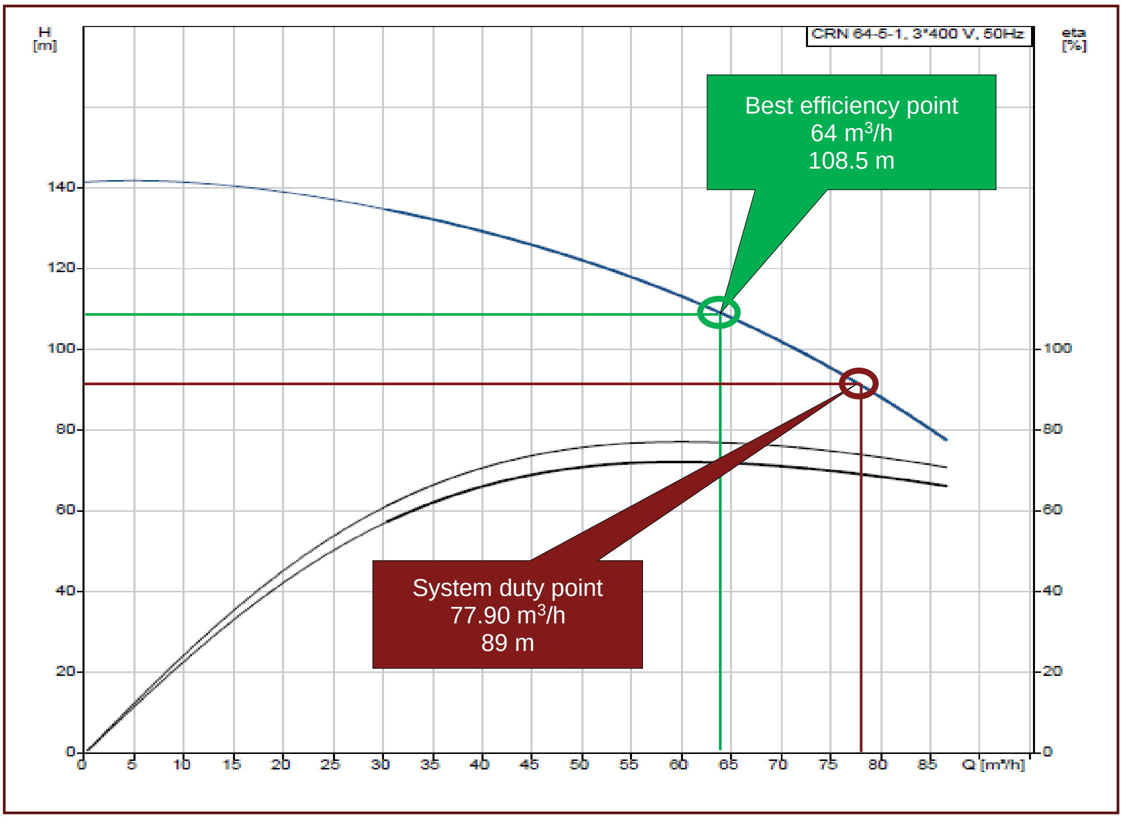


Figure 12 Transfer pump-2 duty point vs design

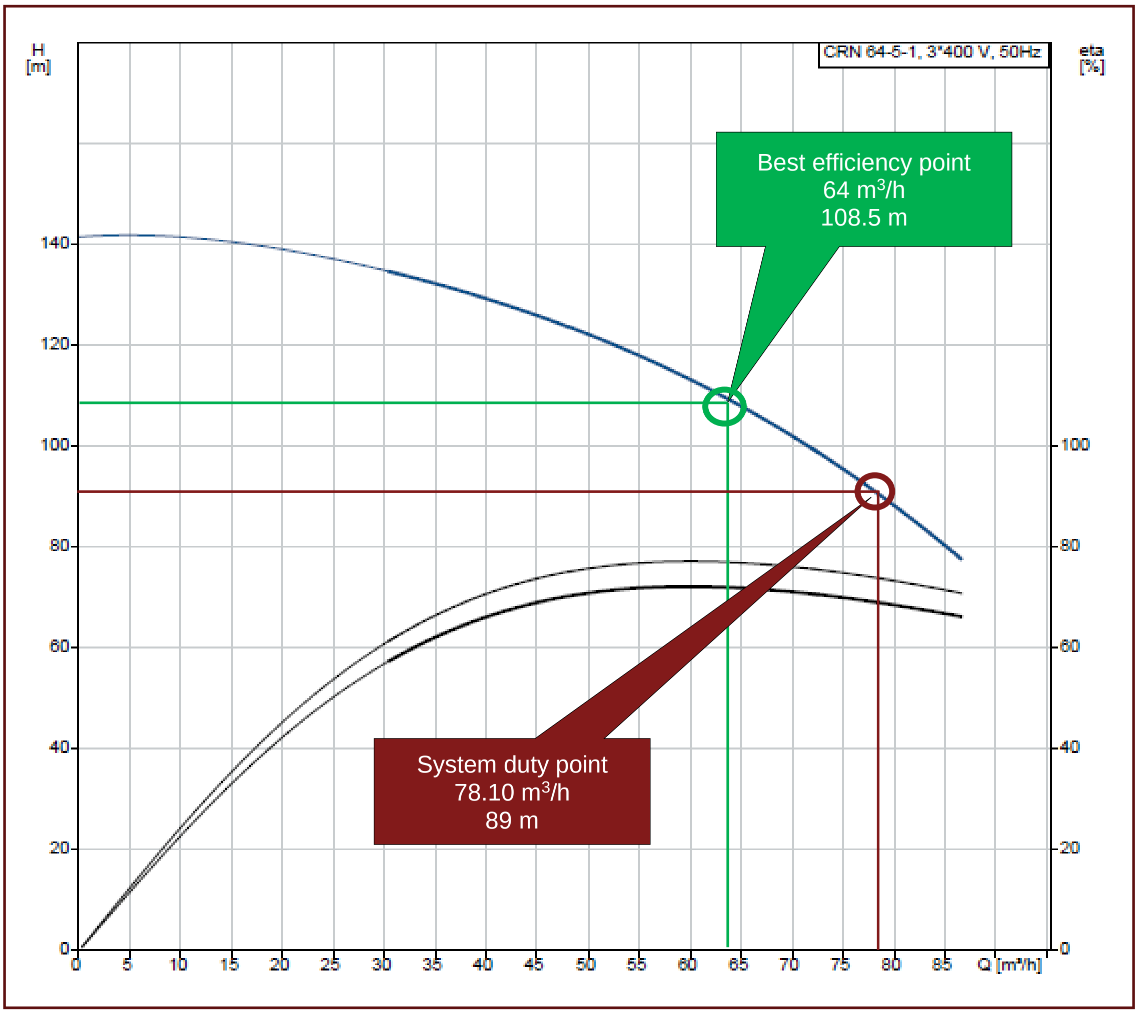


Figure 14 Transfer pump-3 duty point vs design

As seen in pump curve, all the three transfer pumps are operating on the pump curve itself without any deviation. The performance is satisfactory. The total daily water pumped by transfer pumps was 3225.9 m^3. The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 9**.

Table 9 Transfer pumps motor performance

Particular	Unit	Motor 1	Motor 2	Motor-3
Voltage	V	441.70	436.00	441.00
Current	I	37.90	38.50	38.30
Power factor	-	0.891	0.895	0.893
Power input	kW	25.83	26.02	26.12
Motor Efficiency	%	92.0	92.0	92.0
Power shaft	kW	23.77	23.94	24.03
Motor loading	**%**	**79.22**	**79.80**	**80.11**

The performance test was conducted with two pumps running in parallel i.e. combination of pump1+2, pump 2+3 and pump 3+1. The results of the parallel operation performance test are presented in **Table 10**.

Table 10 Performance assessment of transfer pumps in parallel

Particular	Unit	Pump 1 and 2	Pump 3 and 1	Pump 2 and 3
Operating flow (combined)	m^3/h	159.50	158.80	161.10
Suction head	m	-2.00	-2.00	-2.00
Discharge head	m	90.00	90.00	91.00
Total head	m	88.0	88.0	89.0
Combined hydraulic power	kW	38.25	38.08	39.07
2 Motors input power	kW	52.42	52.07	52.19
Shaft power	kW	48.23	47.90	48.02
Pump efficiency	**%**	**79.30**	**79.50**	**81.37**

The performance of the transfer pumps operating in parallel was satisfactory. As the pumps are operating on the pump curve itself, without much deviation, installing a VFD to operate pump at lower will reduce power consumption. However, as the flowrate of pump will also reduce, the overall operating hours for same duty will increase, leading to similar energy consumption.

4.2. Borehole pumps

4.2.1. Performance assessment

The Tasahe pump station has four borehole pumps. The power measurement was taken using three-phase power analyser, flow was measured using ultrasonic water flow meter, head was measured using a water depth measurement instrument available with Solomon Water (Shaun, Hydrogeologist) and head from borehole surface level to receiver tank is measured using digital pressure meter. The performance assessment of borehole pumps is presented in **Table 11**.

Table 11 Performance assessment of borehole pumps

Particular	Unit	Bore-pump 1	Bore-pump 2	Bore-pump 3	Bore-pump 4
Operating flow	m^3/h	51.80	32.50	39.20	13.90
Well depth to water level	m	31.31	45.56	27.53	73.00
Head from surface to reservoir	m	12.50	24.70	39.00	30.00
Total head	m	43.81	70.26	66.53	103.00
Hydraulic power	kW	6.18	6.22	7.11	3.90
Motor power	kW	11.41	13.91	12.13	10.42
Shaft power	kW	9.35	11.40	9.95	8.54
Pump efficiency	**%**	**66.12**	**54.56**	**71.43**	**45.67**

The operating hours of the bore-hole pumps was taken from the SCADA system. The measured flow rate of water was then converted to arrive at daily water production from borefields, same is presented in **Table 12**.

Table 12 Production from bore-fields

Bore-field	Flow rate (m^3/h)	Operating hours (h)	Daily production (m^3)
Bore-pump 1 (N-1)	51.8	24.0	1243.2
Bore-pump 2 (N-2)	32.5	23.3	757.3
Bore-pump 3 (N-3)	39.2	23.0	901.6
Bore-pump 4 (N-4)	13.9	23.3	323.9
Total			**3225.9**

The duty-point and best efficiency point of the bore-hole pump-1 is depicted in **Figure 15**.

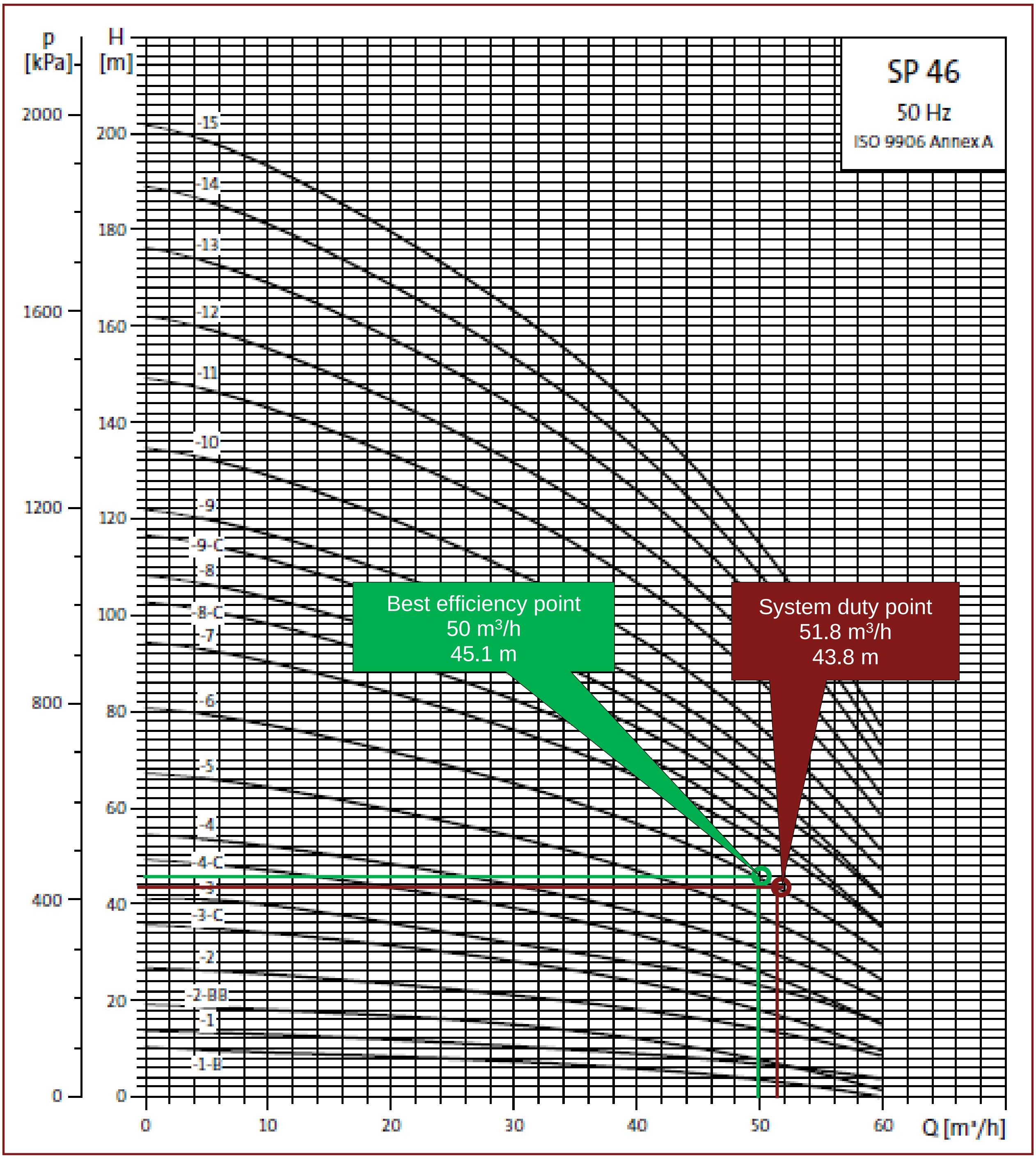


Figure 15 Borehole pump-1 duty point vs design

The borepump-1 was Grundfos SP46 series, model 6. The pump was operating quite close to design of the pump and its performance was satisfactory.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 12.5 m, which is slightly higher than the actual head estimated from this point till reservoir. The throttling has minimum effect on system head. It is recommented to carry out detailed study (long-term) to identify affect after unthrottling on system head and pump operation.

The duty-point and best efficiency point of the bore-hole pump-2 is depicted in **Figure 16**.

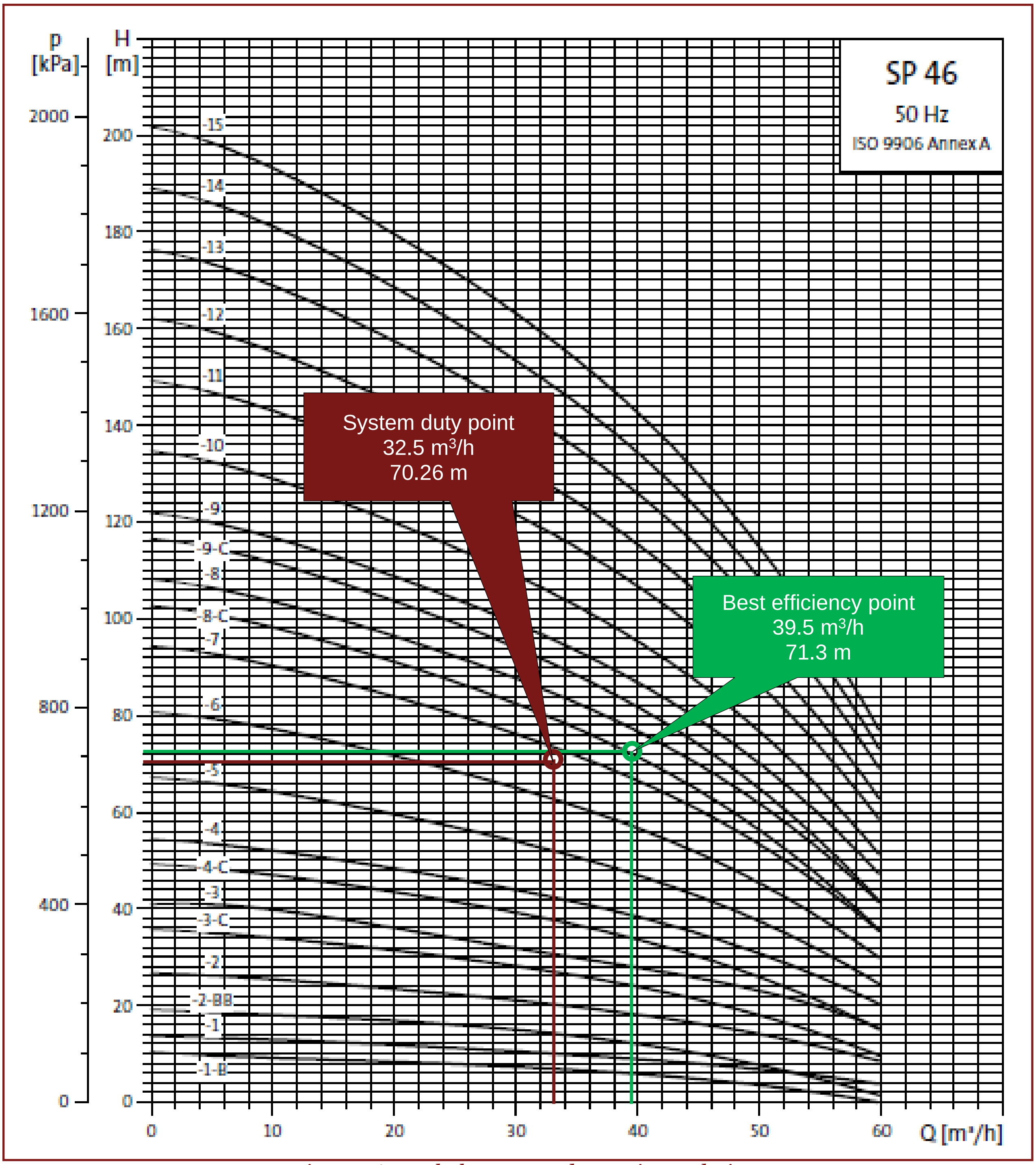


Figure 16 Borehole pump-2 duty point vs design

The borepump-2 was Grundfos SP46 series, model 8C. The pump was operating close to design head however the flow rate was 15% lesser than design. The suspected reason for the less flow rate is slightly worn-out impeller.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 24.7 m, which is close to the actual head estimated from this point till reservoir. Hence the throttling has minimum effect on system head. It is recommented to carry out detailed study (long-term) to identify affect after unthrottling on system head and pump operation.

The duty-point and best efficiency point of the bore-hole pump-3 is depicted in **Figure 17**.

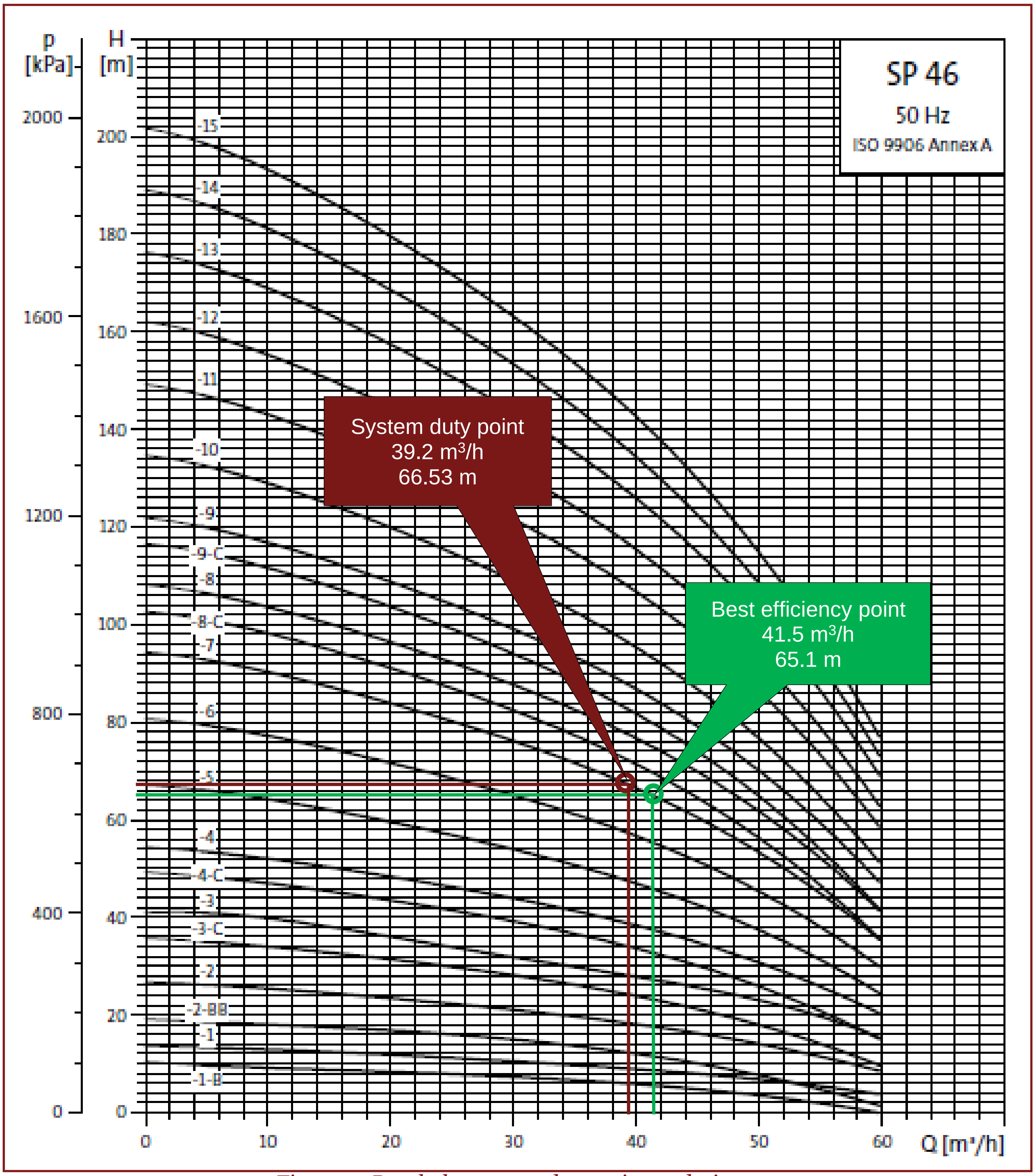


Figure 17 Borehole pump-3 duty point vs design

The borepump-3 was Grundfos SP46 series, model 7. The pump was operating quite close to design of the pump and its performance was satisfactory.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 39 m, which is close to the actual head estimated from this point till reservoir. Hence the throttling has minimum effect on system head. The reason for higher head as compared to borehole 1 & 2 is physical distance and elevation from pump station. It is recommented to carry out detailed study (long-term) to identify affect after unthrottling on system head and pump operation.

The duty-point and best efficiency point of the bore-hole pump-4 is depicted in **Figure 18**.

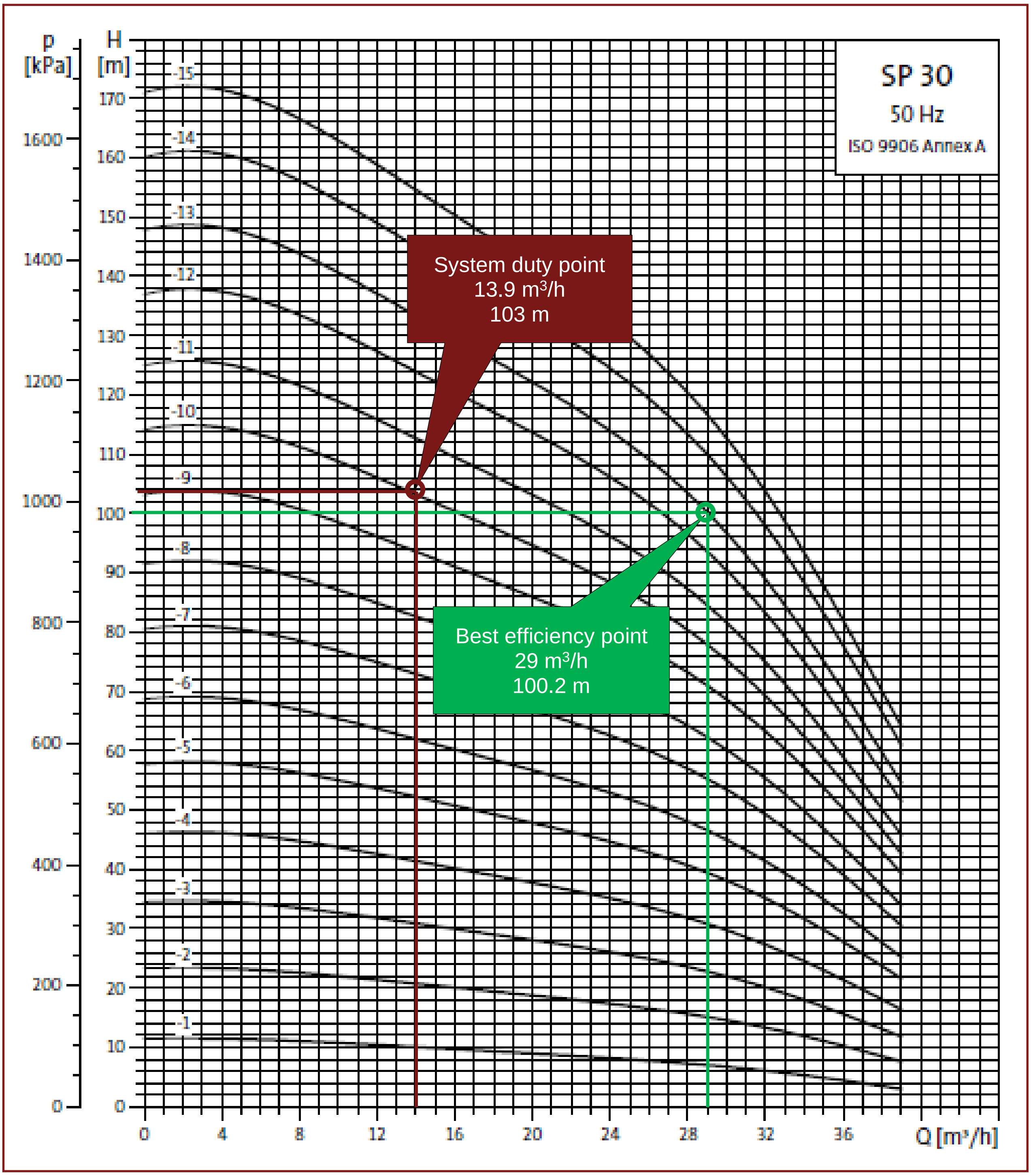


Figure 18 Borehole pump-4 duty point vs design

The borehole pump-4 was Grundfos SP30 series, model 13. The pump was operating close to design head however the flow rate was 52% lesser than design. It is suggested to check if the installed pump is model SP30-13 or was it replaced with some other model, as the duty point fits Grundfos SP30-10 pump perfectly. If the pump is SP30-13, then the suspected reason for the less flow rate is slightly worn-out impeller.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 24.7 m, which is close to the actual head estimated from this point till reservoir. Hence the throttling has minimum effect on system head. It is recommented to carry out detailed study (long-term) to identify affect after unthrottling on system head and pump operation.

4.2.2. Energy conservation measure

The borehole pump-2 and 4 were operating at lower efficiency, 54.6 and 45.7% respectively. The recommendation is to replace these pumps with suitable size pumps of better efficiency. The pump specification of the existing bore pump, system duty-point and recommended pump is presented in **Table 13**.

Table 13 Technical specification of existing pump, system duty point and recommended pump

Particular	Unit	Existing Pump	System duty point	Proposed pump
Bore-hole pump N-2				
Model	-	Grundfos SP46-8C	-	Grundfos SP 46-5
Flow rate	m^3/h	39.5	32.5	33.1
Total head	m	71.3	70.26	70.5
Bore-hole pump N-4				
Model	-	Grundfos SP30-13	-	Grundfos SP 30-11
Flow rate	m^3/h	29.0	13.9	21.6
Total head	m	100.2	103.0	100.0

The proposed submersible pump as replacement for bore pumps is capable of handling head variation of ± 5 m, without substantial difference in discharge head. Detailed technical specification of the recommended submersible pump is provided in **Appendix A**. ***The energy saving is estimated considering the sustainable daily water production for the bore field shared by Solomon Water Hydrogeologist***. The daily production from borefield-2 and 4 is 795 and 518 m^3 respectively, for saving estimation is based on this daily production. Detailed saving estimation is shown in **Table 14**.

The annual energy saving by replacing borehole pumps 2 and 4 is 60,072 kWh equivalent to monetary saving of US $ 41,150. The investment required for installation of submersible pump is US $ 11,425. The freight cost of shipping from Australia is US $ 500. Overall landed cost in Honiara inclusive of all applicable duties is US $ 16,156. The simple payback period of the recommendation is six months. The GHG emission reduction potential of the recommendation is 39.65 tCO_2 equivalent.

Table 14 Borehole pumps energy saving estimation

Particular	Unit	N-2	N-4
Net daily water duty*	m^3	795	518
Proposed pump flow rate	m^3/h	33.1	21.6
Proposed annual energy consumption	kWh/year	68266	55306
Existing annual energy consumption	kWh/year	104992	78653
Annual energy saving	kWh/year	36725	23347
Monetary saving	SBD/year	201256	127942
	USD/year	$ 25,157	$ 15,993
Cost of new bore-pump	USD	$ 5,850	$ 5,575
Freight cost	USD	$ 250	$ 250
Cost at port in Solomon Islands	USD	$ 6,100	$ 5,825
Import duty	%	10	10
GST	%	15	15
Net landed cost of bore-pump	USD	$ 8,250	$ 7,906
Simple payback period	**years**	**0.3**	**0.5**
GHG emission reduction	**tCO_2/year**	**24.24**	**15.41**
**** Arrived based on sustainable flowrate share by Solomon Waters' Hydrogeologist***			

4.3. Electrical system

4.3.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel and bore-pumps panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. The logging of total power for 24 hours is shown in **Figure 19**.

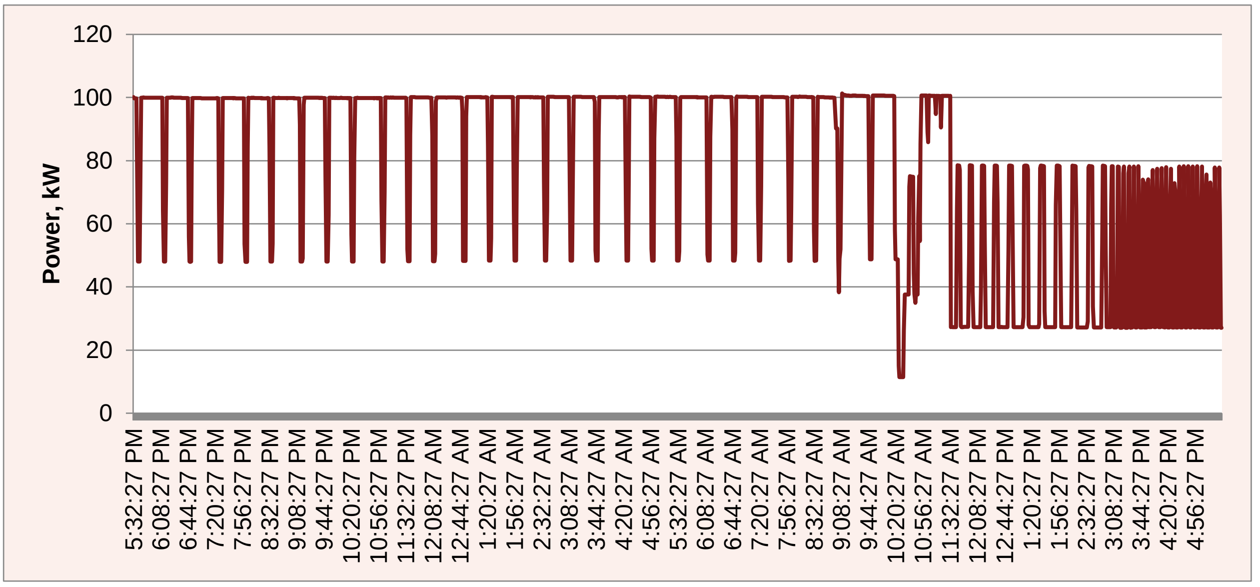


Figure 19 Tasahe pump station total power log 24 hours

The power factor (PF) at the main incomer of pump station was varying between 0.700 – 0.860, with an average PF 0.815. The PF variation over 24 hours is presented in **Figure 20**.

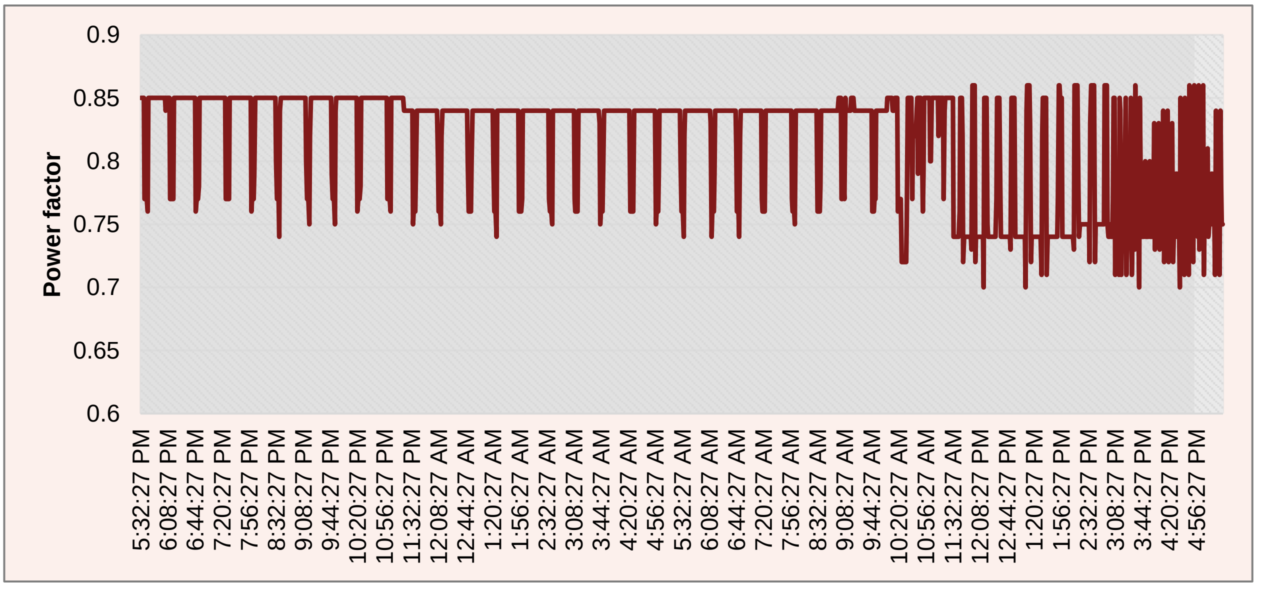


Figure 20 Power factor variation over 24 hours

4.3.2. Automatic Power Factor Correction

Figure 21 APFC panel

The average PF is 0.815 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install a 75 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 25+20+15+10+2+2+1 kVAr.

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 15** and **Table 18**. The pictorial view of APFC panel is presented is **Figure 21**.

Table 15 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.815
Average daily reactive power	kVAr	61.76
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.170
Annual charge for PF	US$/year	$ 7,929
Capacitor bank requirement	**kVAr**	**75**
Investment cost	US$	$ 3,750
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 4,000
Import duty	%	10
GST	%	15
Net landed cost of APFC system	USD	$ 5,625
Simple payback period	**years**	**0.7**

Table 16 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.815
Power factor tariff as % of fuel charge	%	5.00
Annual fuel charge	US$/year	263,089
Annual charge for PF	US$/year	$ 13,154
Capacitor bank requirement	**kVAr**	**75**
Investment cost	US$	$ 3,750
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 4,000
Import duty	%	10
GST	%	15
Net landed cost of APFC	USD	$ 5,625
Simple payback period	**years**	**0.4**

4.4. Lighting system

4.4.1. Performance assessment

The pump station was equipped with 24 six feet fluorescent tube lights (FTL) of 36 W rating (T8). 12 fixtures are installed in pump room and 12 fixtures in electrical & diesel set room. The details of the existing system are provided in **Table 17**.

Table 17 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	12	528
FTL T8	Electrical & DG room	36+8	12	528
Total			**24**	**1056**

4.4.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 6 LED tube pump room and 6 in DG room. Details of the present lighting system are given in **Table 18**. The pictorial view of FTL tube and LED tube is shown in **Figure 22.**

Figure 22 LED tube vs florescent tube

Table 18 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	24	12
Total rating	W	1056	252
Operating hours	h/year	250	250
Annual consumption	kWh/year	264	63
Annual saving	kWh/year		201
Monetary saving	SBD/year		1101
	USD/year		$ 138
Investment cost	USD		$ 240
Simple payback	**Years**		**1.74**
GHG emission reduction	**tCO_2/year**		**0.13**

The estimated annual energy savings with new LED lighting system is 201 kWh of electricity, effectively equivalents to a monetary savings of US $ 138. The investment requirement is US $ 240. The simple payback period of the recommendation is 1.8 years. The annual reduction in GHG emission is estimated to be 0.13 tCO_2.

5. Self-generation option

5.1. Renewable energy assessment

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic. Detailed feasibility analysis for solar is presented in this chapter.

5.2. Site description

Tasahe pump station is in Tasahe area of Honiara city in Guadalcanal province. The pump station is spread across an area of about 530 m². The projected roof area as seen from the top, over the pump house building is about 160 m². The rest of the area is used servicing purpose and one of the bore-hole is situated inside pump house. There are no buildings nearby to cause shading. Roof is made of concrete and support installation of solar roof top PV modules.

5.3. Solar resource assessment

The solar data source i.e. Global Horizontal Irradiance (GHI) for Honiara, is derived from a Japan International Cooperation Agency (JICA) report on Pilot Survey for Disseminating SME's Technologies for Introduction of Utility Interactive Grid-Connected Photovoltaic Generation System Possessed in Okinawa Prefecture for Small Island Regions, 2015. These values are an estimation of the solar resource on a horizontal surface. Solar data for Honiara is presented in **Table 19**.

Table 19 Daily Global Horizontal Irradiation at site location

Daily Global Horizontal Irradiation in kWh/m²/day											
Latitude -9.45⁰, Longitude 159.96⁰											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

The roof orientation yields optimum results when the tilt angle is equal to the latitude which in this case is 9.4⁰. The sun elevation diagram for the pump station is presented in **Figure 23**.

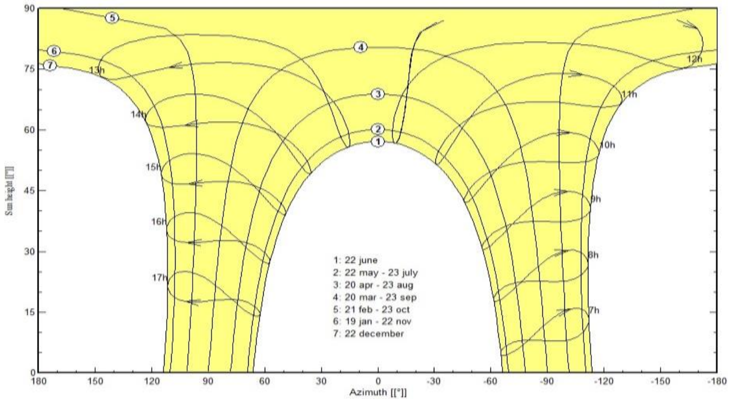


Figure 23 Sun elevation diagram for the site

5.4. System sizing and cost benefit

The effective area available for solar-roof PV installation is 136 m². Capacity for PV systems is measured at Standard Testing Conditions, of 1000 W/m², AM 1.5 and 25°C cell temperature. These conditions may not be the same on site. Site specific capacity varies intermittently with changing irradiance, ambient temperature, wind speed and air mass with respect to time, calendar day and other effects like cloud cover. The Polycrystalline technology generally has efficiency of ~ 16%. Monocrystalline Silicon technology can achieve ~20% although they are more expensive. The power delivered at the interconnection will be further reduced due to inverter efficiency, transformer efficiency, module fouling and cabling losses. The system sizing along with cost benefit considering thin film and monocrystalline technology is presented in **Table 20**. This is considering there is no standby charges fees and the utility i.e. SIEA pays fuel charges to Solomon Water for imported energy to grid which is SBD 2.65 per kWh.

Table 20 Cost benefit of solar roof PV - Thin film and monocrystalline

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m^2	160	160
Utilization area	m^2	136	136
Nominal power	kW_p	13.6	21.8
Average global horizontal irradiance	$kWh/m^2/day$	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	20974	33620
Avg fuel charges	SBD/kWh	2.65	2.65
Monetary saving	SBD/year	55547	89038
	USD/year	$ 6,943	$ 11,130
Module cost	USD	$ 12,716	$ 20,346
Supports cost	USD	$ 15,558	$ 15,558
Inverter and wiring cost	USD	$ 4,787	$ 4,787
Transport and mounting cost	USD	$ 18,370	$ 26,755
Cost at port in Solomon Islands	USD	$ 51,431	$ 67,446
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost	USD	$ 64,914	$ 84,933
Simple payback period	**years**	**9.3**	**7.6**

The cost benefit considering present tariff structure is presented in **Table 21**. With present regulation we have considered the standby changes in addition with cost system.

Table 21 Cost benefit of solar roof PV with present tariff

Particular	Unit	Thin-film	Monocrystalline
Nominal power	kW_p	13.6	21.8
Annual solar yield	kWh/year	20974	33620
Monetary saving by avoided energy consumption	SBD/year	59392	95202
	USD/year	$ 7,424	$ 11,900
Annual standby charges	USD/year	$ 9,244	$ 14,818
Net landed cost	USD	$ 74,158	$ 99,751
Simple payback period	**years**	10.0	8.4

The detailed analysis for Solar roof PV system sizing was performed on PVSyst software. PVSyst software provides possibility of complex simulation input and output parameters of PV plant and is also commercially to calculate the total production of electricity. As per the PVSyst simulation results, the estimated energy generation for the first year is 21.0 MWh/year, with Specific Energy Yield of 1545 kWh/kW_p/year for thin film technology-based modules. The simulation was run considering monocrystalline cell modules and the estimated energy generation for the first year is 33.6 MWh/year. The detailed results of PVSyst are presented in **Appendix C** – PVSYST simulation results.

5.5. Regulatory framework

The policies, processes and forms for solar system connection to SIEA grid are available in Solar Manual of SIEA. Some of the key highlights are:

- Inverter energy systems that have a continuous rating of no more than 30 kVA for three-phase systems.
- The installation should as a minimum comply with Australian Standards AS3000, AS4777 and AS5033 and all other relevant Australian Standards and Solomon Islands statutory requirements.
- All energy consumed from the grid at the premises will be metered by an import-only meter and billed to the customer under the applicable tariff(s). It is only any 'excess' energy will be exported to the SIEA grid. This energy will be metered but will NOT be paid for by SIEA.

The process for solar grid connection as provided by SIEA is presented in **Figure 24**.

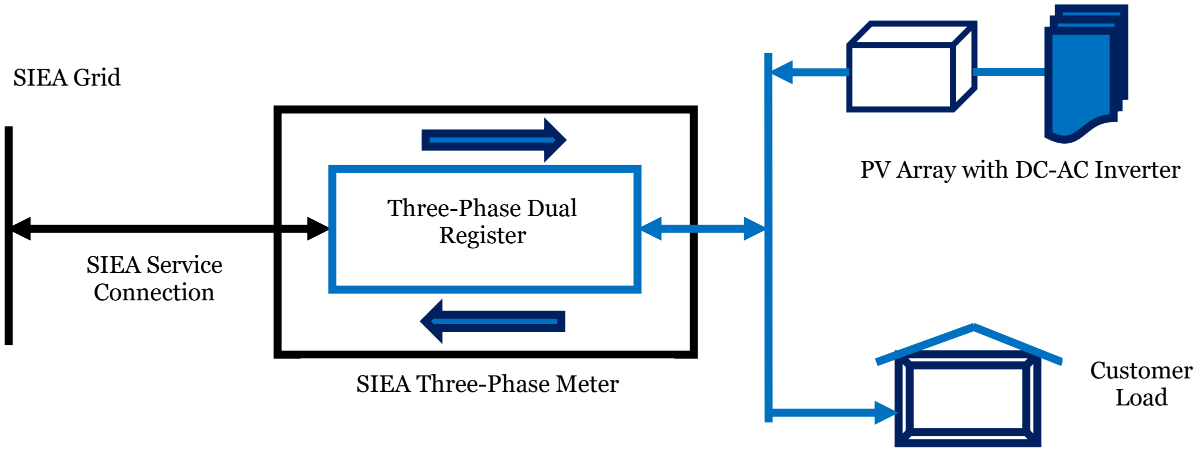


Figure 24 Schematics of solar PV interconnection with SIEA grid

Net metering is a utility billing mechanism that offers a credit to customers who are making excess electricity with their solar panel systems and sending it back to the grid. Solomon Islands at present does not have provision for net metering. However, SIEA is in process of reviewing and restructuring its electricity tariff. It may introduce the net metering option for solar roof top.

*Solar PV option for the pump station is **technically feasible**. But, the financially feasibility is dependent on future SIEA tariff structure. With present tariff structure and regulatory elements, the solar PV is not feasible.*
*The Solomon Water can **take a strategic call** if to invest in solar PV now or to wait for favorable regulatory regime.*

5.6. Other grid-connected solar initiatives in Solomon Islands

The World Bank is implementing a scaling-up of renewable energy project in Solomon Islands in the period 2018 to 2023. The Project intends to improve lifestyle and increase shared prosperity for the low-income household through scaling-up off and on-grid renewable energy projects.

The project is being implemented in four components, which are presented in **Table 22**.

Table 22 Components of WB Scaling-up RE project

Component – 1	Renewable energy hybrid mini-grids – Supply, installation and initial maintenance
Component – 2	Electricity connections in low income areas – Households, micro enterprise and community infrastructure
Component – 3	Grid-connected solar power - Supply, installation and initial maintenance
Component – 4	Enabling environment and project management – including gender related activities, technical assistance and training activities

The third component deals with grid connected solar power. World Bank intendeds to support supply, implementation and initial maintenance of grid-connected solar power projects. The project financing and source of funding for the gird connected solar power is presented in **Table 23**.

Table 23 Project financing and source of funding

Source of Fund	Project financing (US$ million)	Share of financing
International Development Association (IDA) financing credits	3.5	**70%**
IDA financing grant	0.55	**11%**
Trust funds GEF	0.95	**19%**
Total	**5.0**	**100%**

The reason for the solar power project being financially feasible as compared to solar power project proposed at pumps station are as follows:

- About 30% of the total funding for the project is through grant or funds, thus, reducing financing burden
- The remaining cost of project is also in terms of IDA financing credits, which has very low interest charge and repayments been stretched over long term
- The economy of scale, the solar power supported by World Bank is of MW capacity, however, the pump station projects capacity is in kW size
- One component of the World Bank project is on reducing regulatory barriers for solar project while creating the conditions for future replication. (This is in progress)

In case, the solar power project proposed for pump station can be financed through similar mechanism i.e. close to 30% grant/funds, the project finances will improve. Moreover, a further strengthened regulatory regime will be an advantage. The sensitivity analysis of grid connected solar power project with and without grant funding is presented in **Table 24**.

Table 24 Sensitivity analysis - Solar power project with and without grant

Particular	Unit	Without grant	With grant
Solar rooftop plant capacity for Tasahe Pump Station	kWp	21.8	21.8
Monetary savings	US $	11130	11130
Investment	US $	84933	59453
Simple payback period	**Years**	**7.6**	**5.3**

6. Conclusion

6.1. Summary of study

Tasahe pump station is in Tasahe area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Tasahe JICA reservoir using three transfer pumps. The pump station produces 3225.9 m^3 water daily consuming about 2213 kWh electrical energy. The existing specific energy consumption is 0.686 kWh per m^3. The study has identified three recommendations for energy conservation (**Table 25**). These recommendations could save annually about 60,273 kWh of electricity. These recommendations have an estimated investment of US $ 16,396 and can yield a monetary savings of US $ 41,287 per year. The annual energy saving is estimated to be 7.6% of total energy consumption by the pump station (**Figure 25**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 39.78 tonnes of CO_2.

Table 25 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement of borepump-2 with efficient pump	36,725	$ 25,157	$ 8,250	0.3	24.24
ECM-2	Replacement of borepump-4 with efficient pump	23,347	$ 15,993	$ 7,906	0.5	15.41
ECM-3	Replacement of FTL with LED lights	201	$ 138	$ 240	1.7	0.13
	Total	**60,273**	**$ 41,287**	**$ 16,396**	**0.4**	**39.78**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 26**.

Table 26 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.686 kWh/m^3	0.625 kWh/m^3
Specific CO_2 emission	0.447 kg CO_2/m^3	0.413 kg CO_2/m^3

On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

6.2. Funding options

The overall investment proposed for four energy conservation measures for Tasahe pump station is US$ 16,396. The simple payback on this investment is 5 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 5 months. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Tasahe pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

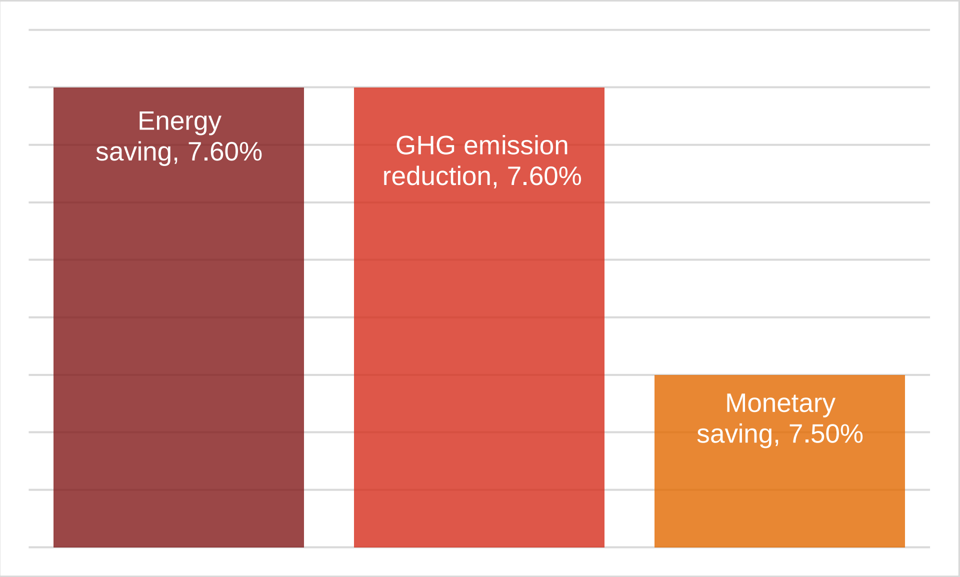


Figure 25 Identified saving potential

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

A collage of select pictures taken during the detailed feasibility study is presented in **Appendix D**.

Appendix

Appendix A – Proposed pump technical specification

Borehole pump N-2

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

Qty.	Description
1	**SP 46-5**

Note! Product picture may differ from actual product

Product No.: 15A00005

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	60 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	37.14 m³/h
Resulting head of the pump:	50.06 m
Curve tolerance:	ISO9906:2012 3B

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304

Installation:

Pump outlet:	RP4
Motor diameter:	6 inch

Electrical data:

Power (P2) required by pump:	7.5 kW

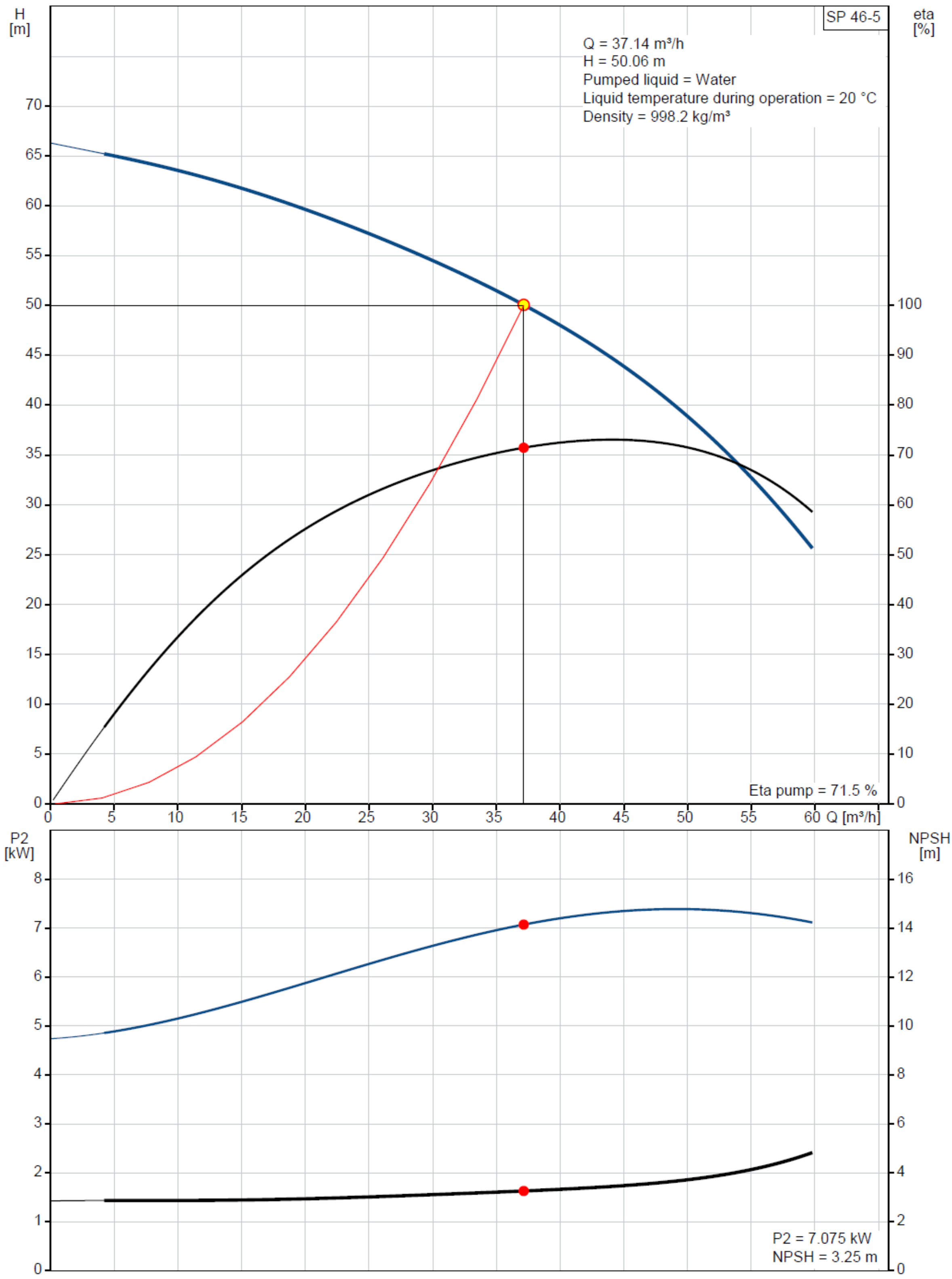
Others:

Minimum efficiency index, MEI ≥:	0.40
ErP status:	EuP Standalone/Prod.
Net weight:	17.2 kg
Gross weight:	19.8 kg
Shipping volume:	0.032 m³

Company name:
Created by:
Phone:

Date: 06/02/2020

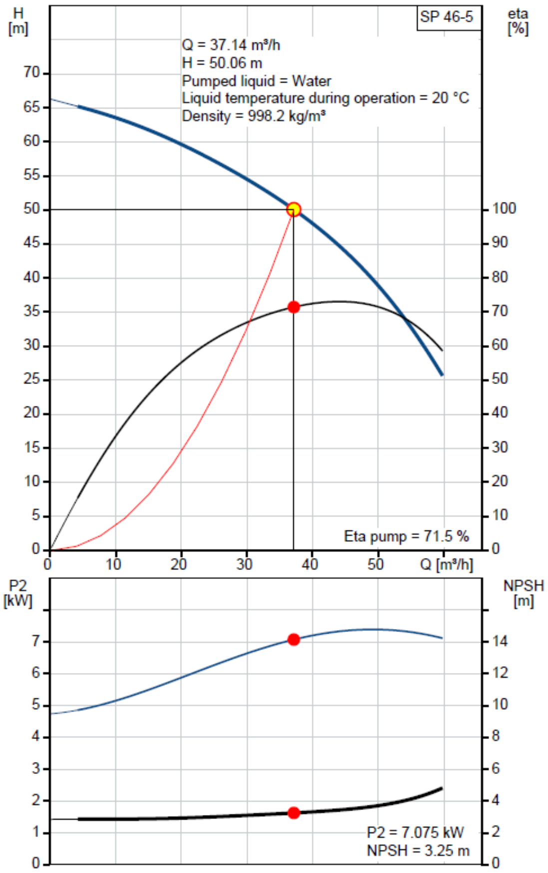
15A00005 SP 46-5 50 Hz



Company name:
Created by:
Phone:

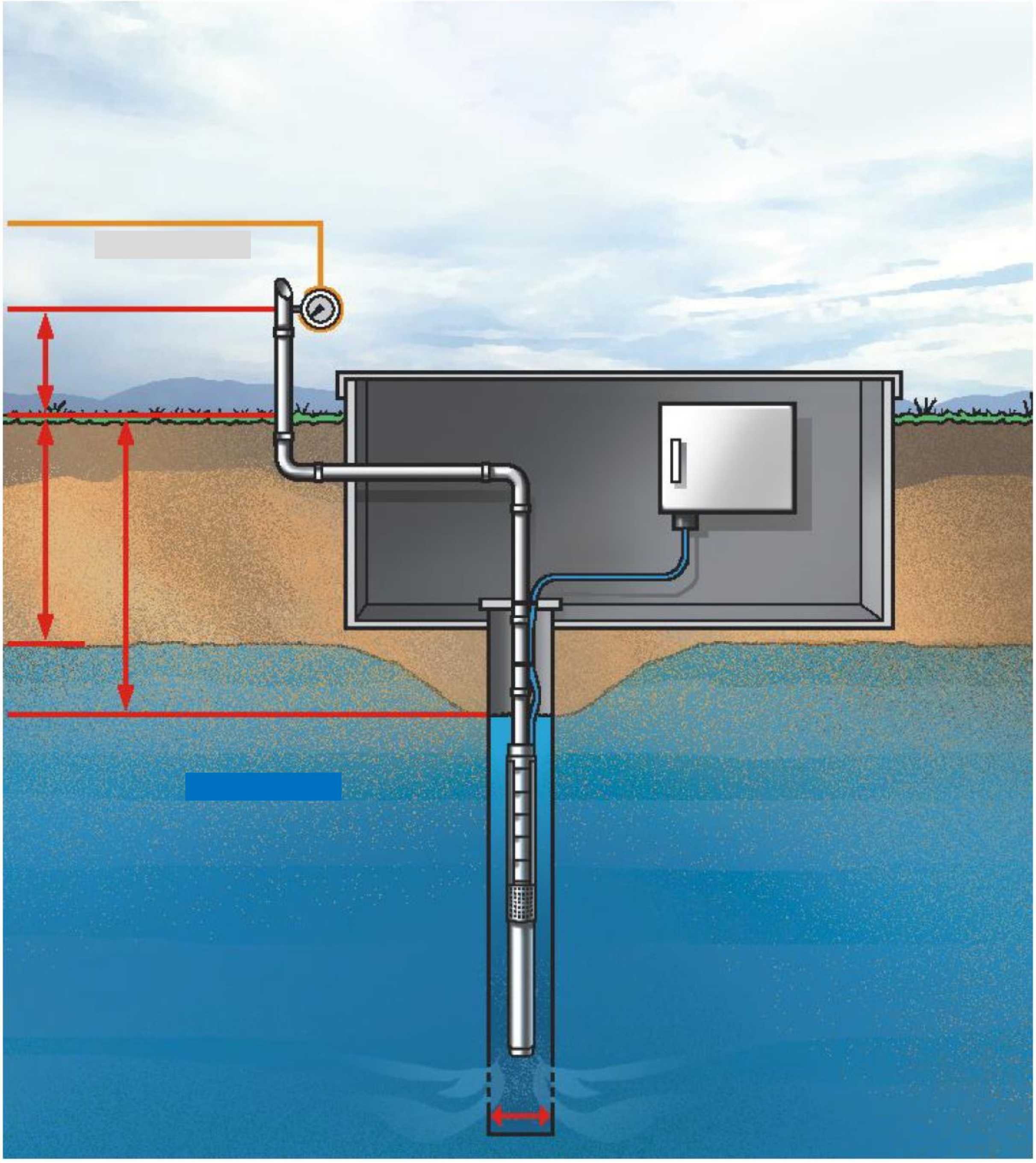
Date: 06/02/2020

Description	Value
General information:	
Product name:	SP 46-5
Product No:	15A00005
EAN number:	5700391148262
	5700391148262
Technical:	
Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	37.14 m³/h
Resulting head of the pump:	50.06 m
Stages:	5
Impeller reduc.:	NONE
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Installation:	
Pump outlet:	RP4
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	60 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Applic. motor:	GRUNDFOS
Power (P2) required by pump:	7.5 kW
Others:	
Minimum efficiency index, MEI ≥:	0.40
ErP status:	EuP Standalone/Prod.
Net weight:	17.2 kg
Gross weight:	19.8 kg
Shipping volume:	0.032 m³



Company name:
Created by:
Phone:

Date: 21/10/2019



Borehole pump N-4

GRUNDFOS	**Company name:** **Created by:** **Phone:** **Date:** 06/02/2020

Qty.	Description
1	**SP 30-11**

Note! Product picture may differ from actual product

Product No.: 13A01911

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 9.2 kW MS6000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	21.72 m³/h
Resulting head of the pump:	101.1 m
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP3

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

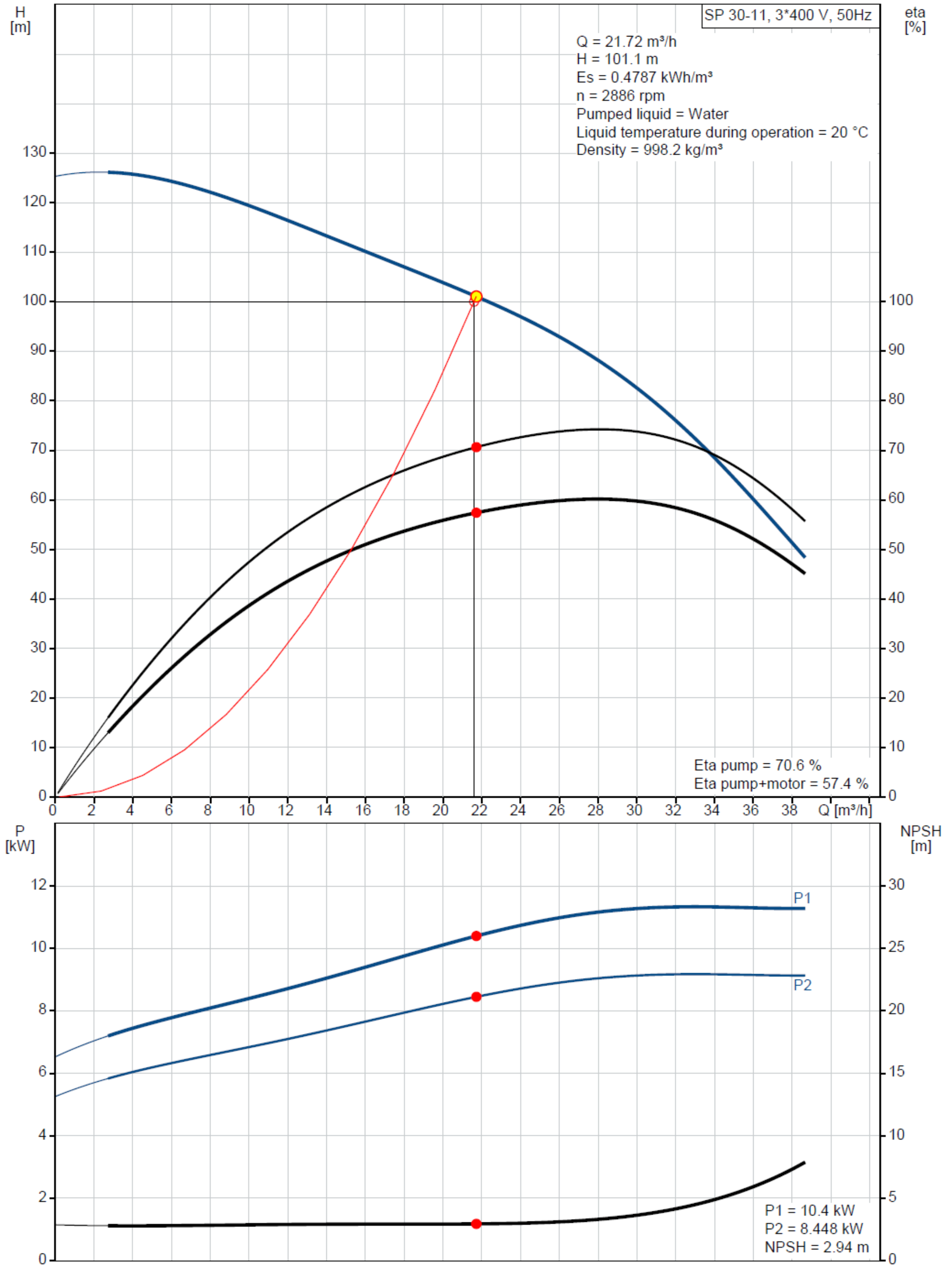
Qty.	Description	
	Motor diameter:	6 inch
	Electrical data:	
	Motor type:	MS6000
	Rated power - P2:	9.2 kW
	Power (P2) required by pump:	9.2 kW
	Mains frequency:	50 Hz
	Rated voltage:	3 x 380-400-415 V
	Rated current:	21.8-21.2-21.2 A
	Starting current:	480-520-550 %
	Cos phi - power factor:	0.84-0.82-0.78
	Rated speed:	2850-2870-2880 rpm
	Start. method:	direct-on-line
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	78195513
	Others:	
	Minimum efficiency index, MEI ≥:	0.50
	ErP status:	EuP Standalone/Prod.
	Net weight:	70.8 kg
	Gross weight:	105 kg
	Shipping volume:	0.264 m^3
	Danish VVS No.:	388338110
	Finnish LVI No.:	4762740

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

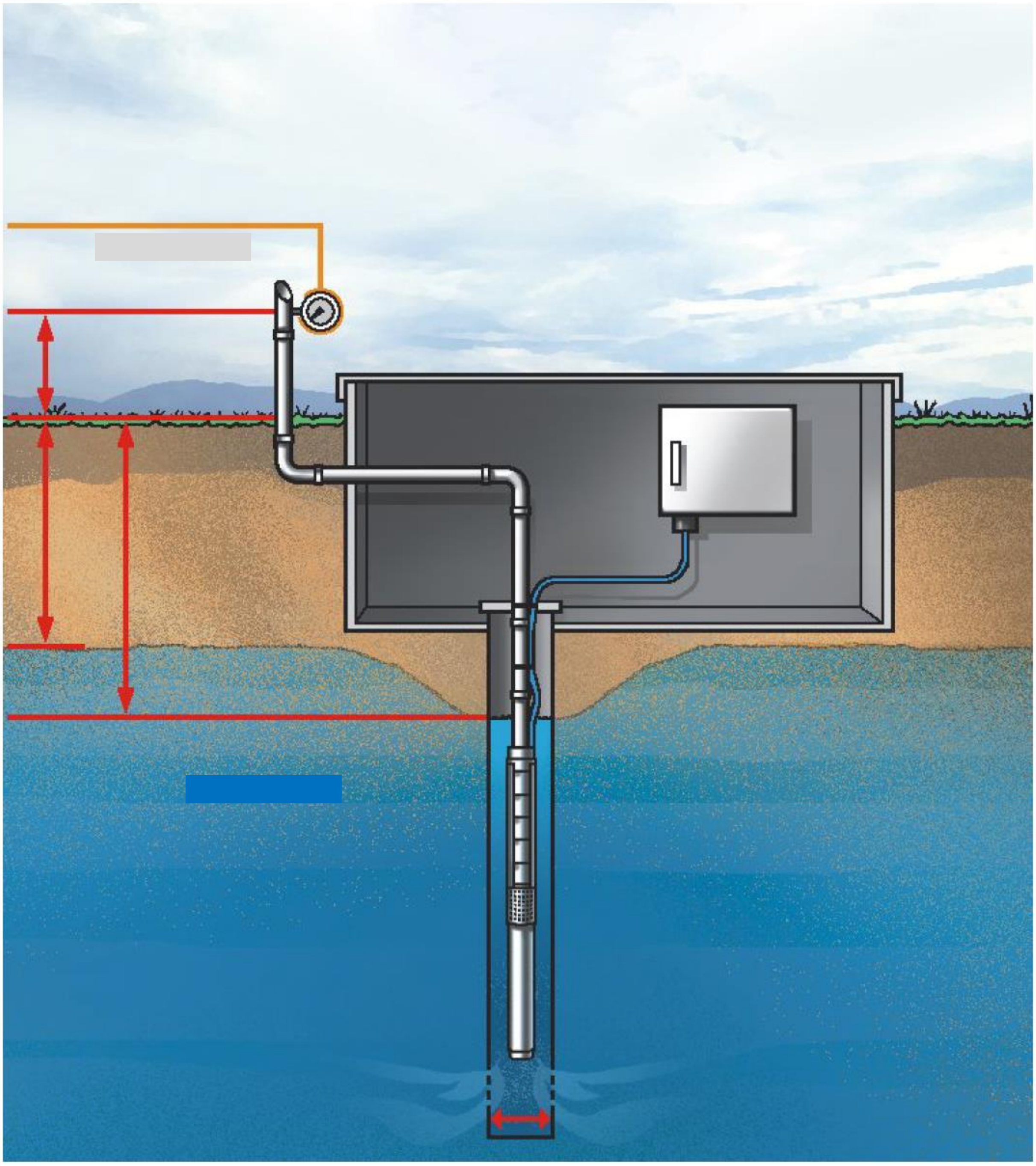
13A01911 SP 30-11 50 Hz



GRUNDFOS

Company name:
Created by:
Phone:

Date: 21/10/2019



Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
11/09/2019	5:32:27 PM	50.001	432.6	434.3	433.8	155.3	157.6	159.7	100.11	0.85
11/09/2019	5:33:27 PM	50.001	432.9	434.6	433.9	153.7	157.9	159.5	99.78	0.85
11/09/2019	5:34:27 PM	49.999	433.0	434.4	434.1	154.0	157.3	159.6	99.75	0.85
11/09/2019	5:35:27 PM	50.004	432.8	434.3	433.9	153.9	157.5	159.7	99.78	0.85
11/09/2019	5:36:27 PM	50.002	433.0	434.4	434.0	154.0	157.5	159.5	99.78	0.85
11/09/2019	5:37:27 PM	50.002	435.6	437.0	436.5	124.4	126.7	128.0	69.51	0.77
11/09/2019	5:38:27 PM	50.006	438.6	439.7	439.5	81.6	82.4	82.5	48.06	0.77
11/09/2019	5:39:27 PM	50	438.5	439.8	439.5	81.5	82.5	82.5	48.06	0.77
11/09/2019	5:40:27 PM	50.007	438.6	439.7	439.5	81.6	82.4	82.5	48.06	0.77
11/09/2019	5:41:27 PM	49.999	435.3	436.4	436.3	126.2	127.8	129.6	68.28	0.76
11/09/2019	5:42:27 PM	50	433.1	434.1	434.2	154.7	156.9	159.9	99.99	0.85
11/09/2019	5:43:27 PM	49.999	433.1	434.1	434.3	154.7	156.8	160.0	99.99	0.85
11/09/2019	5:44:27 PM	49.999	433.2	434.0	434.3	154.9	156.7	159.8	99.96	0.85
11/09/2019	5:45:27 PM	50.004	433.2	434.3	434.4	154.6	156.9	160.0	100.02	0.85
11/09/2019	5:46:27 PM	49.999	433.2	434.4	434.4	154.4	157.1	159.8	99.96	0.85
11/09/2019	5:47:27 PM	49.998	433.3	434.6	434.4	154.2	157.3	159.9	99.96	0.85
11/09/2019	5:48:27 PM	50.003	433.3	434.5	434.3	154.4	157.4	159.7	99.99	0.85
11/09/2019	5:49:27 PM	49.999	433.3	434.4	434.3	154.5	157.2	159.7	99.96	0.85
11/09/2019	5:50:27 PM	50.002	433.1	434.3	434.3	154.4	157.1	159.9	99.96	0.85
11/09/2019	5:51:27 PM	50.002	433.1	434.4	434.2	154.4	157.2	159.8	99.99	0.85
11/09/2019	5:52:27 PM	49.999	433.2	434.3	434.4	154.7	156.8	159.9	99.96	0.85
11/09/2019	5:53:27 PM	50.002	433.4	434.2	434.5	154.9	156.7	159.7	99.96	0.85

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
11/09/2019	5:54:27 PM	50	433.4	434.4	434.5	154.7	156.8	159.7	99.96	0.85
11/09/2019	5:55:27 PM	50.002	433.5	434.6	434.6	154.5	156.9	159.8	99.96	0.85
11/09/2019	5:56:27 PM	50.003	433.5	434.6	434.6	154.6	156.9	159.8	99.99	0.85
11/09/2019	5:57:27 PM	49.998	433.4	434.4	434.4	154.7	156.9	159.6	99.93	0.85
11/09/2019	5:58:27 PM	50.001	433.7	434.6	434.7	154.9	156.7	159.6	99.96	0.85
11/09/2019	5:59:27 PM	50	433.9	434.7	434.9	154.8	156.7	159.6	99.96	0.85
11/09/2019	6:00:27 PM	50.004	433.7	434.8	435.0	154.5	156.8	159.9	99.96	0.85
11/09/2019	6:01:27 PM	49.999	433.5	434.8	434.8	154.3	156.9	159.9	99.93	0.85
11/09/2019	6:02:27 PM	50	433.5	435.0	434.9	154.0	157.0	160.0	99.93	0.85
11/09/2019	6:03:27 PM	50.001	433.7	434.9	434.7	154.3	157.1	159.7	99.93	0.85
11/09/2019	6:04:27 PM	50	433.7	435.2	435.0	154.0	157.1	159.9	99.93	0.85
11/09/2019	6:05:27 PM	50.001	434.3	435.5	435.3	154.2	157.1	159.6	99.96	0.84
11/09/2019	6:06:27 PM	50.001	434.2	435.5	435.2	154.2	157.2	159.5	99.93	0.85
11/09/2019	6:07:27 PM	50	434.1	435.3	435.3	154.3	156.8	159.8	99.93	0.85
11/09/2019	6:08:27 PM	50.002	434.2	435.3	435.3	154.4	156.8	159.7	99.93	0.85
11/09/2019	6:09:27 PM	50	433.9	435.0	435.2	154.4	156.6	159.9	99.90	0.85
11/09/2019	6:10:27 PM	49.999	433.8	435.0	435.2	154.4	156.5	160.0	99.90	0.85
11/09/2019	6:11:27 PM	50	437.4	438.2	438.2	112.9	114.1	115.3	64.20	0.77
11/09/2019	6:12:27 PM	50	439.5	440.0	440.3	82.1	82.4	82.4	48.09	0.77
11/09/2019	6:13:27 PM	50.002	439.0	439.7	439.9	82.0	82.3	82.4	48.09	0.77
11/09/2019	6:14:27 PM	50.002	438.8	439.3	439.6	82.0	82.3	82.3	48.06	0.77
11/09/2019	6:15:27 PM	49.981	434.9	435.7	435.8	132.3	133.9	135.6	72.84	0.77
11/09/2019	6:16:27 PM	49.999	432.6	433.5	433.6	154.8	157.0	159.7	99.96	0.85
11/09/2019	6:17:27 PM	50.005	432.6	434.3	433.8	155.3	157.6	159.7	99.96	0.85

Appendix C – PVSYST simulation results

Definition of Geographical Site

Geographical Site **Honiara** Country **Solomon Islands**

File New.SIT of 01/10/19 12h40

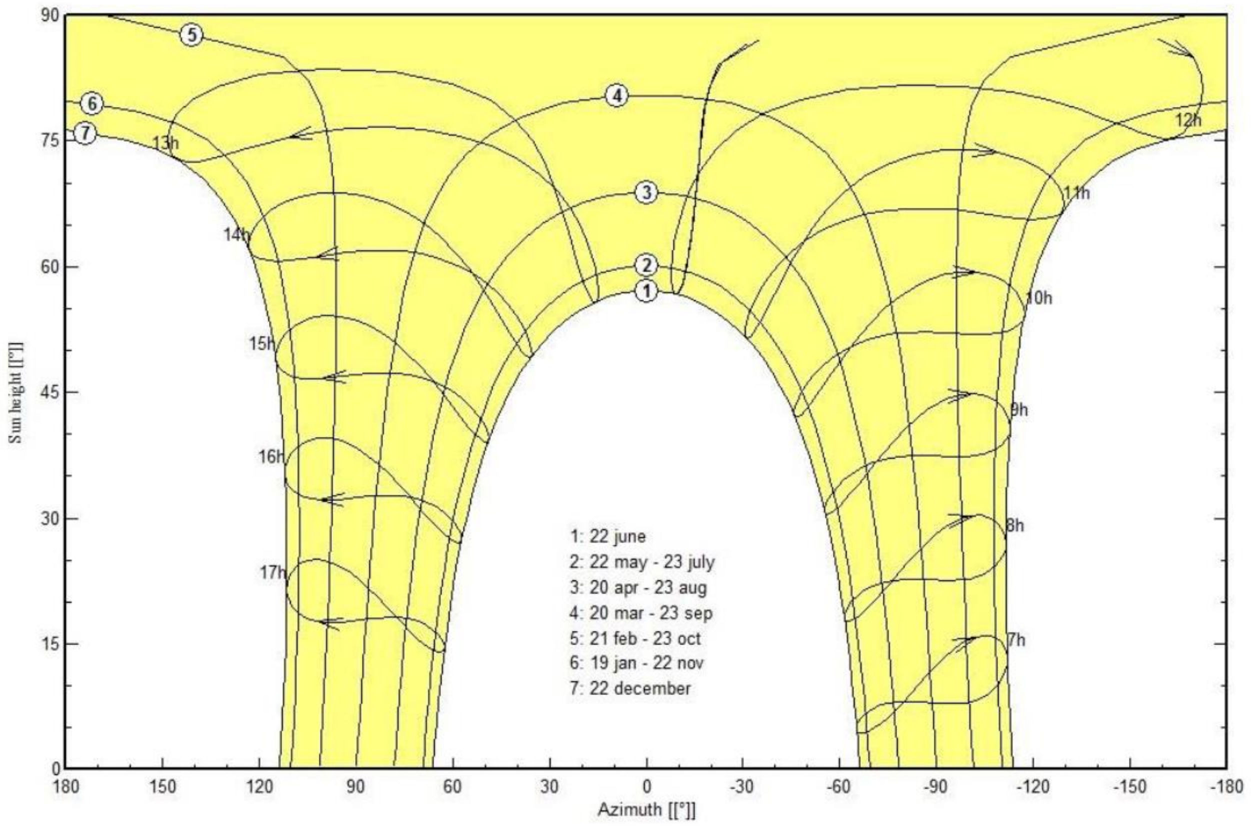
Situation Latitude: -9.45° S Longitude: 159.96° E

Time defined as Legal Time Time zone UT+11 Altitude: 10 m

Monthly Meteo values

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m² day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m² day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

Solar paths at Honiara, (Lat. -9.4517° S, long. 159.9612° E, alt. 10 m) - Legal Time



Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt: 10°		Azimuth 0°

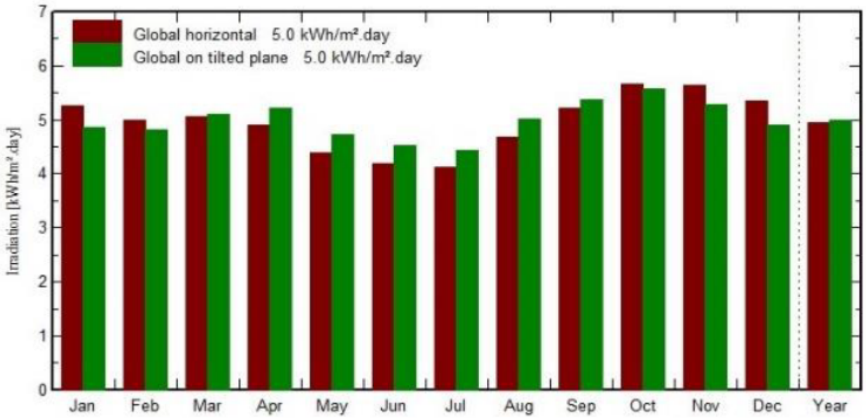
PV Installation main features

Module Type	Standard
Technology	Thin film
Mounting method	Flat roof
Back ventilation properties	Free Standing

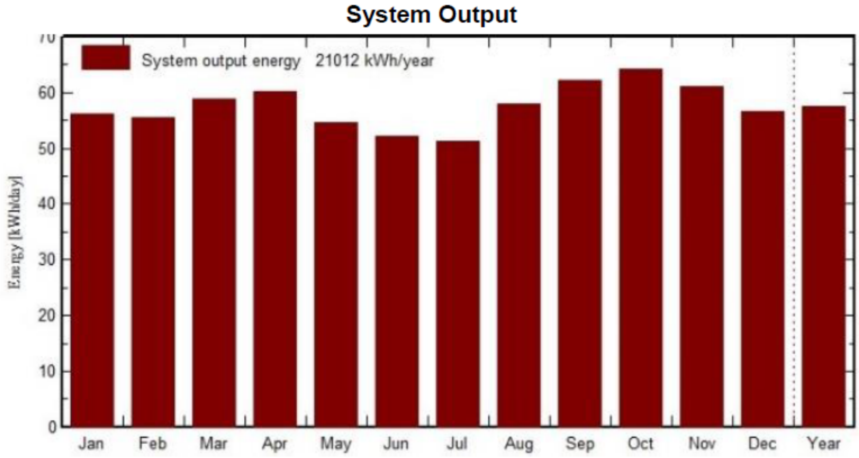
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	13.6 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	21.0 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	56.16	1741
Feb	4.99	4.81	55.58	1556
Mar	5.05	5.10	58.93	1827
Apr	4.91	5.21	60.18	1806
May	4.39	4.72	54.53	1690
June	4.19	4.52	52.16	1565
Jul	4.12	4.43	51.22	1588
Aug	4.67	5.02	58.03	1799
Sept	5.21	5.38	62.09	1863
Oct	5.67	5.57	64.29	1993
Nov	5.64	5.28	61.02	1831
Dec	5.35	4.90	56.59	1754
Year	4.95	4.98	57.57	21012

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt:10°		Azimuth: 0°

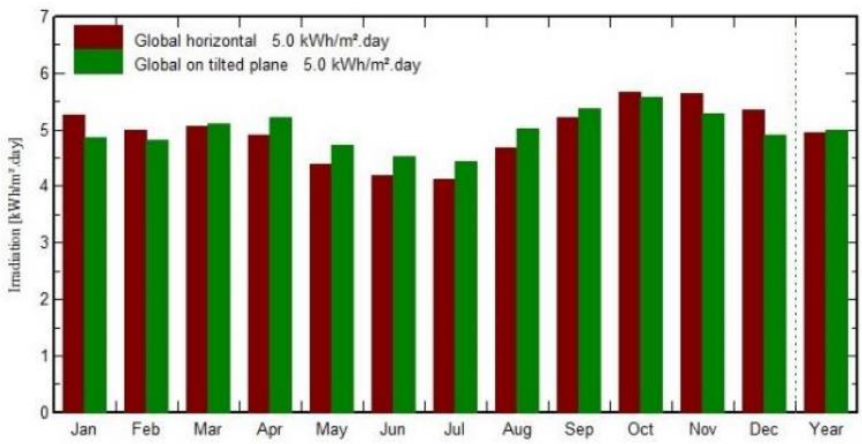
PV Installation main features

Module Type	Standard
Technology	Monocrystalline cell
Mounting method	Flat roof
Back ventilation properties	Free Standing

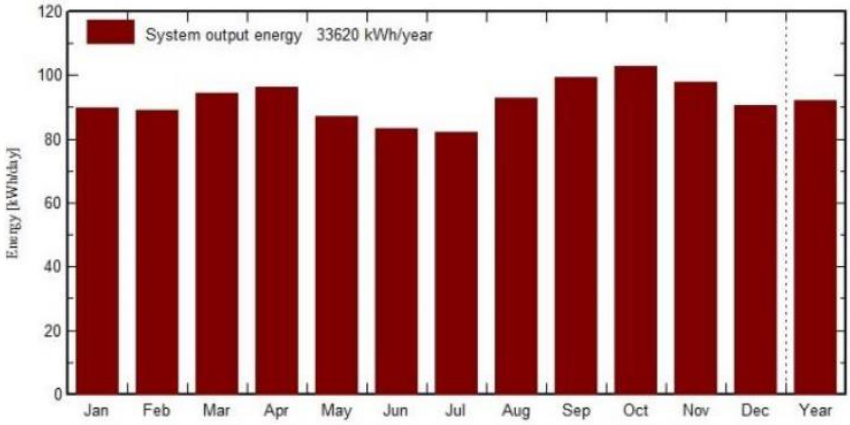
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	21.8 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	33.6 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	89.85	2785
Feb	4.99	4.81	88.93	2490
Mar	5.05	5.10	94.29	2923
Apr	4.91	5.21	96.29	2889
May	4.39	4.72	87.25	2705
June	4.19	4.52	83.45	2504
Jul	4.12	4.43	81.95	2540
Aug	4.67	5.02	92.86	2879
Sept	5.21	5.38	99.34	2980
Oct	5.67	5.57	102.9	3189
Nov	5.64	5.28	97.63	2929
Dec	5.35	4.90	90.55	2807
Year	4.95	4.98	92.11	33620

Appendix D – Photographs taken during the study

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Detailed Feasibility Report Titinge Pump Station

Prepared for
UNIDO – CTCN

Under the project
Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious "technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan".

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Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Titinge pump station is in Mbokono area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Titinge JICA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. However, at present only two bore pumps are operated at a time. This is to avoid unsustainable depletion of boreholes. Details of Titinge pump station is presented below.

Name of the pump station	Titinge
No. of transfer pumps	3 (2 Run + 1 Standby)
No. of bore-hole pumps	4 (2 Run)
Monthly electricity consumption	31933 kWh (average of last 12 months)
Monthly water production	39307 m^3 (based on onsite measurement)
Name and details of contact person	Livingston Kute, Plumber +677-7459172 Danny Titiri, Electrical and Mechanical Team Lead dtitiri@solomonwater.com.sb, +677-8876857
Annual working days	365

A detailed feasibility study of Titinge pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Titinge pump station is in Mbokono area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m3 water receiver tank, which receives water from four boreholes. The water from receiving tanks is pumped to Titinge JICA reservoir using three transfer pumps. The pump station produces 1292.3 m3 water daily consuming about 1052.7 kWh electrical energy. The existing specific energy consumption is 0.815 kWh per m3. The study has identified four recommendations for energy conservation (Table). These recommendations could save annually about 39,955 kWh of electricity. These recommendations have an estimated investment of US $ 38,246 and can yield a monetary savings of US $ 27,396 per year. The annual energy saving is estimated to be 10.4% of total energy consumption by the pump station (Figure). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 26.37 tonnes of CO2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Installation of VFD on transfer pumps	6,370	$ 4,368	$ 20,000	4.6	4.20
ECM-2	Replacement of borepump-1 with efficient pump	29,133	$ 19,977	$ 9,444	0.5	19.23
ECM-3	Replacement of borepump-4 with efficient pump	4,251	$ 2,915	$ 8,563	2.9	2.81
ECM-4	Replacement of FTL with LED lights	201	$ 137	$ 240	1.8	0.13
	Total	**39,955**	**$ 27,396**	**$ 38,246**	**1.4**	**26.37**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.815 kWh/m^3	0.728 kWh/m^3
Specific CO_2 emission	0.536 kg CO_2/m^3	0.480 kg CO_2/m^3

On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

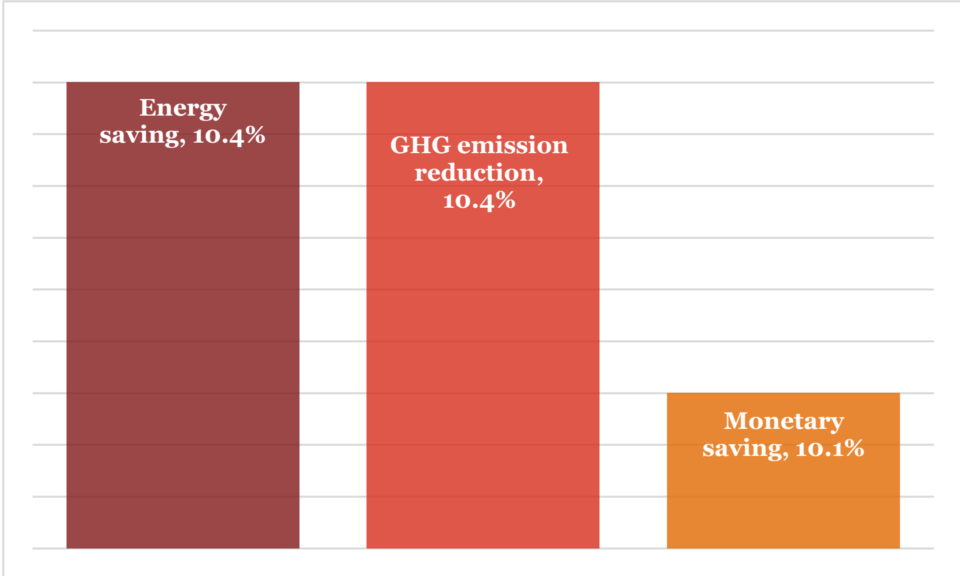
Funding options

The overall investment proposed for four energy conservation measures for Titinge pump station is US$ 38,246. The simple payback on this investment is 11 months. Solomon Water can fund the project through internal funds.

It is recommended to implement the bore-hole pump recommendation first, as the payback is under 6 months, which can be followed by VFD on transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Titinge pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Proposed saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m^3	1,000 liters
1 USD	8 SBD

** Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[1] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

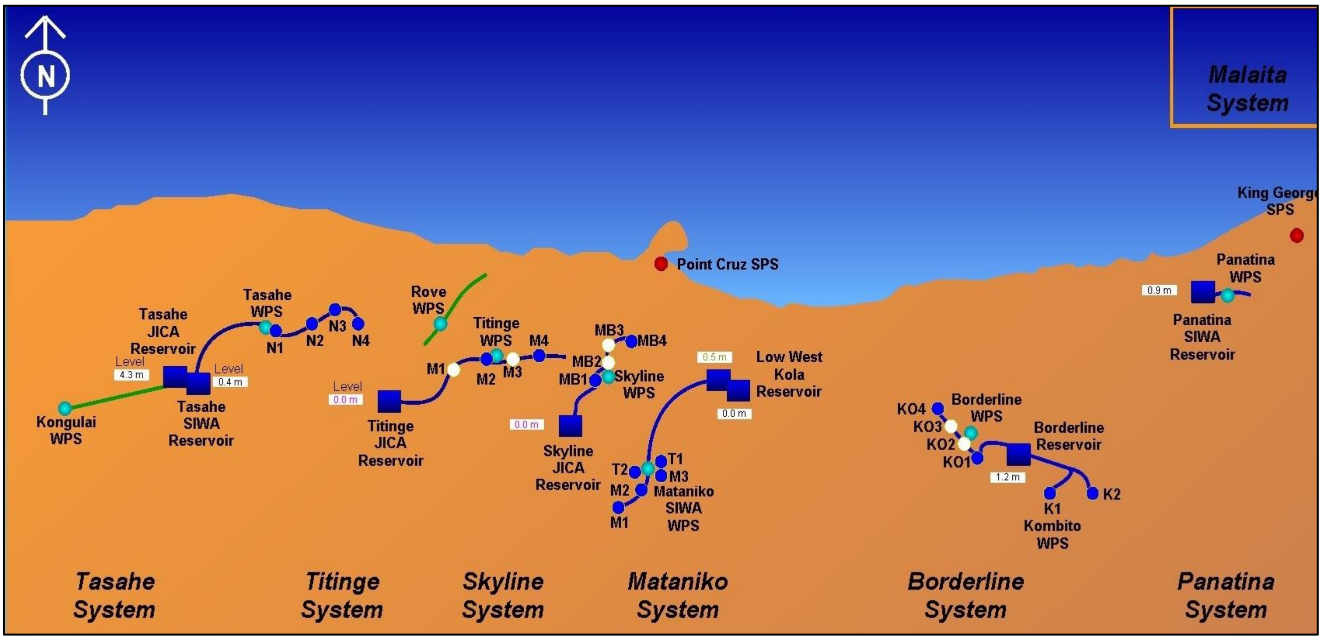


Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[1]

[1] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[2]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

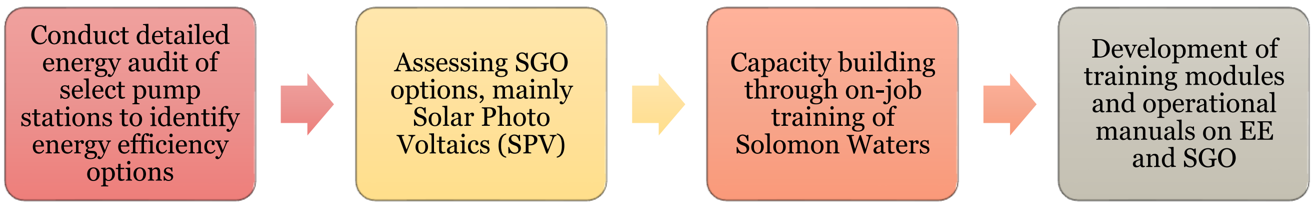


Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[2] *Response Plan, CTCN request ID: 2017000039*

Assessment of Energy Efficiency and RE options
- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options

Capacity building through on-job training for Solomon Water
- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation

Detail assessments of shortlisted EE and SGO options for Solomon Water
- Technical analysis
- Financial analysis

Monitoring of impact
- Monitoring and evaluation of Impacts
- Report on Gender co-benefits

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

Environmental Benefits	Economic Benefits	Social Benefits
• Enhanced energy efficiency • Improved energy security • Lower dependence on imported fuels • Contribution towards climate change mitigation	• Reduced operating (energy) cost for Solomon Water • Increased investments in energy efficiency and renewable energy	• Skill enhancement of Solomon Water professionals on EE and RE • Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

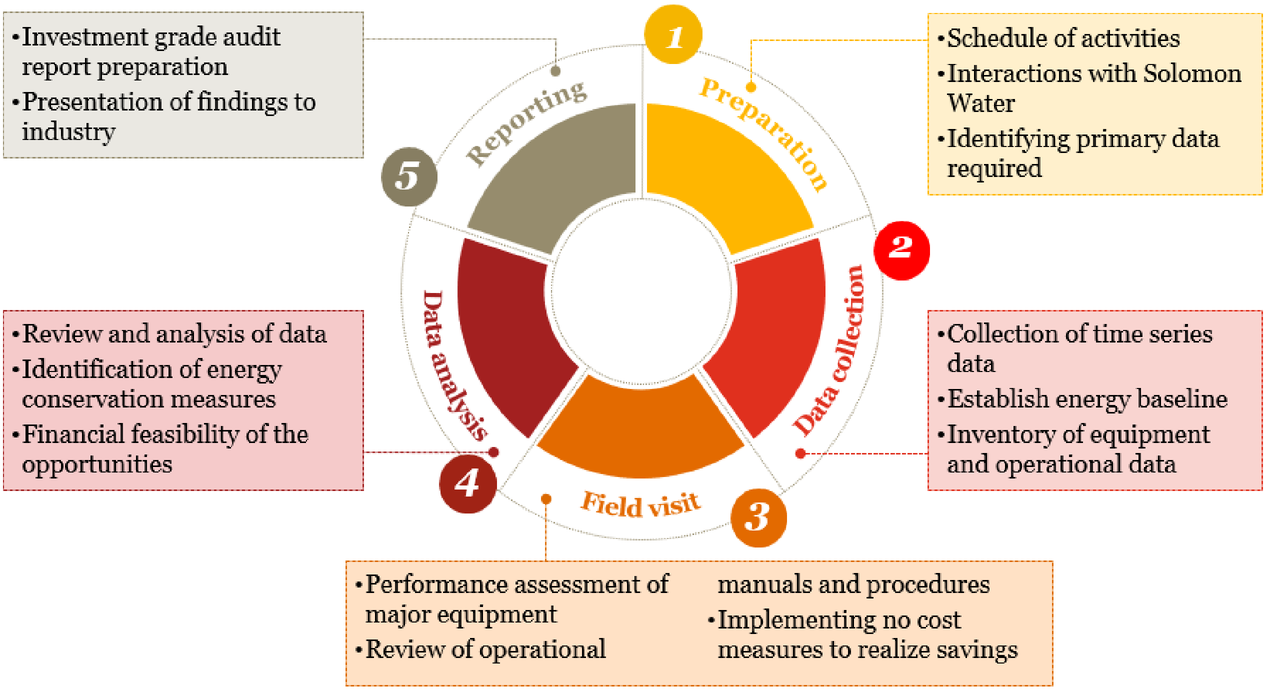


Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Titinge pump station

2.1. About Titinge pump station

Titinge pump station is in Mbokono area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m^3 water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Titinge JICA reservoir using three transfer pumps. The system is designed for continuous operation of four bore pumps. However, at present only two bore pumps are operated at a time. This is to avoid unsustainable depletion of boreholes. The overview of Titinge pump station as seen in Solomon Water SCADA system is shown in **Figure 6**.

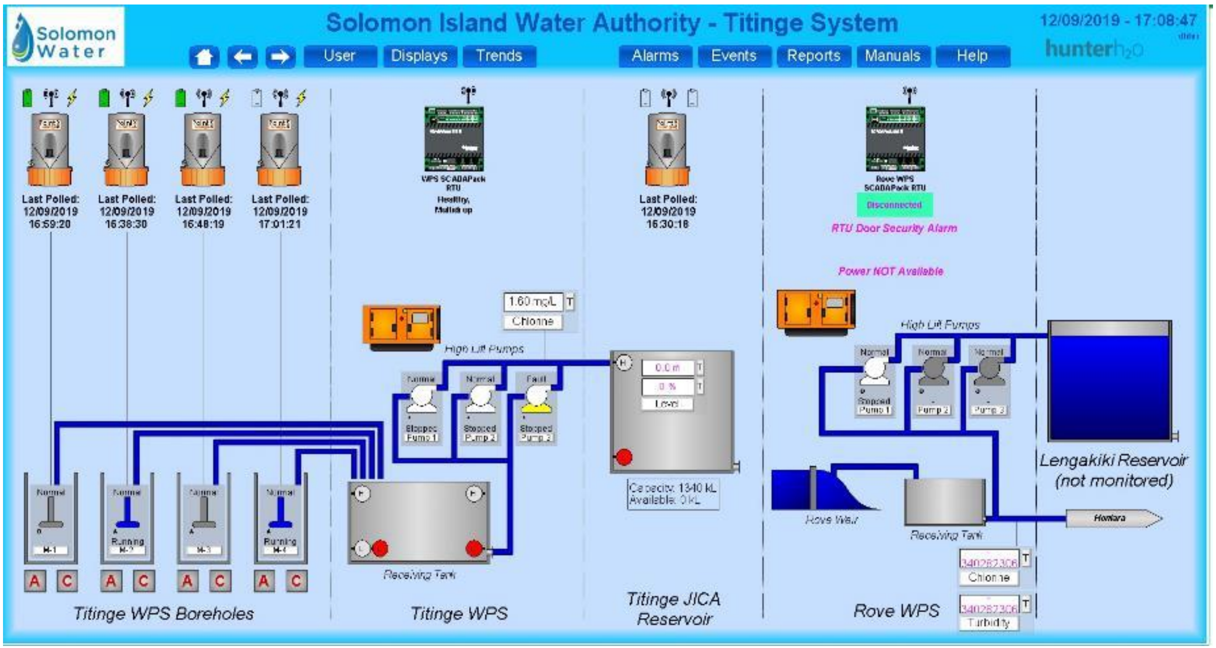


Figure 6 Titinge pump station overview in SCADA system

2.2. Transfer pumps

The Titinge pump station is equipped with three vertical multi-stage centrifugal pumps of Grundfos make CRN 64-5-1 model. Each pump is designed to deliver 64 cubic meter per hour water. These three transfer pumps are connected to operate in parallel. Transfer pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Titinge JICA reservoir. Two transfer pumps operate in parallel at any given time, with one pump remaining as standby.

Design details of the transfer pumps and its corresponding motor is presented in **Table 2** and **Table 3** respectively.

The pictorial view of transfer pumps is presented in **Figure 7**.

Figure 7 Titinge transfer pumps

Table 2 Design details of transfer pumps

Particular	Unit	Pump #1, #2, #3
Make	-	Grundfos
Model	-	CRN 64-5-1 AFGV-HQQV
Design flow	m^3/h	64.0
Design head	m	108.5
Max. head	m	139.2
Impeller type	-	Stainless Steel
Pump speed	rpm	2951
Recommended motor rating	kW	30.0
Max. pressure	bar	16.0
Pump efficiency	%	79.0

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor #1, #2, #3
Make	-	Grundfos
Power	kW	30
Voltage	V	400.0
Current	I	51.5
Power Factor	-	0.88
Motor speed	rpm	2962
Frequency	Hz	50.0
Rating	-	IE2
Efficiency	%	92.0

2.3. Borehole pumps

The Titinge pump station receives water from four borehole pumps. Water is extracted using submersible centrifugal pumps. As the pumps were underground, name plates could not be checked physically. The design details were collected from records available at Solomon Water maintenance office. Initially, the system was designed for 24 x 7 operation of four bore pumps. However, at present only two bore pumps are operated.

The design details of bore pumps is presented in **Table 4** and schematic view of Titinge bore-field is presented in **Figure 8**.

Table 4 Design details of borehole pumps

Particular	Unit	M-1	M-2	M-3	M-4
Make	-	Grundfos	Grundfos	Grundfos	Grundfos
Model	-	SP46-8C	SP30-12	SP46-10	SP30-16
Design flow	m^3/h	48.5	29.5	41.0	33.5
Design head	m	56.6	91.9	95.6	105.0
Pump depth	m	46	85	82	87
Pump efficiency	%	74.5	74.5	74.4	70.0

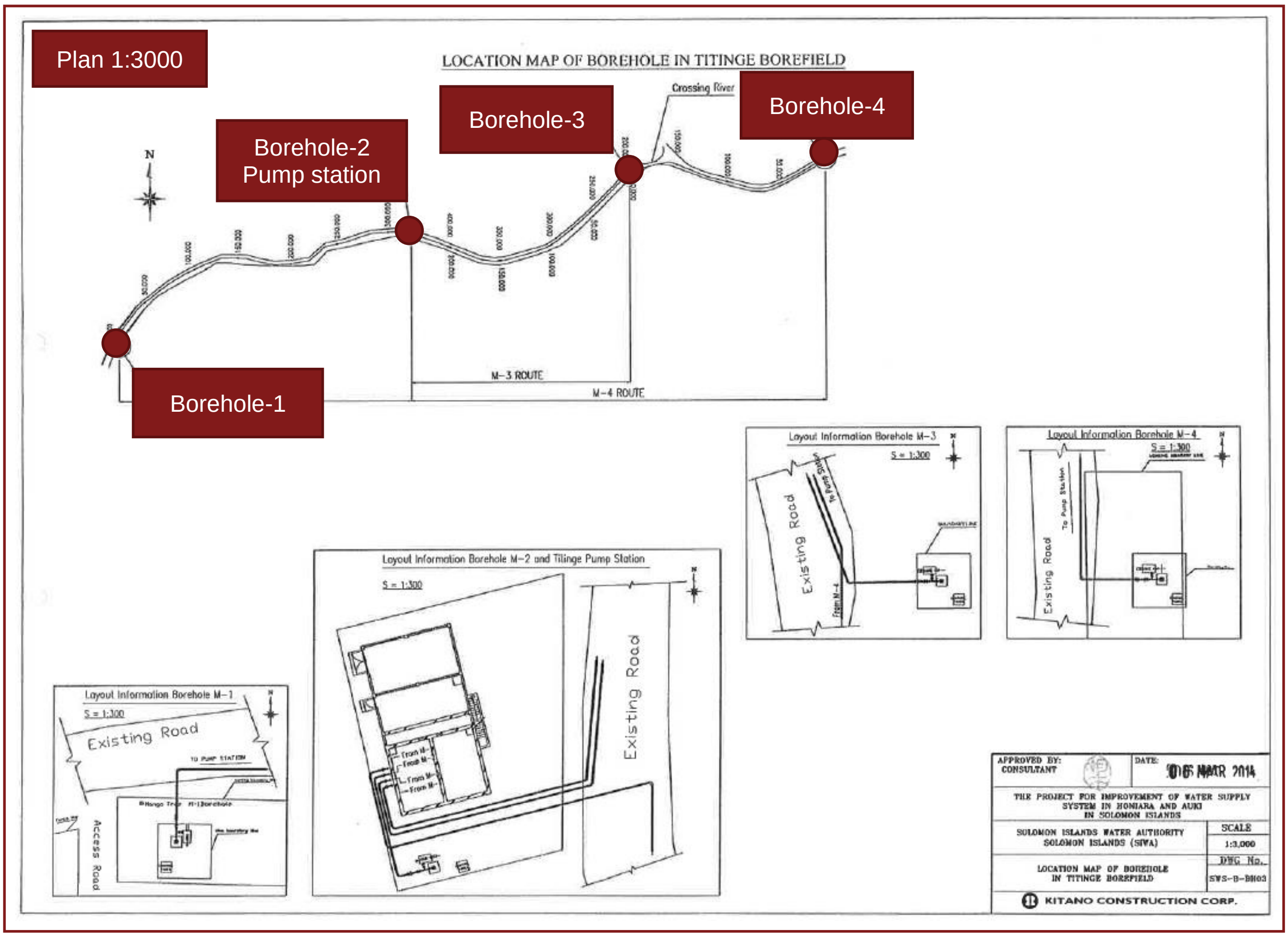


Figure 8 Location of boreholes in Titinge bore-field

3. Energy consumption analysis

3.1. Energy source and tariff details

Titinge pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Titinge pump station is under Industrial I3 type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff for last 12 months was captured during feasibility study and same is presented in **Table 5**.

Table 5 Electricity tariff details – Last 12 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)			NAC (SBD/month)[3]
		I1[4]	I2[5]	I3[6]	
Aug-18	2.85	3.68	3.16	2.81	3,175.72
Sep-18	2.85	3.7	3.18	2.83	3,199.91
Oct-18	2.71	3.71	3.19	2.84	3,204.42
Nov-18	2.83	3.72	3.2	2.85	3,218.49
Dec-18	2.81	3.75	3.23	2.87	3,242.95
Jan-19	2.77	3.77	3.24	2.89	3,258.18
Feb-19	2.49	3.11	2.68	2.38	2,690.01
Mar-19	2.71	3.79	3.26	2.9	3,277.82
Apr-19	2.53	3.61	3.11	2.77	3121.85
May-19	2.64	3.85	3.31	2.95	3328.04
Jun-19	2.21	3.85	3.31	2.95	3,324.80
Jul-19	2.38	3.84	3.3	2.94	3,316.60
Average	**2.65**	**3.70**	**3.18**	**2.83**	**3,196.57**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 18 months for Titinge pump station was analyzed. The average electricity tariff and consumption for last 12 months was evaluated. These 12-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 12 months (August 2018 to July 2019) was 383,200 kWh. The bill amount corresponding to this consumption was SBD 2.16 million i.e. USD 269,005.

The electricity consumption along with monthly energy charges is presented in **Table 6**. Variation of electricity consumption is presented in **Figure 9**.

[3] *I3 connection electricity consumption>6000 kWh*
[4] *First 1300 units of the monthly consumption*
[5] *Next 4700 units of the monthly consumption*
[6] *Remaining consumption of the month*

Table 6 Electricity consumption details

Month	Consumption	NAC	Fuel charge	Non-fuel charge			Total
	kWh	(SBD)	(SBD)	I1	I2	I3	(SBD)
Aug-18	29,680	3,176	84,588	4,784	14,852	66,541	**173,941**
Sep-18	8,160	3,200	23,256	4,810	14,946	6,113	**52,325**
Oct-18	67,520	3,204	182,979	4,823	14,993	174,717	**380,716**
Nov-18	17,360	3,218	49,129	4,836	15,040	32,376	**104,599**
Dec-18	27,160	3,243	76,320	4,875	15,181	60,729	**160,348**
Jan-19	30,120	3,258	83,432	4,901	15,228	69,707	**176,526**
Feb-19	42,520	2,690	105,875	4,043	12,596	86,918	**212,121**
Mar-19	43,920	3,278	119,023	4,927	15,322	109,968	**252,518**
Apr-19	1720	416	4,352	4,693	1,306	0	**10,767**
May-19	47,400	3,328	125,136	5,005	15,557	122,130	**271,156**
Jun-19	45,440	3,325	100,422	5,005	15,557	116,348	**240,657**
Jul-19	22,200	3,317	52,836	4,992	15,510	47,628	**124,283**
Average	**31,933**	**2,971**	**83,946**	**4,808**	**13,841**	**74,431**	**179,996**
Annual	**383,200**	**35,653**	**1,007,348**	**57,694**	**166,088**	**893,174**	**2,159,957**

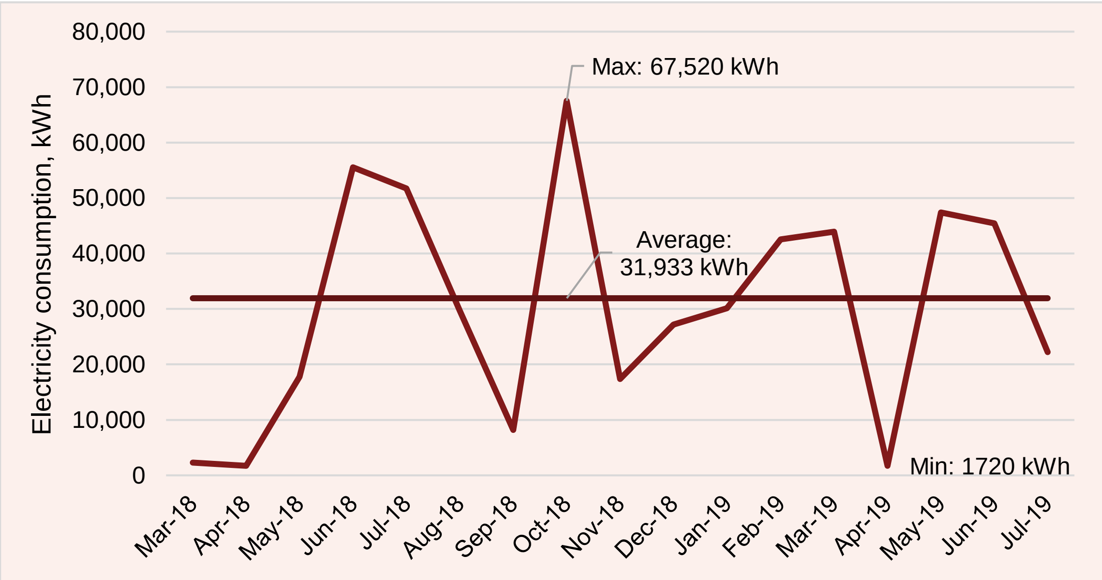


Figure 9 Electricity consumption profile March 2018 – July 2019 (18 months)

Key observations for the period August 2018 to July 2019:

- Monthly average consumption of electricity was 31,933 kWh (varying between 1,720 to 67,520)
- Average electricity tariff (excluding fixed NAC) was SDB 5.54 per kWh (US$ 0.69 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.65 per kWh (US¢ 33.1 per kWh)

Average monthly electricity consumption of Titinge Pump Station is 31,933 kWh

A sample electricity bill of Titinge pump station is presented in **Figure 10**.

Solomon Islands Electricity Authority
trading as SOLOMON POWER

INVOICE / STATEMENT

Customer

SIWA- Titinge Pump Station
P O Box 1407
Honiara

Date	06/January/2019
Customer Number	01129-05
Customer Type	**INDUSTRIAL**
Customer Category	**I3**

Location: Titinge Pump Station
Titinge

Previous Month

Balance at Previous Account Date	$264,947.04
Payment Received to 19 Dec Thank you	($104,599.29)
Balance Prior to 6 Jan 19	$160,347.75

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$176,526.38	$160,347.75	$0.00	$0.00	$336,874.13

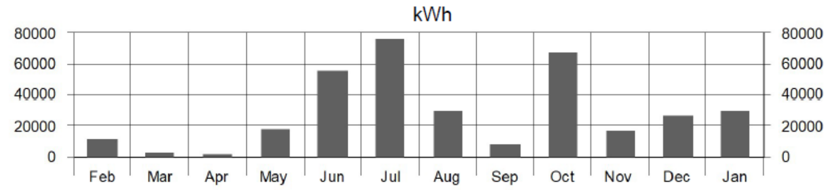
Month 06/January/2019

Readings from 6/Dec/2018 to 6/Jan/2019 **Days** 31

Usage	**Meter no.**	**Previous**	**Present**	**Multi**	**Units**
1	217039069	3,747	4,500	40	30,120

Total **30,120.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 344760 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	I3	Days	31	3,258.18		3,258.18
Fuel	I1	kWh	30,120.00	2.7700	1.0000	83,432.40
Non-Fuel	I1	kWh	1,300.00	3.7700	1.0000	4,901.00
	I2	kWh	4,700.00	3.2400	1.0000	15,228.00
	I3	kWh	24,120.00	2.8900	1.0000	69,706.80
			30,120.00			89,835.80

TOTAL THIS PERIOD	**$176,526.38**
TOTAL DUE	**$336,874.13**
FINAL DATE FOR PAYMENT:	21/January/2019

No further notices will be issued. Unpaid accounts will have supply disconnected.
Previous month balances are payable immediately.

Figure 10 Sample electricity bill of Titinge pump station

The total electricity consumption in the pump station can be categorized in four parts: (a) transfer pumps, (b) borehole pumps, (c) lighting system and (d) electrical system losses and miscellaneous. The average consumption by each category is presented in **Figure 11**.

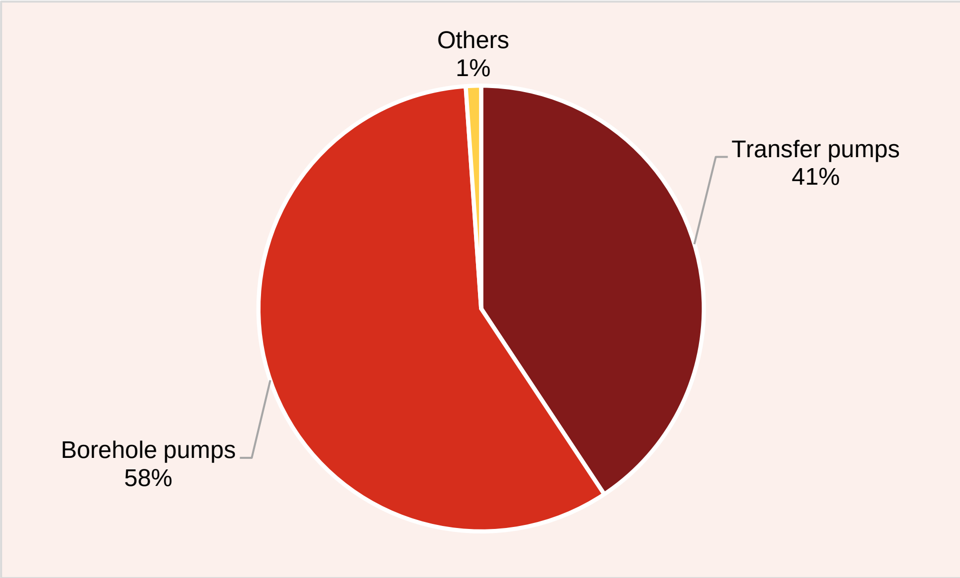


Figure 11 Electricity consumption share

3.3. Specific energy consumption

The daily water production from the bore-fields was 1292.3 m^3 and the daily total electrical energy consumption was 1053 kWh. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 12 months data, which was 1064 kWh. The specific energy consumption is presented in **Table 7**.

Table 7 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	1292.3
Daily electricity consumption	kWh	1052.7
Specific energy consumption	**kWh/m^3**	**0.815**

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with three transfer pumps. These are multistage vertical centrifugal pumps with stainless steel impeller. Pumps are of Grundfos make and are driven by individual 30 kW motor. Typically, two pumps operate in parallel at any given time and third pump is standby. During the site visit pump 1 and 2 were in operating condition and performance assessment test was conducted on both separately. However, the soft starter of pump 3 had some issue and it was not in operation, thus performance assessment could not be conducted.

The performance assessment of transfer pumps was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump was operating intermittently i.e. operating in ON-OFF mode. It was based on level switch control installed in receiver tank. Daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. **Figure 12** shows three-phase power analyser connected to main incomer of Titinge pump station.

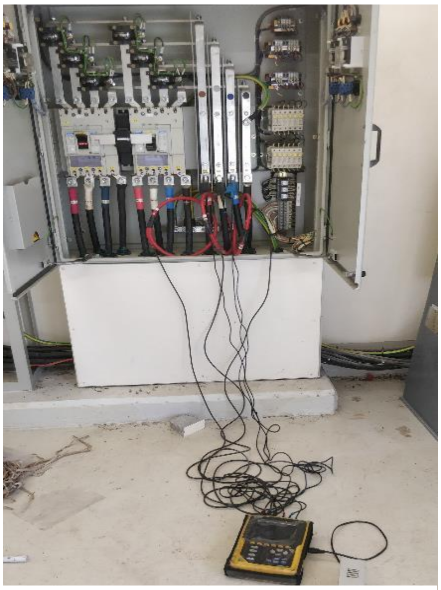


Figure 12 Power measurement photographs

The measured data such as operating hours and flow are verified using system data available at Solomon Islands Water Authority. The performance assessment of transfer pump 1 and 2 is presented in **Table 8**.

Table 8 Performance assessment of transfer pumps 1 and 2

Particular	Unit	Pump 1	Pump 2
Operating flow	m^3/h	77.80	76.10
Suction head	m	-2.00	-2.00
Discharge head	m	87.50	87.50
Total head	m	85.5	85.5
Hydraulic power	kW	18.13	17.73
Motor input power	kW	25.65	25.91
Shaft power	kW	23.60	23.84
Pump efficiency	**%**	**76.80**	**74.38**

The operating efficiency of the transfer pumps 1 and 2 were 76.8 and 74.4% respectively, which is close to the design rating. The reason for slight drop in efficiency was actual system duty point being away from best efficiency point of pump. The actual duty point, and best efficiency point of pump 1 and 2 are depicted in **Figure 13** and **Figure 14**.

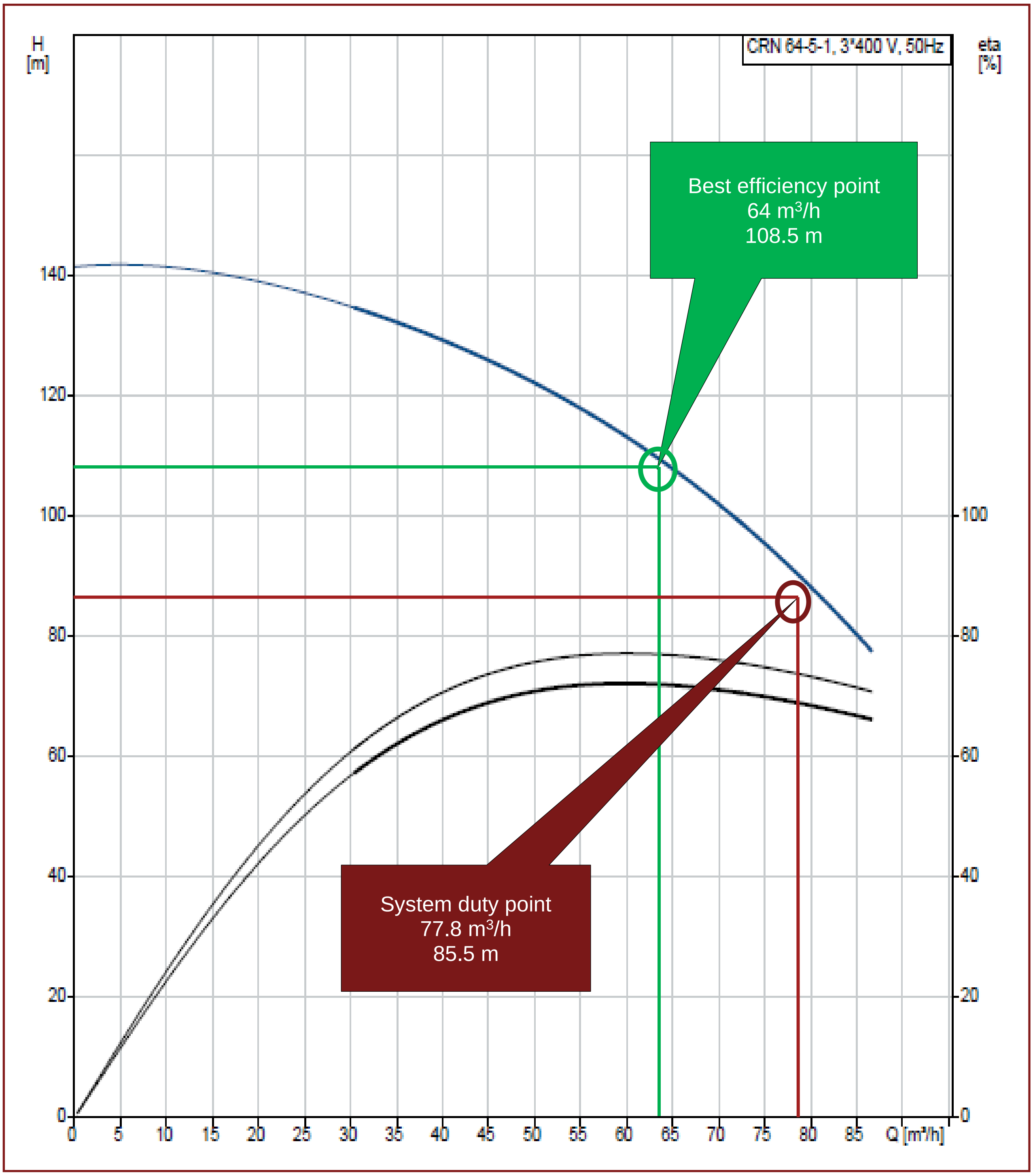


Figure 13 Transfer pump-1 system duty point vs design

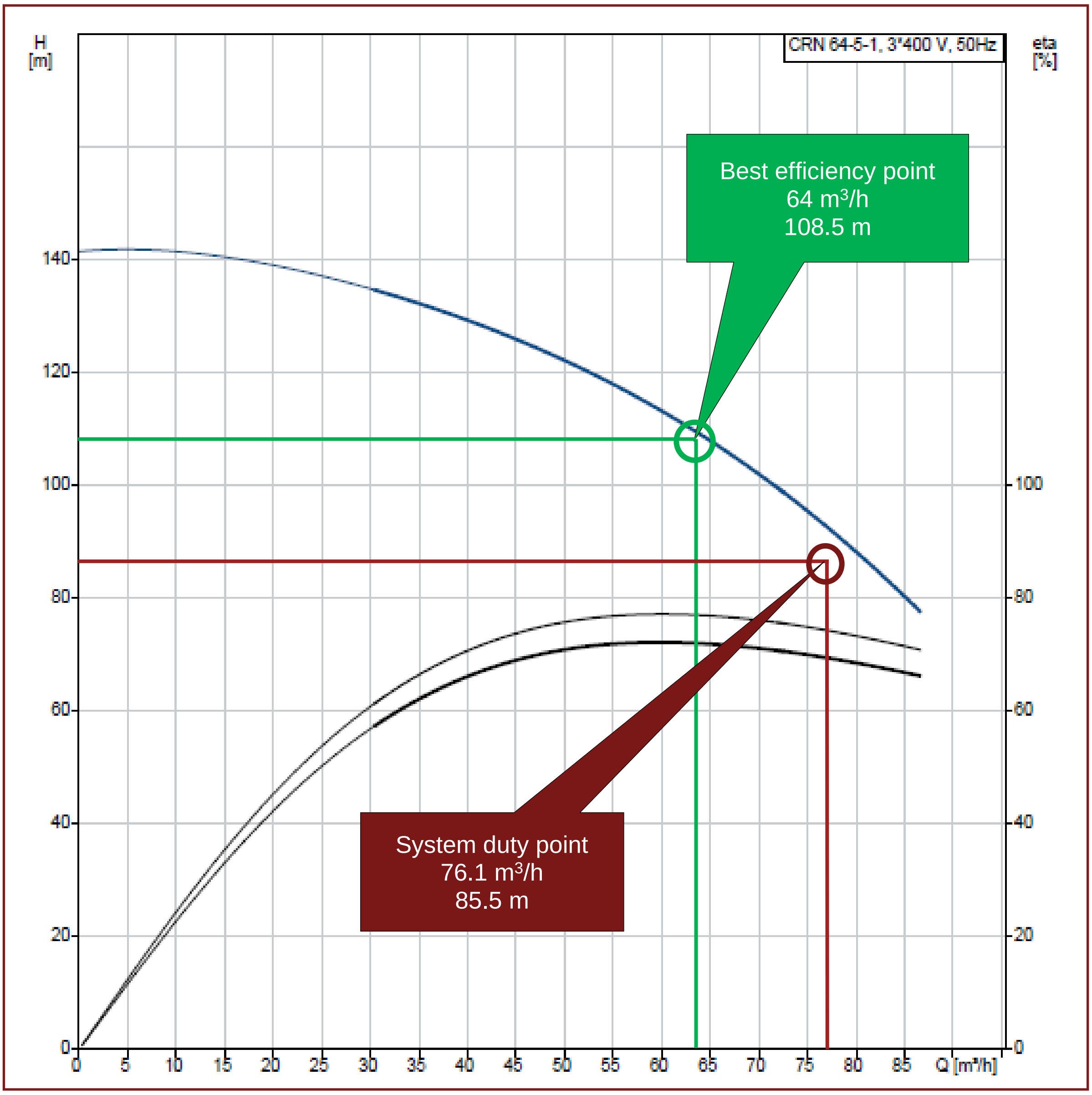


Figure 14 Transfer pump-2 system duty point vs design

The operating hours of the transfer pumps was recorded using power log taken by three-phase power analyser and it was 8.38 hours per day. The total daily water pumped by transfer pumps was 1292.3 m3. The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 9**.

Table 9 Transfer pumps motor performance

Particular	Unit	Motor 1	Motor 2
Voltage	V	415.40	415.40
Current	I	38.80	39.40
Power factor	-	0.919	0.914
Power input	kW	25.65	25.91
Motor Efficiency	%	92.0	92.0
Power shaft	kW	23.60	23.84
Motor loading	**%**	**78.67**	**79.46**

4.1.2. Energy conservation measure

The transfer pump installed is the nearest best pump available for the ststem duty requirements. However, the efficiency of operation can be inproved by installing a variable frequency drive (VFD) on the pump and operating at a lower head to meet the system requirements. The motor is rated at 50 Hz and operates at 2950 rpm. By installing a VFD and operating the motor at 43.67 Hz the speed of shaft can be brought down to 2620 rpm, thus delivering 56.8 m^3/h flow at 85.5 m head, which close to system requirments. The flow, head and power are estimated using pump affinity laws. VFD generally has internal losses of about 2%. In saving estimation is conservative and VFD internal loss is taken as 3%. In addition, it is recommended to replace existing IE2 motor on the pumps with IE4 motor. The efficiency of 30 kW IE4 motor is 2.5% higher than the IE2 rating motor. This will give additional energy savings.

The duty point calculation with VFD is presented in **Table 10** and saving estimation is shown in **Table 11**.

Table 10 Duty point estimation with VFD

Parameter	Unit	Design	Present	Proposed
F – Frequency	Hz	50.00	50.00	43.67
N – Speed	Rpm	2951	2951	2620
Q – Flow	m^3/h	64.0	77.8	56.8
H – Head	m	108.5	85.5	85.5
P – Power	kW	26.0	25.7	18.3[7]

Table 11 Energy saving estimation - VFD on transfer pumps

Particular	Unit		Value
Net daily water duty	m^3		1292.3
Total operating hours	h/day		22.74
Annual energy consumption	kWh/year		151,668
Existing consumption	kWh/year		158,038
Annual energy saving	kWh/year		6,370
Monetary saving	SBD/year		34,942
	USD/year	$	4,368
Cost of 2 VFDs and 2 IE4 motors	USD	$	15,000
Freight cost for 2 VFDs and 2 IE4 motors	USD	$	500
Cost at port in Solomon Islands	USD	$	15,500
Import duty	%		10
GST on imported goods	%		15
Net landed cost	**USD**	$	**20,000**
Simple payback period	**years**		**4.6**
GHG emission reduction potential	**tCO_2/year**		**4.20**

The annual energy saving by installing VFD and IE4 motor on transfer pumps is 6,370 kWh equivalent to monetary saving of US$ 4,368. The investment required for installation of two VFDs and replacement of IE2 motors with IE4 motors is US $ 15,000. The freight cost of shipping from Australia is US$ 500. Overall landed cost in Honiara inclusive of all applicable duties is US$ 20000. Simple payback period of the recommendation is 4.6 years. The GHG emission reduction potential of the recommendation is 4.20 tCO_2 equivalent.

[7] *Considering IE4 motor efficiency*

4.2. Borehole pumps

4.2.1. Performance assessment

The Titinge pump station has four borehole pumps. At the time of study two boreholes were operational. Performance was assessed for these two bore-pumps. The power measurement was taken using three-phase power analyser, flow was measured using ultrasonic water flow meter, head was measured using a water depth measurement instrument available with Solomon Water (Shaun, Hydrogeologist) and head from borehole surface level to receiver tank is measured using digital pressure meter.

The duty-point and best efficiency point of bore-hole pump 2 and 4 are depicted in **Figure 15** and **Figure 16**. The performance assessment of borehole pump 1 and 4 and estimation of operating pump efficiency is presented in **Table 12**.

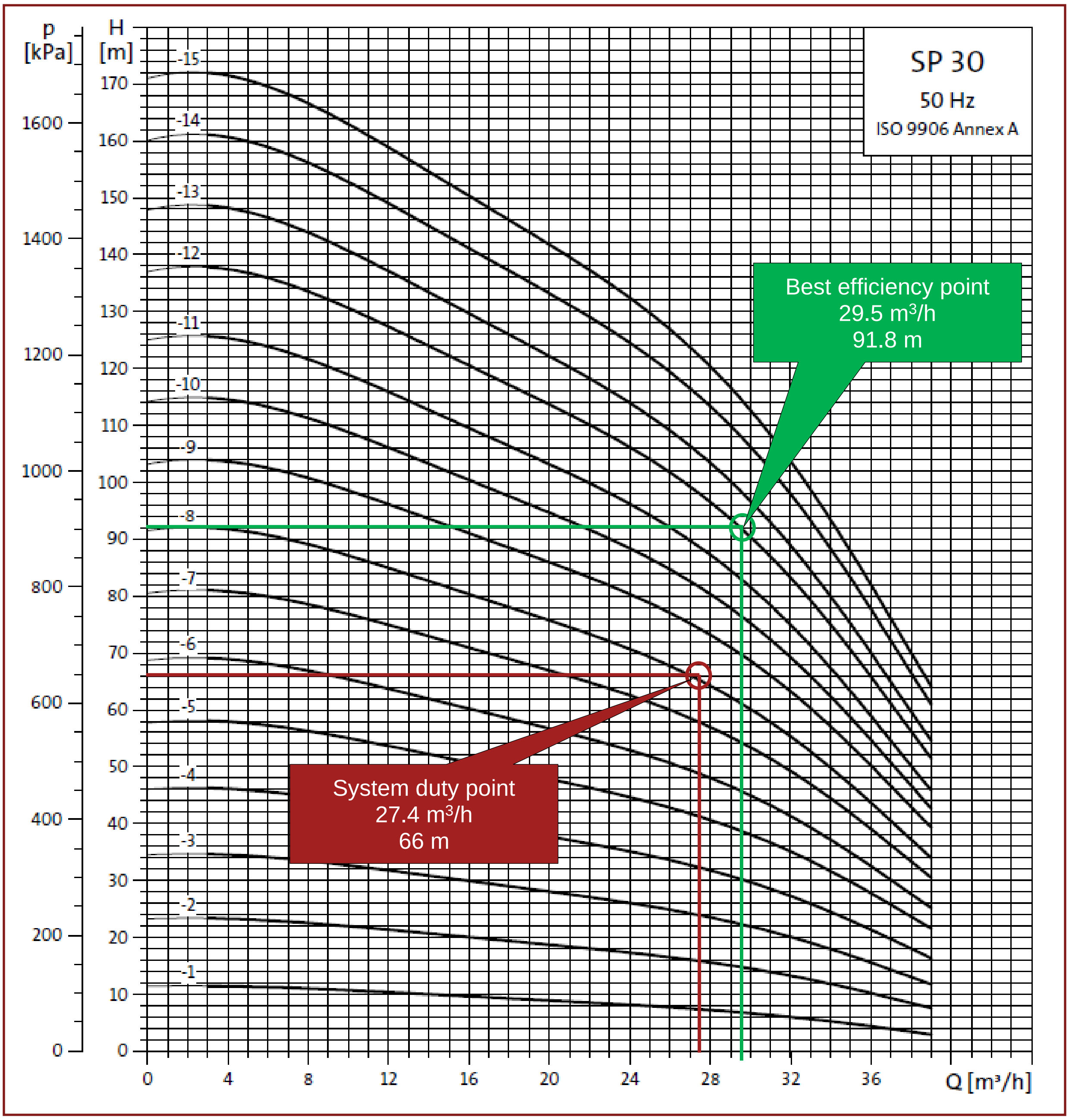


Figure 15 Borehole pump-2 design vs system duty point

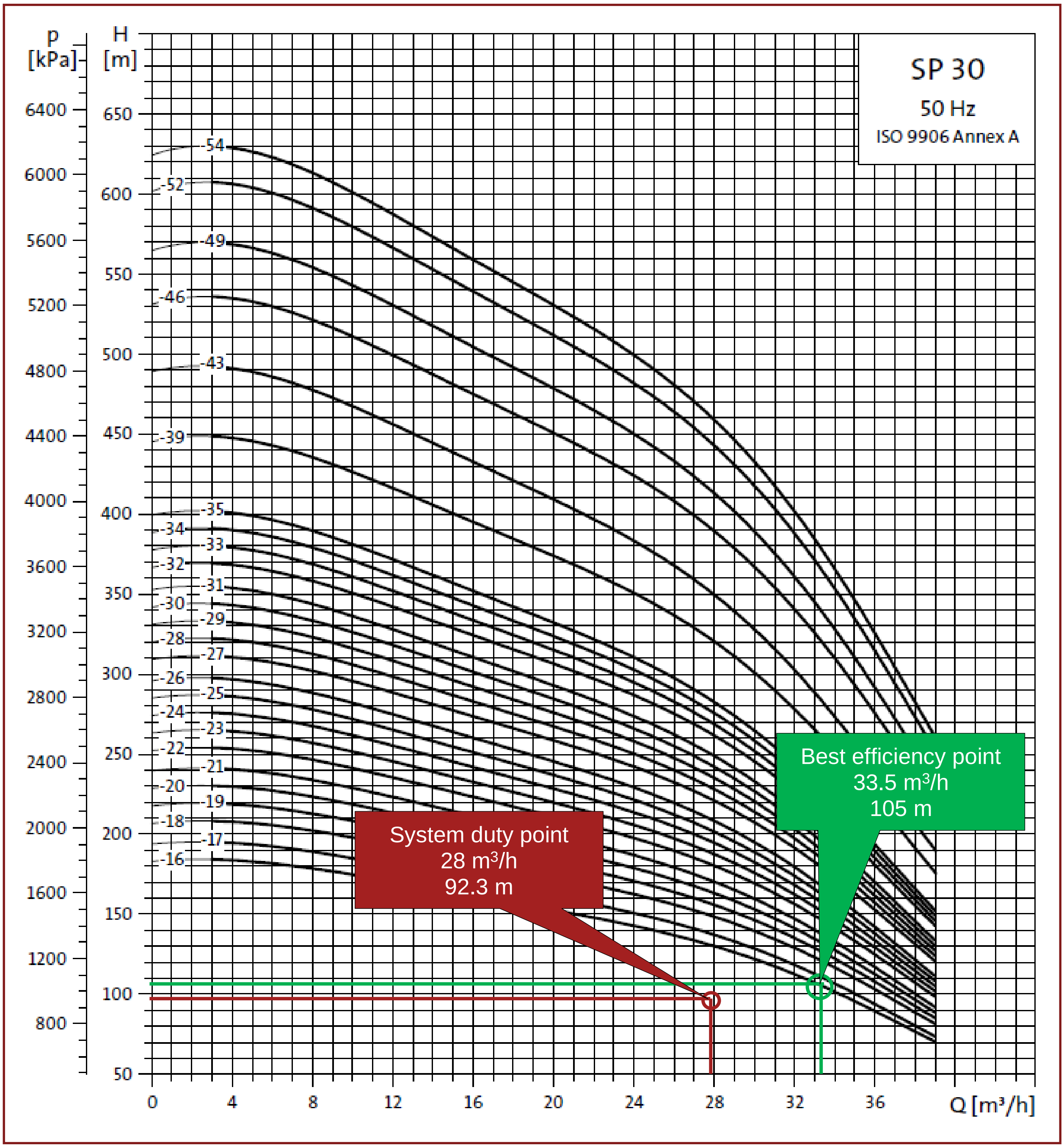


Figure 16 Borehole pump-4 design vs system duty point

The duty points of borehole pump M-2 and M-4 were away from design best efficiency duty point of the pumps. M-2 the actual head was less than design however the flow was close to design. It is requested to check if the pump installed and design specification provided are same or if the pump was replaced with some other design pumps. For M-4, as the actual flow was less than design flow. This could be result of slightly worn impeller due to ageing and erosion due to dirt in suction water.

The valve on the discharge pipe coming out of well was throttlled, leading to a head of 5.9 m for M-2. The estimated head from this point till reservoir is about 4 m, hence the throttling has minimum effect on system head.

For M-4 the valve on the discharge pipe coming out of well was throttled, leading to a head of 17.3 m. The reason for higher head for M-4 as compared to M-2 is physical distance and elevation from pump station.

Table 12 Performance assessment of borehole pump 2 and 4

Particular	Unit	Bore-pump 2	Bore-pump 4
Operating flow	m^3/h	27.40	28.00
Well depth to water level	m	60.00	75.00
Head from surface to receiver tank	m	5.98	17.30
Total head	m	65.98	92.30
Hydraulic power	kW	4.93	7.04
Motor power	kW	12.59	13.93
Pump efficiency	**%**	**47.41**	**61.30**

The operating hours of the bore-hole pumps was taken from the SCADA system. The measured flow rate of water was then converted to arrive at daily water production from borefields, same is presented in **Table 13**.

Table 13 Production from bore-fields

Bore-field	Flow rate (m^3/h)	Operating hours (h)	Daily production (m^3)
Bore-pump 2 (M-2)	27.4	23.6	647.7
Bore-pump 4 (M-4)	28.0	23.0	644.6
Total			**1292.3**

4.2.2. Energy conservation measure

The bore-pumps were operating away from pumps best efficiency duty point. It is recommended to properly size the submersible pump for specific requirement of the bore-pump. **It is suggested that before replacement of the bore-pumps the water inlet screens in the bore-hole must should be cleaned**. In addition, we propose Solomon Water to have a regular half-yearly or yearly maintenance program to ensure efficient extraction of water from bore-field. The pump specification of the existing bore pump, system duty-point and recommended pump is presented in **Table 14**. ***Based on recommendation from Hydrogeologist, the bore pump 1 and 4 will both run in future to meet demand of 1080 m^3 per day against only pump 4 running presently.***

Table 14 Technical specification of existing pump, system duty point and recommended pump

Particular	Unit	Existing Pump	System duty point	Proposed pump
Bore-hole pump M-2				
Model	-	Grundfos SP 30-12	-	Grundfos SP 30-10
Flow rate	m^3/h	29.5	27.4	21.6
Total head	m	91.9	66.0	88.0
Bore-hole pump M-4				
Model	-	Grundfos SP 30-16	-	Grundfos SP 17-12
Flow rate	m^3/h	33.5	28.0	15.1
Total head	m	105.0	92.3	105

The proposed submersible pump as replacement for bore pumps is capable of handling head variation of ± 5 m, without substantial difference in discharge head. Detailed technical specification of the recommended submersible pump is provided in **Appendix A**. ***The energy saving is estimated considering the sustainable daily water production for the bore field shared by Solomon Water Hydrogeologist***. Detailed saving estimation is presented in **Table 15**. The bore pump 2 & 4 will also require a variable frequency drive (VFD) to run pump at optimum duty point.

The annual energy saving by replacing two borehole pumps (M-2 and M-4) is 33,384 kWh equivalent to monetary saving of US $ 22,892. Investment required for installation of two pumps with VFDs is US $ 12,905. The freight cost of shipping from Australia is US $ 500. Overall landed cost in Honiara inclusive of all applicable duties is US $ 18,006. The simple payback period of the recommendation is about nine months. The GHG emission reduction potential of the recommendation is 22.03 tCO_2 equivalent.

Table 15 Borehole pumps energy saving estimation

Particular	Unit	M-2	M-4
Net daily water duty *	m^3	518	363
Proposed pump flow rate	m^3/h	21.6	15.1
Proposed annual energy consumption	kWh/year	78353	64449
Existing annual energy consumption	kWh/year	107486	68700
Annual energy saving	kWh/year	29133	4251
Monetary saving	USD/year	$ 19,977	$ 2,915
Cost of new bore-pumps	USD	$ 6,805	$ 6,100
Freight cost	USD	$ 250	$ 250
Cost at port in Solomon Islands	USD	$ 7,055	$ 6,350
Import duty	%	10	10
GST	%	15	15
Net landed cost of bore-pump	USD	$ 9,444	$ 8,563
Simple payback period	**years**	**0.5**	**2.9**
GHG emission reduction	**tCO_2/year**	**19.23**	**2.81**
**** Arrived based on sustainable flowrate share by Solomon Waters' Hydrogeologist***			

4.3. Electrical system

4.3.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel and bore-pumps panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B** – Main incomer sample power log**.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current. The logging of total power for 24 hours is shown in **Figure 17**.

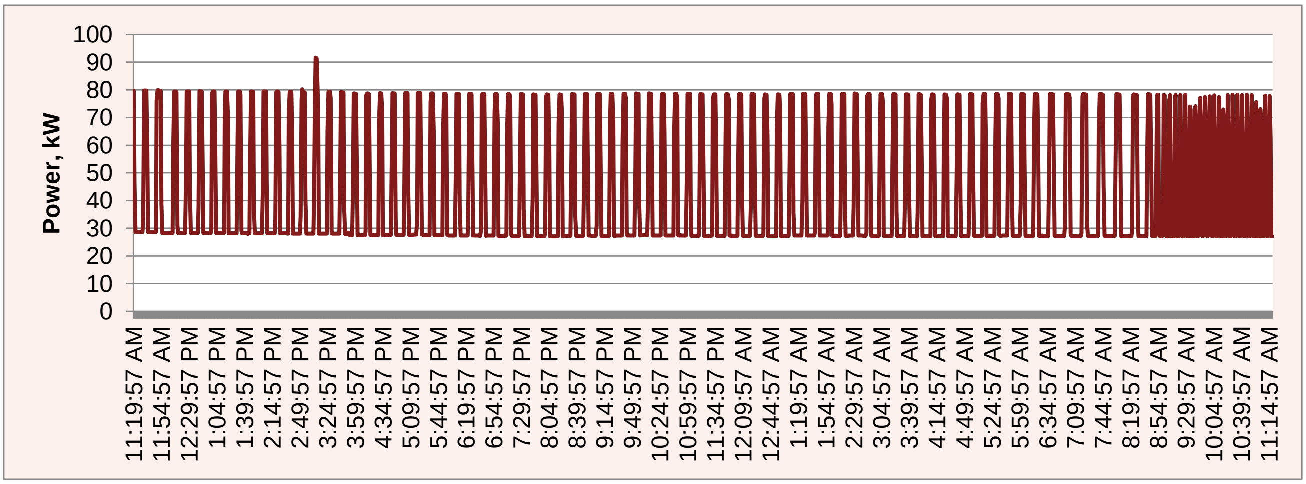


Figure 17 Titinge pump station total power log 24 hours

The power factor (PF) at the main incomer of pump station was varying between 0.69 – 0.86. The PF variation over 24 hours is presented in **Figure 18**.

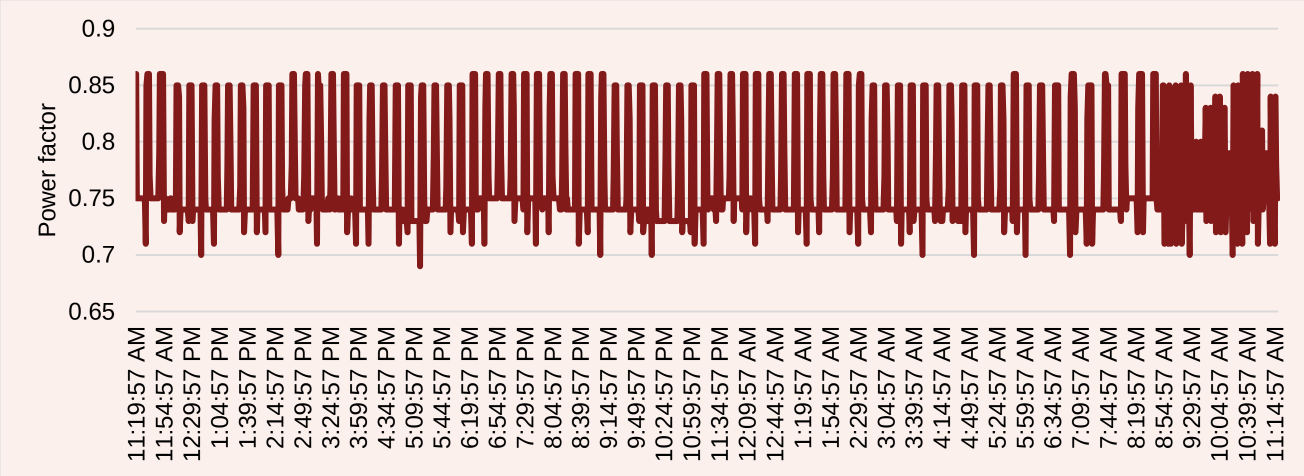


Figure 18 Power factor variation over 24 hours

4.3.2. Automatic Power Factor Correction

Figure 19 APFC panel

The average PF is 0.767 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install a 60 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 25+15+10+5+2+2+1 kVAr. All the banks recommended are detuned capacitors.

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 16** and **Table 17**. The pictorial view of APFC panel is presented is **Figure 19**.

Table 16 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.767
Average daily reactive power	kVAr	33.49
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.17
Annual charge for PF	US$/year	$ 4,299
Capacitor bank requirement	kVAr	60
Investment cost	US$	$ 3,000
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 3,250
Import duty	%	10
GST	%	15
Net landed cost of 60 kVAr APFC	USD	$ 4,688
Simple payback period	**years**	**1.1**

Table 17 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.767
Power factor tariff as % of fuel charge (if PF < 0.90)	%	5.00
Annual fuel charge	US$/year	125919
Annual charge for PF	US$/year	$ 6,296
Capacitor bank requirement	kVAr	60
Investment cost	US$	$ 3,000
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 3,250
Import duty	%	10
GST	%	15
Net landed cost of 60 kVAr APFC	USD	$ 4,688
Simple payback period	**years**	**0.7**

4.4. Lighting system

4.4.1. Performance assessment

The pump station was equipped with 24 six feet fluorescent tube lights (FTL) of 36 W rating (T8). 12 fixtures are installed in pump room and 12 fixtures in electrical & diesel set room. The details of the existing system are provided in **Table 18**.

Table 18 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	12	528
FTL T8	Electrical & DG room	36+8	12	528
Total			**24**	**1056**

4.4.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 6 LED tube pump room and 6 in DG room. Details of the present lighting system are given in **Table 19**. The pictorial view of FTL tube and LED tube is shown in **Figure 20.**

Figure 20 LED tube vs florescent tube

Table 19 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	24	12
Total rating	W	1056	252

Particular	Unit	Existing	Proposed
Operating hours	h/year	250	250
Annual consumption	kWh/year	264	63
Annual saving	kWh/year		201
Monetary saving	SBD/year		1125
	USD/year		$ 137
Investment cost	USD		$ 240
Simple payback	**Years**		**1.75**
GHG emission reduction	**tCO_2/year**		**0.13**

The estimated annual energy savings with new LED lighting system is 201 kWh of electricity, effectively equivalents to a monetary savings of US $ 137. The investment requirement is US $ 240. The simple payback period of the recommendation is 1.8 years. The annual reduction in GHG emission is estimated to be 0.13 tCO_2.

5. Self-generation option

5.1. Renewable energy assessment

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic. Detailed feasibility analysis for solar is presented in this chapter.

5.2. Site description

Titinge pump station is in Mbokono area of Honiara city in Guadalcanal province. The pump station is spread across an area of about 530 m². The projected roof area as seen from the top, over the pump house building is about 160 m². The rest of the area is used servicing purpose and one of the bore-hole is situated inside pump house. There are no buildings nearby to cause shading. Roof is made of concrete and support installation of solar roof top PV modules.

5.3. Solar resource assessment

The solar data source i.e. Global Horizontal Irradiance (GHI) for Honiara, is derived from a Japan International Cooperation Agency (JICA) report on Pilot Survey for Disseminating SME's Technologies for Introduction of Utility Interactive Grid-Connected Photovoltaic Generation System Possessed in Okinawa Prefecture for Small Island Regions, 2015. These values are an estimation of the solar resource on a horizontal surface. Solar data for Honiara is presented in **Table 20**.

Table 20 Daily Global Horizontal Irradiation at site location

Daily Global Horizontal Irradiation in kWh/m²/day											
Latitude -9.45⁰, Longitude 159.96⁰											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

The roof orientation yields optimum results when the tilt angle is equal to the latitude which in this case is 9.4⁰. The sun elevation diagram for the pump station is presented in **Figure 21**.

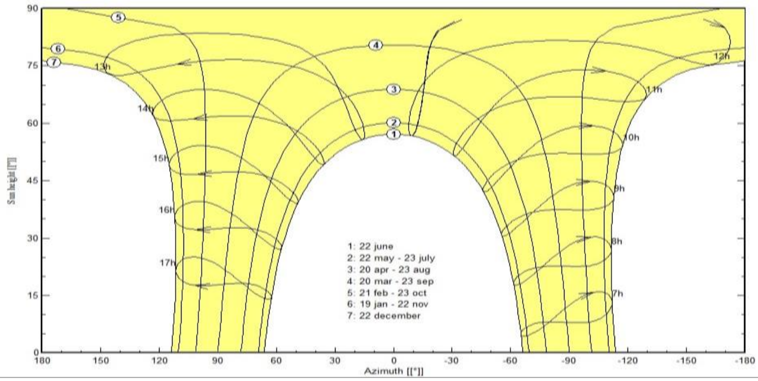


Figure 21 Sun elevation diagram for the site

5.4. System sizing and cost benefit

The effective area available for solar-roof PV installation is 136 m². Capacity for PV systems is measured at Standard Testing Conditions, of 1000 W/m², AM 1.5 and 25°C cell temperature. These conditions may not be the same on site. Site specific capacity varies intermittently with changing irradiance, ambient temperature, wind speed and air mass with respect to time, calendar day and other effects like cloud cover. The Polycrystalline technology generally has efficiency of ~ 16%. Monocrystalline Silicon technology can achieve ~20% although they are more expensive. The power delivered at the interconnection will be further reduced due to inverter efficiency, transformer efficiency, module fouling and cabling losses. The system sizing along with cost benefit considering thin film and monocrystalline technology is presented in **Table 21**. This is considering there is no standby charges fees and the utility i.e. SIEA pays fuel charges to Solomon Water for imported energy to grid which is SBD 2.65 per kWh.

Table 21 Cost benefit of solar roof PV - Thin film and monocrystalline

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m^2	160	160
Utilization area	m^2	136	136
Nominal power	kWp	13.6	21.8
Average global horizontal irradiance	$kWh/m^2/day$	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	20974	33620
Avg fuel charges	SBD/kWh	2.65	2.65
Monetary saving	SBD/year	55547	89038
	USD/year	$ 6,943	$ 11,130
Module cost	USD	$ 12,716	$ 20,346
Supports cost	USD	$ 15,558	$ 15,558
Inverter and wiring cost	USD	$ 4,787	$ 4,787
Transport and mounting cost	USD	$ 18,370	$ 26,755
Cost at port in Solomon Islands	USD	$ 51,431	$ 67,446
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost	USD	$ 64,914	$ 84,933
Simple payback period	**years**	**9.3**	**7.6**

The cost benefit considering present tariff structure is presented in **Table 22**. With present regulation we have considered the standby changes in addition with cost system.

Table 22 Cost benefit of solar roof PV with present tariff

Particular	Unit	Thin-film	Monocrystalline
Nominal power	kWp	13.6	21.8
Annual solar yield	kWh/year	20974	33620
Monetary saving by avoided energy consumption	SBD/year	59392	95202
	USD/year	$ 7,424	$ 11,900
Annual standby charges	USD/year	$ 9,244	$ 14,818
Net landed cost	USD	$ 74,158	$ 99,751
Simple payback period	**years**	10.0	8.4

The detailed analysis for Solar roof PV system sizing was performed on PVSyst software. PVSyst software provides possibility of complex simulation input and output parameters of PV plant and is also commercially to calculate the total production of electricity. As per the PVSyst simulation results, the estimated energy generation for the first year is 21.0 MWh/year, with Specific Energy Yield of 1545 kWh/kW_p/year for thin film technology-based modules. The simulation was run considering monocrystalline cell modules and the estimated energy generation for the first year is 33.6 MWh/year. The detailed results of PVSyst are presented in **Appendix C** – PVSYST simulation results.

5.5. Regulatory framework

The policies, processes and forms for solar system connection to SIEA grid are available in Solar Manual of SIEA. Some of the key highlights are:

- Inverter energy systems that have a continuous rating of no more than 30 kVA for three-phase systems.
- The installation should as a minimum comply with Australian Standards AS3000, AS4777 and AS5033 and all other relevant Australian Standards and Solomon Islands statutory requirements.
- All energy consumed from the grid at the premises will be metered by an import-only meter and billed to the customer under the applicable tariff(s). It is only any ‘excess’ energy will be exported to the SIEA grid. This energy will be metered but will NOT be paid for by SIEA.

The process for solar grid connection as provided by SIEA is presented in **Figure 22**.

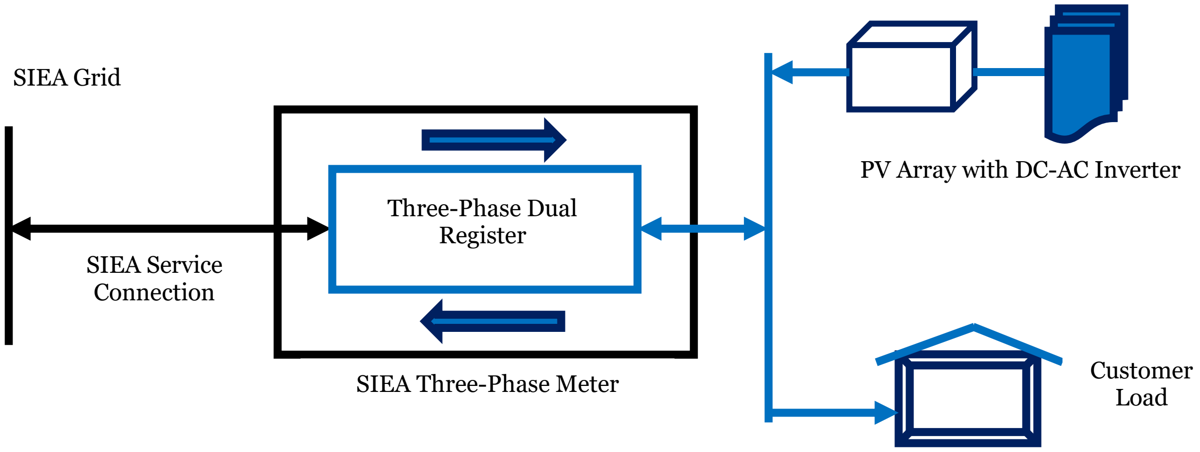


Figure 22 Schematics of solar PV interconnection with SIEA grid

Net metering is a utility billing mechanism that offers a credit to customers who are making excess electricity with their solar panel systems and sending it back to the grid. Solomon Islands at present does not have provision for net metering. However, SIEA is in process of reviewing and restructuring its electricity tariff. It may introduce the net metering option for solar roof top.

*Solar PV option for the pump station is **technically feasible**. But, the financially feasibility is dependent on future SIEA tariff structure. With present tariff structure and regulatory elements, the solar PV is not feasible.*
*The Solomon Water can **take a strategic call** if to invest in solar PV now or to wait for favorable regulatory regime.*

5.6. Other grid-connected solar initiatives in Solomon Islands

The World Bank is implementing a scaling-up of renewable energy project in Solomon Islands in the period 2018 to 2023. The Project intends to improve lifestyle and increase shared prosperity for the low-income household through scaling-up off and on-grid renewable energy projects.

The project is being implemented in four components, which are presented in **Table 23**.

Table 23 Components of WB Scaling-up RE project

Component – 1	Renewable energy hybrid mini-grids – Supply, installation and initial maintenance
Component – 2	Electricity connections in low income areas – Households, micro enterprise and community infrastructure
Component – 3	Grid-connected solar power - Supply, installation and initial maintenance
Component – 4	Enabling environment and project management – including gender related activities, technical assistance and training activities

The third component deals with grid connected solar power. World Bank intendeds to support supply, implementation and initial maintenance of grid-connected solar power projects. The project financing and source of funding for the gird connected solar power is presented in **Table 24**.

Table 24 Project financing and source of funding

Source of Fund	Project financing (US$ million)	Share of financing
International Development Association (IDA) financing credits	3.5	**70%**
IDA financing grant	0.55	**11%**
Trust funds GEF	0.95	**19%**
Total	**5.0**	**100%**

The reason for the solar power project being financially feasible as compared to solar power project proposed at pumps station are as follows:

- About 30% of the total funding for the project is through grant or funds, thus, reducing financing burden
- The remaining cost of project is also in terms of IDA financing credits, which has very low interest charge and repayments been stretched over long term
- The economy of scale, the solar power supported by World Bank is of MW capacity, however, the pump station projects capacity is in kW size
- One component of the World Bank project is on reducing regulatory barriers for solar project while creating the conditions for future replication. (This is in progress)

In case, the solar power project proposed for pump station can be financed through similar mechanism i.e. close to 30% grant/funds, the project finances will improve. Moreover, a further strengthened regulatory regime will be an advantage. The sensitivity analysis of grid connected solar power project with and without grant funding is presented in **Table 25**.

Table 25 Sensitivity analysis - Solar power project with and without grant

Particular	Unit	Without grant	With grant
Solar rooftop plant capacity for Titinge Pump Station	kWp	21.8	21.8
Monetary savings	US $	11130	11130
Investment	US $	84933	59453
Simple payback period	**Years**	**7.6**	**5.3**

6. Conclusion

6.1. Summary of study

Titinge pump station is in Mbokono area of Honiara city in Guadalcanal province. The pump station was commissioned in 2012. The pump station has a 300 m³ water receiver tank, which receives water from four bore-holes. The water from receiving tanks is pumped to Titinge JICA reservoir using three transfer pumps. The pump station produces 1292.3 m³ water daily consuming about 1052.7 kWh electrical energy. The existing specific energy consumption is 0.815 kWh per m³. The study has identified four recommendations for energy conservation (**Table 26**). These recommendations could save annually about 39,955 kWh of electricity. These recommendations have an estimated investment of US $ 38,246 and can yield a monetary savings of US $ 27,396 per year. The annual energy saving is estimated to be 10.4% of total energy consumption by the pump station (**Figure 23**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 26.37 tonnes of CO_2.

Table 26 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Installation of VFD on transfer pumps	6,370	$ 4,368	$ 20,000	4.6	4.20
ECM-2	Replacement of borepump-1 with efficient pump	29,133	$ 19,977	$ 9,444	0.5	19.23
ECM-3	Replacement of borepump-4 with efficient pump	4,251	$ 2,915	$ 8,563	2.9	2.81
ECM-4	Replacement of FTL with LED lights	201	$ 137	$ 240	1.8	0.13
	Total	**39,955**	**$ 27,396**	**$ 38,246**	**1.4**	**26.37**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 27**.

Table 27 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.815 kWh/m³	0.728 kWh/m³
Specific CO_2 emission	0.536 kg CO_2/m³	0.480 kg CO_2/m³

On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 21.8 kWp with an investment of US $ 84,933, it can replace conventional electrical energy equivalent to 33.62 MWh equivalent to GHG emission reduction of 22.2 tCO_2.

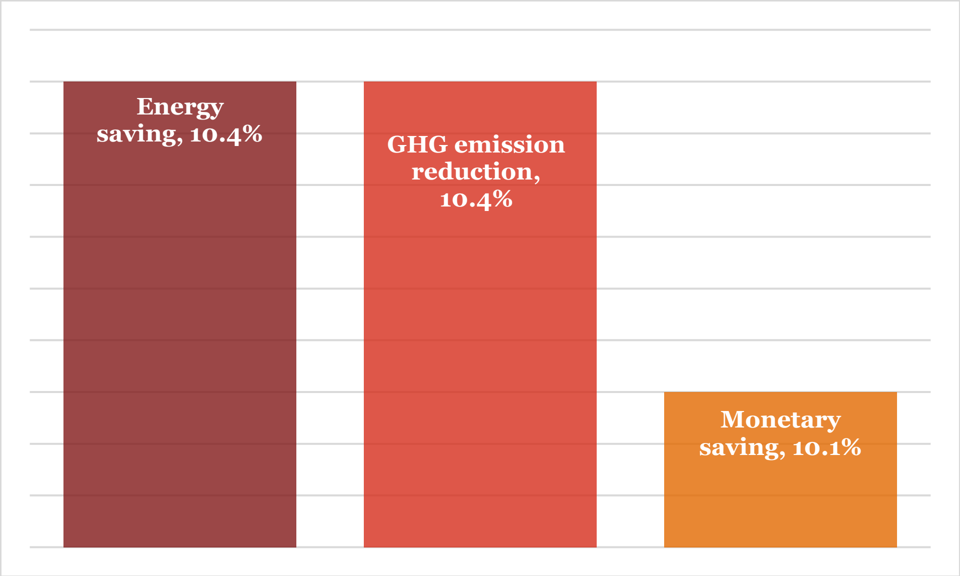


Figure 23 Proposed saving potential

6.2. Funding options

The overall investment proposed for four energy conservation measures for Titinge pump station is US$ 38,246. The simple payback on this investment is 11 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 6 months, which can be followed by VFD on transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Titinge pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

A collage of select pictures taken during the detailed feasibility study is presented in **Appendix D**.

Appendix

Appendix A – Borehole pump technical specification

Borehole pump M-2

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

Qty.	Description
1	**SP 30-10**

Note! Product picture may differ from actual product

Product No.: 13A01910

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 9.2 kW MS6000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	22.1 m³/h
Resulting head of the pump:	92.07 m
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP3

Company name:
Created by:
Phone:

Date: 06/02/2020

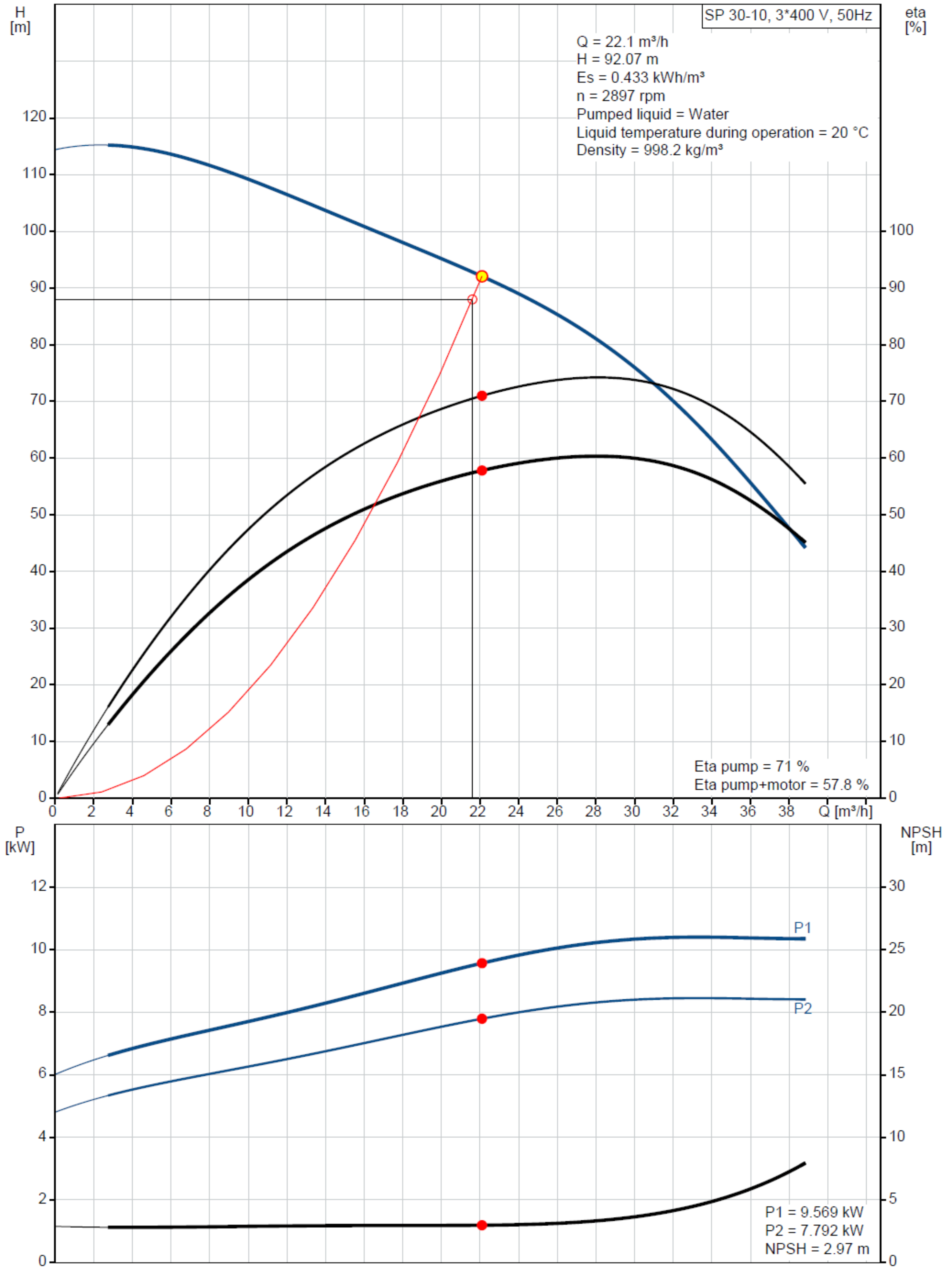
Qty.	Description	
	Motor diameter:	6 inch
	Electrical data:	
	Motor type:	MS6000
	Rated power - P2:	9.2 kW
	Power (P2) required by pump:	9.2 kW
	Mains frequency:	50 Hz
	Rated voltage:	3 x 380-400-415 V
	Rated current:	21.8-21.2-21.2 A
	Starting current:	480-520-550 %
	Cos phi - power factor:	0.84-0.82-0.78
	Rated speed:	2850-2870-2880 rpm
	Start. method:	direct-on-line
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	78195513
	Others:	
	Minimum efficiency index, MEI ≥:	0.50
	ErP status:	EuP Standalone/Prod.
	Net weight:	68.9 kg
	Gross weight:	98.7 kg
	Shipping volume:	0.232 m³
	Danish VVS No.:	388338100
	Finnish LVI No.:	4762739

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

13A01910 SP 30-10 50 Hz

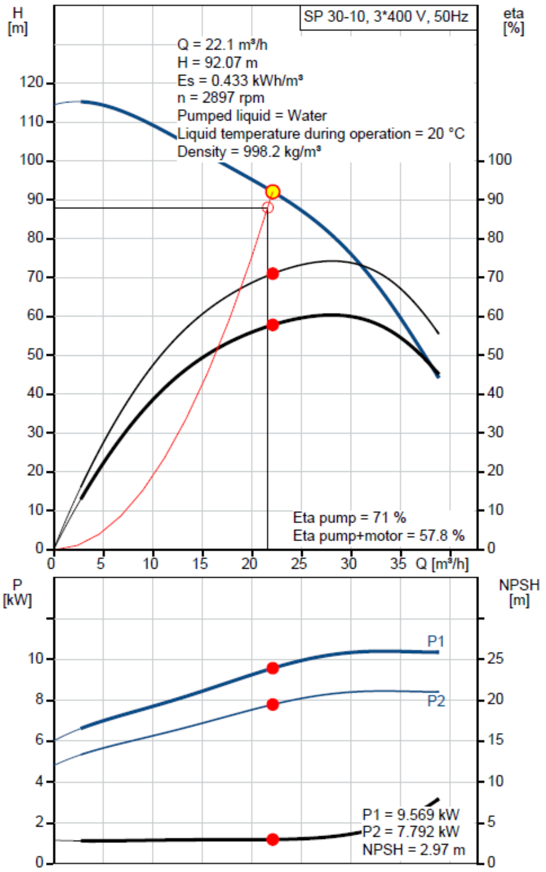


GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

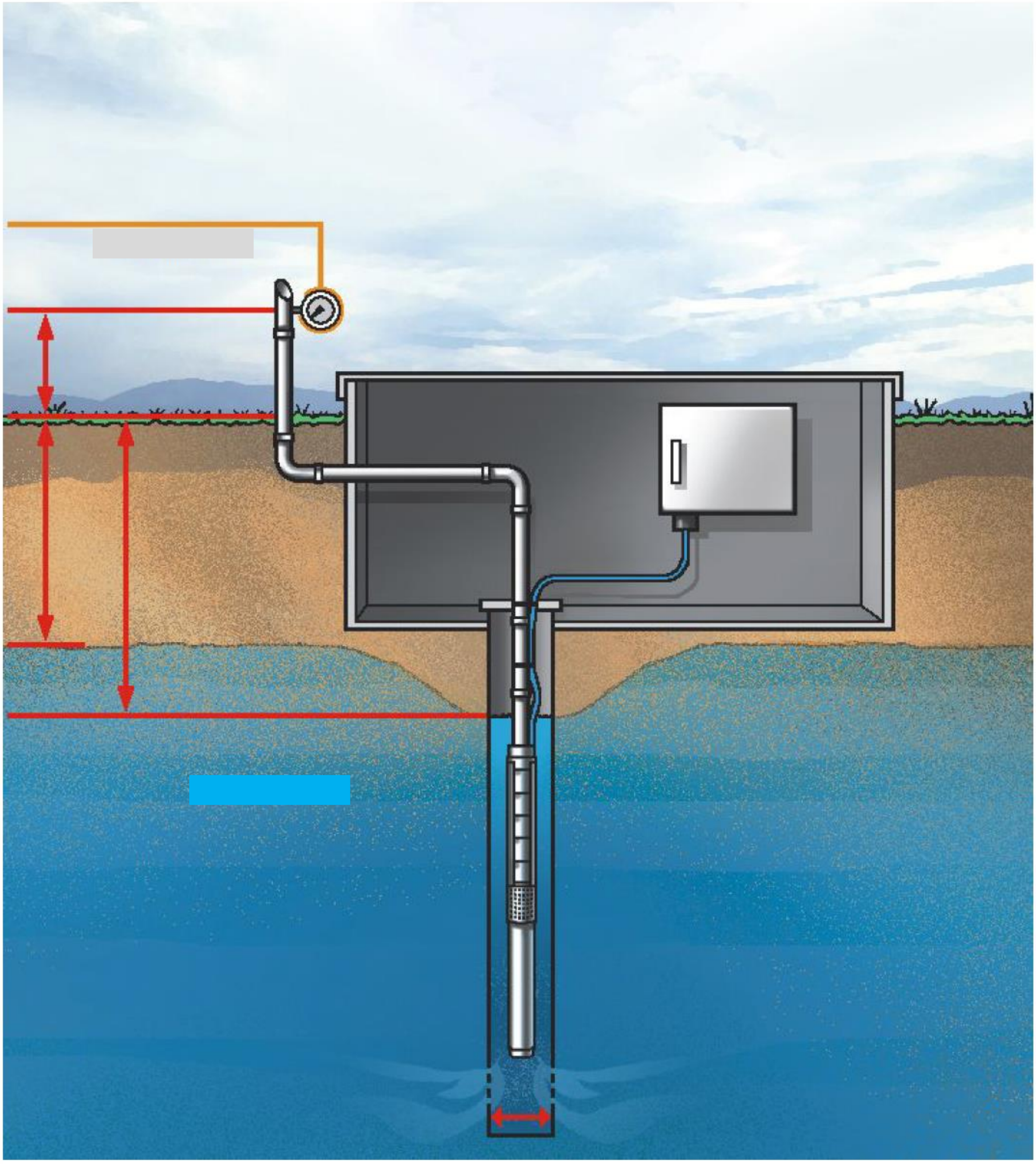
Description	Value
General information:	
Product name:	SP 30-10
Product No:	13A01910
EAN number:	5700390381196
	5700390381196
Technical:	
Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	22.1 m³/h
Resulting head of the pump:	92.07 m
Stages:	10
Impeller reduc.:	NONE
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP3
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS6000
Applic. motor:	GRUNDFOS
Rated power - P2:	9.2 kW
Power (P2) required by pump:	9.2 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-400-415 V
Rated current:	21.8-21.2-21.2 A
Starting current:	480-520-550 %
Cos phi - power factor:	0.84-0.82-0.78
Rated speed:	2850-2870-2880 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	78195513
Others:	
Minimum efficiency index, MEI ≥:	0.50
ErP status:	EuP Standalone/Prod.



GRUNDFOS

Company name:
Created by:
Phone:

Date: 16/10/2019



Borehole pump M-4

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

Qty.	Description
1	**SP 17-12**

Note! Product picture may differ from actual product

Product No.: 12A01912

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 7.5 kW MS6000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	15.18 m³/h
Resulting head of the pump:	106.1 m
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP2 1/2

Company name:
Created by:
Phone:

Date: 06/02/2020

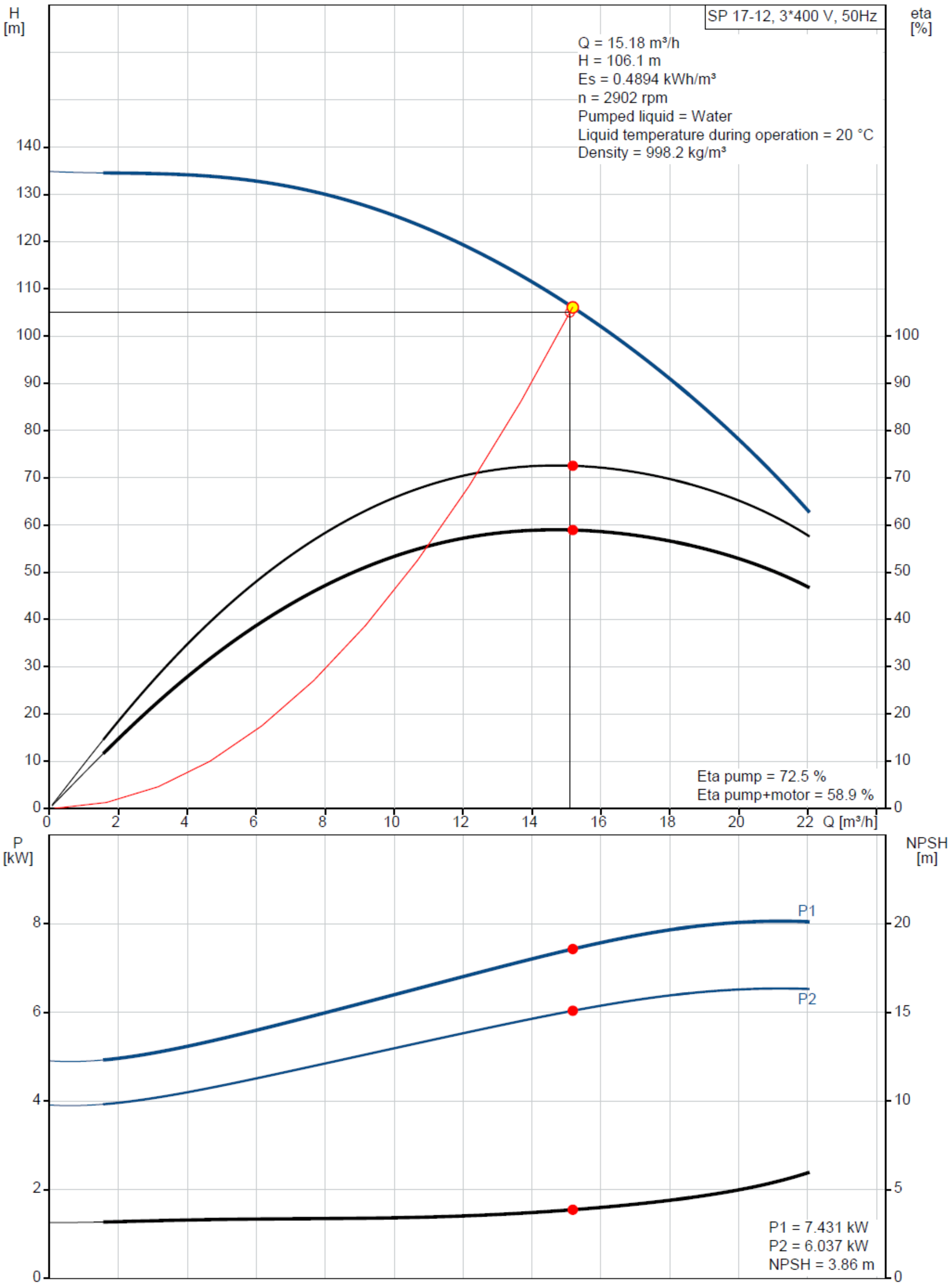
Qty.	Description	
	Motor diameter:	6 inch
	Electrical data:	
	Motor type:	MS6000
	Rated power - P2:	7.5 kW
	Power (P2) required by pump:	7.5 kW
	Mains frequency:	50 Hz
	Rated voltage:	3 x 380-400-415 V
	Rated current:	17.8-17.2-17.2 A
	Starting current:	460-510-530 %
	Cos phi - power factor:	0.84-0.82-0.79
	Rated speed:	2850-2870-2880 rpm
	Start. method:	direct-on-line
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	78195512
	Others:	
	Minimum efficiency index, MEI ≥:	0.70
	ErP status:	EuP Standalone/Prod.
	Net weight:	60.2 kg
	Gross weight:	86 kg
	Shipping volume:	0.2 m³
	Danish VVS No.:	388336120
	Finnish LVI No.:	4762725

GRUNDFOS

Company name:
Created by:
Phone:

Date: 06/02/2020

12A01912 SP 17-12 50 Hz

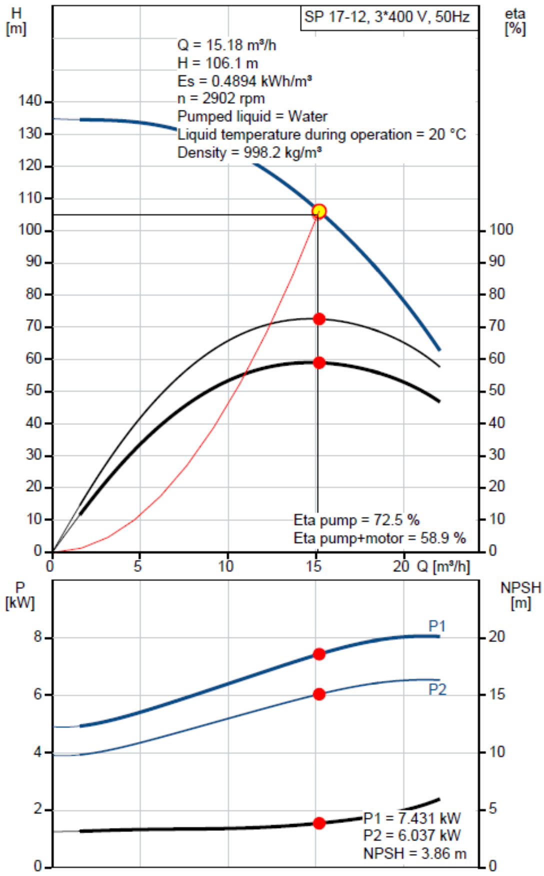


GRUNDFOS

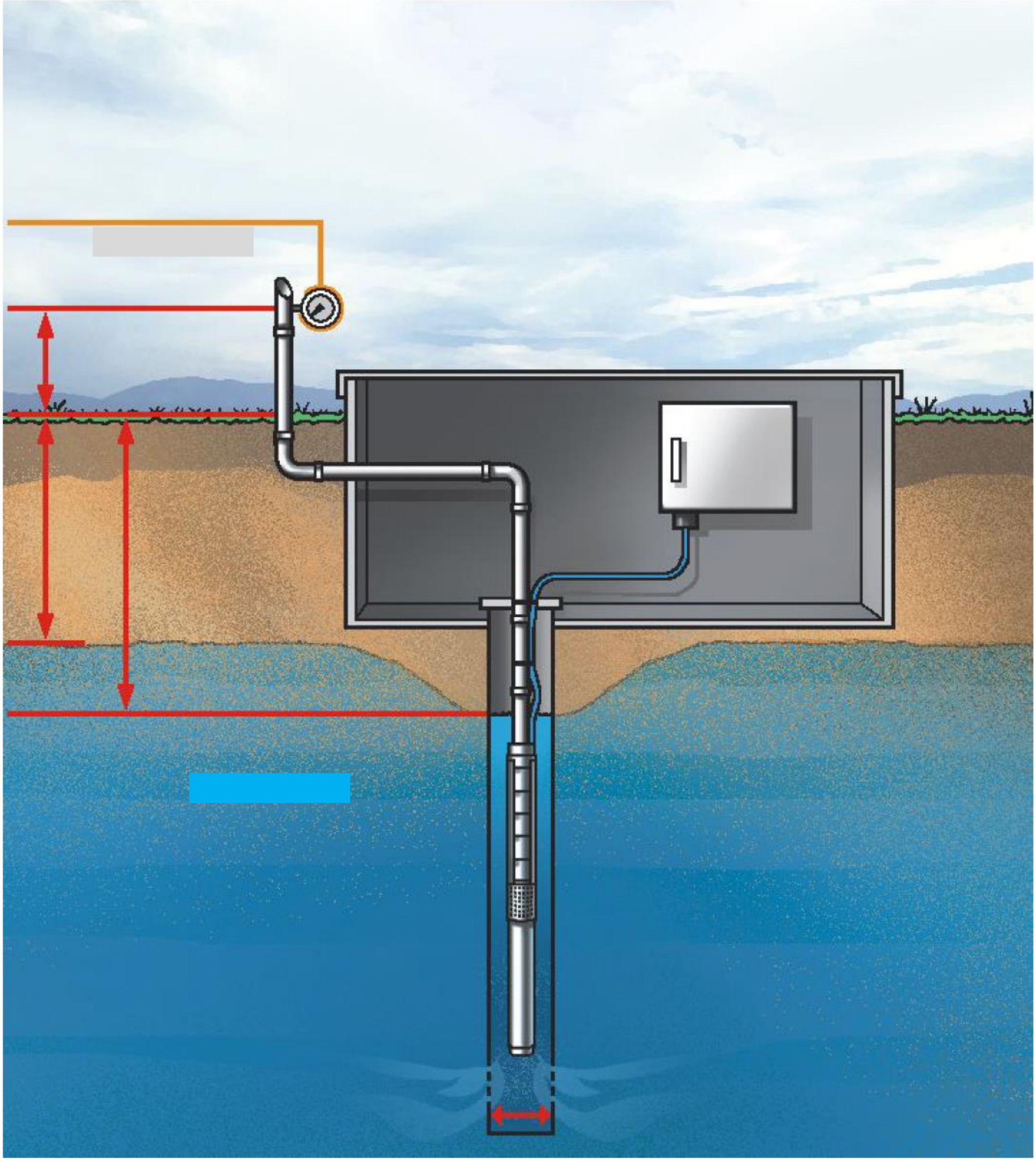
Company name:
Created by:
Phone:

Date: 06/02/2020

Description	Value
General information:	
Product name:	SP 17-12
Product No:	12A01912
EAN number:	5700391131295
	5700391131295
Technical:	
Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	15.18 m³/h
Resulting head of the pump:	106.1 m
Stages:	12
Impeller reduc.:	NONE
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP2 1/2
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS6000
Applic. motor:	GRUNDFOS
Rated power - P2:	7.5 kW
Power (P2) required by pump:	7.5 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-400-415 V
Rated current:	17.8-17.2-17.2 A
Starting current:	460-510-530 %
Cos phi - power factor:	0.84-0.82-0.79
Rated speed:	2850-2870-2880 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	78195512
Others:	
Minimum efficiency index, MEI ≥:	0.70
ErP status:	EuP Standalone/Prod.



GRUNDFOS	**Company name:** **Created by:** **Phone:** **Date:** 16/10/2019



Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
04/09/2019	11:19:57 AM	50.002	414.3	414.3	414.5	130.0	128.3	129.5	79.65	0.86
04/09/2019	11:20:57 AM	49.999	416.4	416.5	416.9	98.2	96.6	96.9	46.23	0.75
04/09/2019	11:21:57 AM	50.000	419.1	419.2	419.6	54.4	51.7	50.7	28.59	0.75
04/09/2019	11:22:57 AM	50.001	419.4	419.2	419.5	54.5	51.8	50.6	28.59	0.75
04/09/2019	11:23:57 AM	50.001	419.4	419.1	419.5	54.5	51.7	50.5	28.59	0.75
04/09/2019	11:24:57 AM	50.002	419.2	419.3	419.2	54.4	51.9	50.6	28.59	0.75
04/09/2019	11:25:57 AM	50.001	418.9	419.1	419.3	54.3	51.7	50.7	28.59	0.75
04/09/2019	11:26:57 AM	50.000	418.9	419.1	419.4	54.3	51.6	50.7	28.59	0.75
04/09/2019	11:27:57 AM	50.000	418.9	419.0	419.3	54.4	51.7	50.7	28.59	0.75
04/09/2019	11:28:57 AM	50.002	418.6	419.1	419.3	54.2	51.6	50.8	28.59	0.75
04/09/2019	11:29:57 AM	50.000	418.9	419.5	419.5	54.2	51.7	50.9	28.59	0.75
04/09/2019	11:30:57 AM	50.000	419.0	419.5	419.3	54.2	51.9	50.7	28.59	0.75
04/09/2019	11:31:57 AM	50.000	417.4	417.7	417.5	91.6	90.8	90.5	33.81	0.71
04/09/2019	11:32:57 AM	49.999	414.1	414.3	414.3	131.4	129.9	130.9	79.74	0.85
04/09/2019	11:33:57 AM	50.003	414.4	414.4	414.8	130.2	128.2	129.9	79.8	0.86
04/09/2019	11:34:57 AM	49.999	414.4	414.5	414.5	130.1	128.5	129.5	79.74	0.86
04/09/2019	11:35:57 AM	49.999	414.5	414.8	414.8	129.8	128.4	129.7	79.74	0.86
04/09/2019	11:36:57 AM	50.002	415.7	415.9	416.0	114.6	113.2	113.7	58.92	0.77
04/09/2019	11:37:57 AM	50.000	419.6	419.8	419.8	54.4	51.9	50.7	28.65	0.75
04/09/2019	11:38:57 AM	50.001	419.7	419.9	420.0	54.5	51.8	50.8	28.65	0.75
04/09/2019	11:39:57 AM	49.999	419.8	419.8	420.0	54.5	51.8	50.7	28.65	0.75
04/09/2019	11:40:57 AM	50.004	419.6	419.8	420.1	54.5	51.8	50.8	28.65	0.75
04/09/2019	11:41:57 AM	50.001	419.6	420.0	420.0	54.4	51.9	50.9	28.65	0.75
04/09/2019	11:42:57 AM	50.000	419.7	420.1	419.9	54.3	52.0	50.8	28.65	0.75
04/09/2019	11:43:57 AM	49.997	419.8	420.0	420.0	54.4	51.9	50.8	28.65	0.75
04/09/2019	11:44:57 AM	49.999	420.0	420.1	420.3	54.5	51.9	50.8	28.65	0.75

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
04/09/2019	11:45:57 AM	49.995	419.9	420.1	420.1	54.5	51.9	50.8	28.65	0.75
04/09/2019	11:46:57 AM	50.004	420.1	420.2	420.4	54.5	51.9	50.8	28.68	0.75
04/09/2019	11:47:57 AM	49.999	420.2	420.3	420.5	54.6	52.0	50.8	28.68	0.75
04/09/2019	11:48:57 AM	50.001	414.3	414.2	414.2	142.5	141.1	141.8	76.02	0.79
04/09/2019	11:49:57 AM	50.001	415.3	415.6	415.3	129.9	128.9	129.4	79.83	0.86
04/09/2019	11:50:57 AM	50.001	415.3	415.6	415.3	129.8	128.9	129.3	79.83	0.86
04/09/2019	11:51:57 AM	50.002	415.3	415.7	415.5	129.7	128.7	129.5	79.8	0.86
04/09/2019	11:52:57 AM	50.002	415.4	415.9	415.5	129.5	128.8	129.3	79.74	0.86
04/09/2019	11:53:57 AM	49.998	415.9	416.0	415.5	129.3	128.7	128.7	79.53	0.86
04/09/2019	11:54:57 AM	50.002	419.1	418.7	418.5	86.8	87.0	86.1	38.94	0.73
04/09/2019	11:55:57 AM	50.000	421.5	420.8	420.8	52.9	52.3	50.5	28.23	0.75
04/09/2019	11:56:57 AM	50.000	421.3	420.8	420.9	52.9	52.5	50.6	28.29	0.75
04/09/2019	11:57:57 AM	50.002	421.5	421.2	421.4	52.9	52.2	50.7	28.23	0.74
04/09/2019	11:58:57 AM	49.999	421.5	421.3	421.6	52.9	52.1	50.9	28.23	0.74
04/09/2019	11:59:57 AM	50.004	421.6	421.6	421.6	52.8	52.2	50.9	28.23	0.74
04/09/2019	12:00:57 PM	50.000	421.6	421.6	421.7	52.8	52.1	50.9	28.23	0.74
04/09/2019	12:01:57 PM	49.993	421.4	421.1	421.5	52.9	52.1	50.8	28.23	0.74
04/09/2019	12:02:57 PM	49.995	421.1	421.2	421.3	52.7	52.1	50.9	28.23	0.75
04/09/2019	12:03:57 PM	49.994	421.1	421.1	421.3	52.8	52.1	50.9	28.23	0.75
04/09/2019	12:04:57 PM	49.996	421.5	421.3	421.6	52.9	52.1	50.9	28.23	0.74
04/09/2019	12:05:57 PM	49.995	421.7	421.5	421.9	53.0	52.1	50.9	28.26	0.74

Appendix C – PVSYST simulation results

Definition of Geographical Site

Geographical Site **Honiara** Country **Solomon Islands**

File New.SIT of 01/10/19 12h40

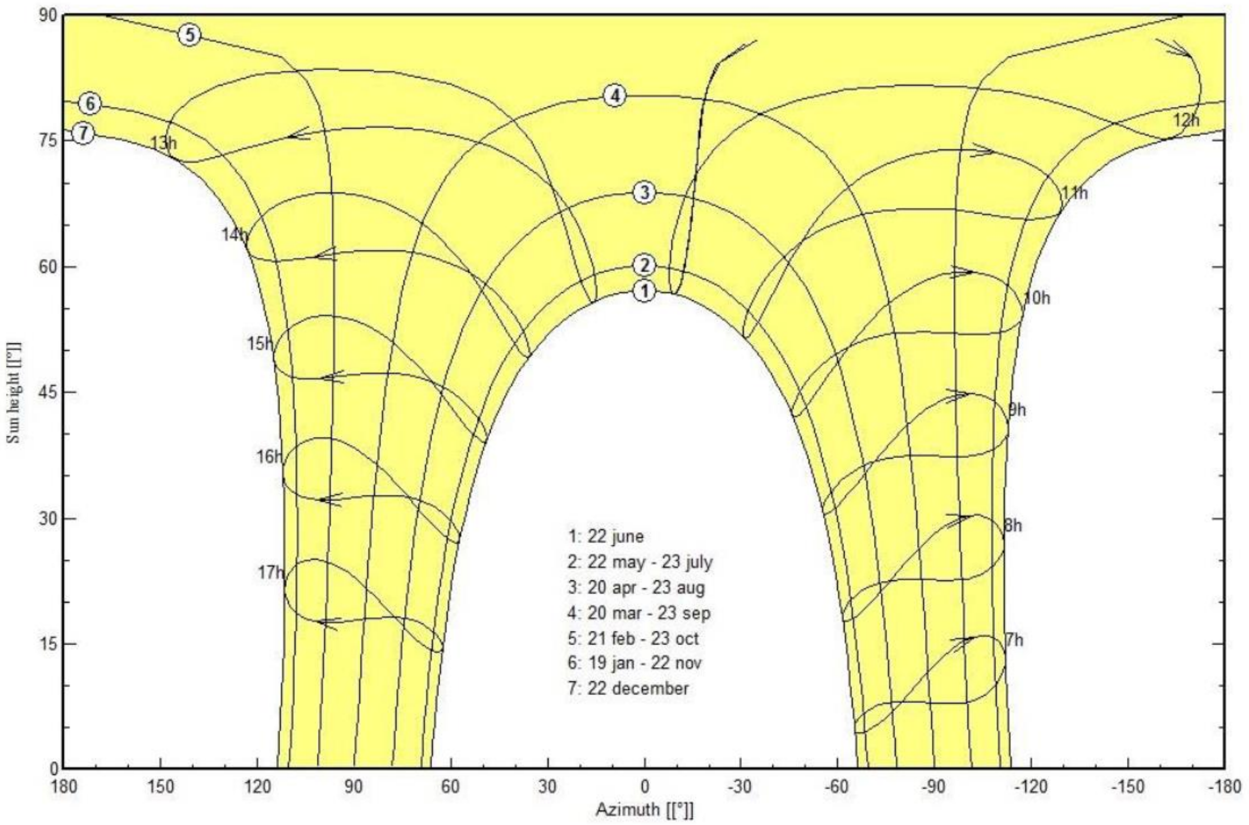
Situation Latitude: -9.45° S Longitude: 159.96° E

Time defined as Legal Time Time zone UT+11 Altitude: 10 m

Monthly Meteo values

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m² day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m² day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

Solar paths at Honiara, (Lat. -9.4517° S, long. 159.9612° E, alt. 10 m) - Legal Time



Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt: 10°		Azimuth 0°

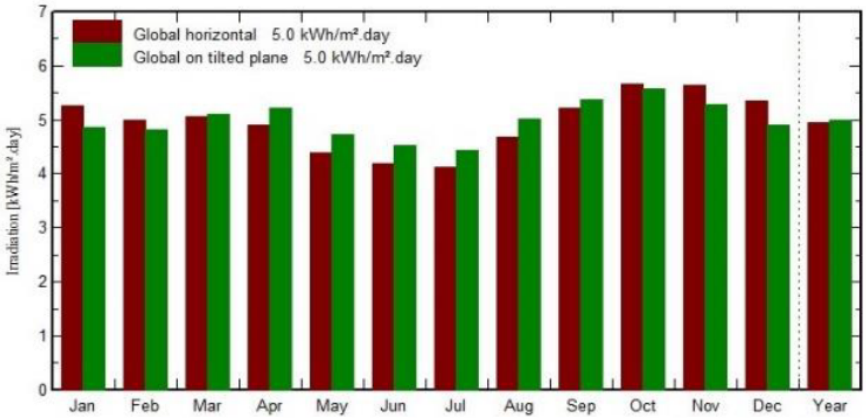
PV Installation main features

Module Type	Standard
Technology	Thin film
Mounting method	Flat roof
Back ventilation properties	Free Standing

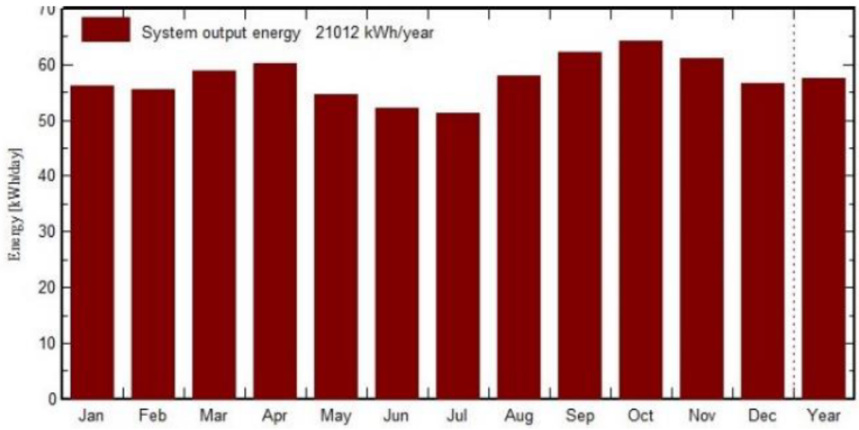
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	13.6 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	21.0 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	56.16	1741
Feb	4.99	4.81	55.58	1556
Mar	5.05	5.10	58.93	1827
Apr	4.91	5.21	60.18	1806
May	4.39	4.72	54.53	1690
June	4.19	4.52	52.16	1565
Jul	4.12	4.43	51.22	1588
Aug	4.67	5.02	58.03	1799
Sept	5.21	5.38	62.09	1863
Oct	5.67	5.57	64.29	1993
Nov	5.64	5.28	61.02	1831
Dec	5.35	4.90	56.59	1754
Year	4.95	4.98	57.57	21012

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude --9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt:10°		Azimuth: 0°

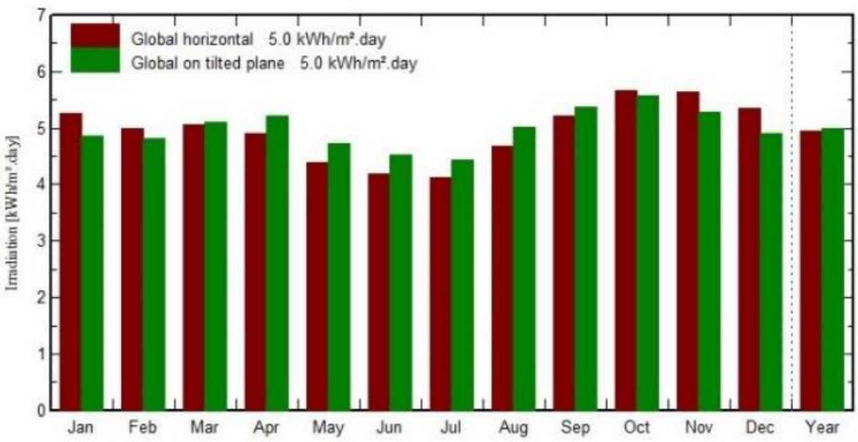
PV Installation main features

Module Type	Standard
Technology	Monocrystalline cell
Mounting method	Flat roof
Back ventilation properties	Free Standing

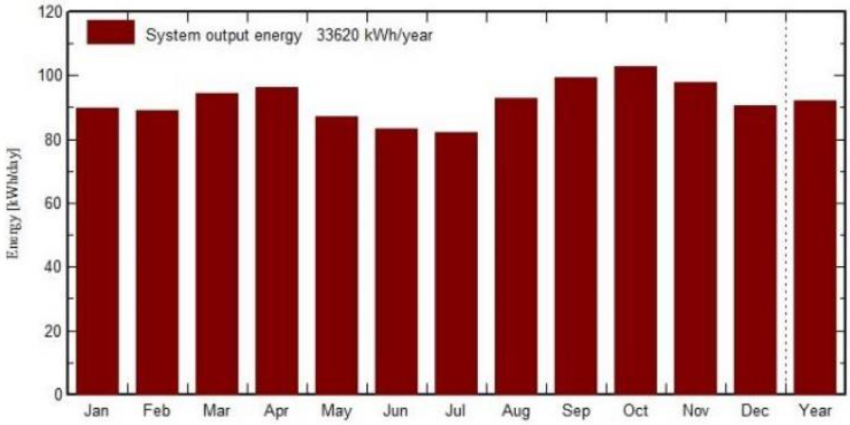
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	21.8 kWp		
Collector Area	Acoll	136 m²		
Annual energy yield	Eyear	33.6 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy

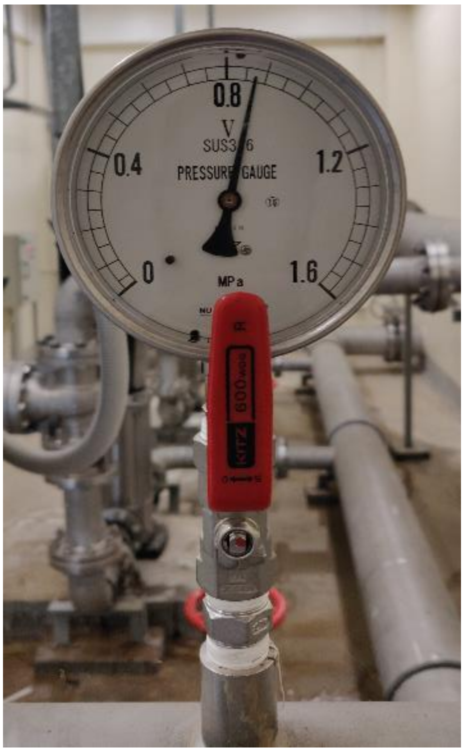


System Output



	GL horiz. kWh/ m² day	Coll. Plane kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	4.86	89.85	2785
Feb	4.99	4.81	88.93	2490
Mar	5.05	5.10	94.29	2923
Apr	4.91	5.21	96.29	2889
May	4.39	4.72	87.25	2705
June	4.19	4.52	83.45	2504
Jul	4.12	4.43	81.95	2540
Aug	4.67	5.02	92.86	2879
Sept	5.21	5.38	99.34	2980
Oct	5.67	5.57	102.9	3189
Nov	5.64	5.28	97.63	2929
Dec	5.35	4.90	90.55	2807
Year	4.95	4.98	92.11	33620

Appendix D – Photographs taken during the study



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The report has been prepared based on study done at the Titinge Pump Station of Solomon Island Water Authority. Our assessment and recommendations are based on the facts and details provided during our visit. If any of these facts or details provided is incomplete or inaccurate, the subsequent analysis might change, causing us to change our opinion. The conclusions drawn and recommendations made are based on the information available at the time of writing this report and PricewaterhouseCoopers will not be responsible to rework any such conclusion or recommendation if new or updated information is made available.

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Detailed Feasibility Report Tuvaruhu JICA Pump Station

Under the project

Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious “technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan”.

The study team is indebted to Mr. Ian Gooden, Chief Executive Officer, Solomon Island Water Authority for showing keen interest in the study and thankful to the progressive management of Solomon Water for their wholehearted support and cooperation for the study and preparation of Detailed Feasibility Report. It is well worthy to mention that the efforts being taken, and the enthusiasm shown by all the personnel towards energy efficiency was admirable. A special thanks to Mr. Mark Waite (Strategic Projects Management Advisor), Mr. Shaun Kies-Ryan (Hydrogeologist), Mr. Noel Orudiana (Project Manager) and Mr. Danny Titiri (Electrical and Mechanical Team Lead) for coordinating the field visits. We would like to thank all the staff for support including technicians, electricians i.e. Mr. Livingston, Mr. Sam and Mr. Moffat.

PwC is grateful to Mr. Hudson Kauhiona, Director Climate Change for his committed support from Ministry of Environment, Climate Change, Disaster Management and Meteorology for executing the technical assistance.

Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Tuvaruhu JICA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station has a 100 m^3 water receiver tank, which receives water from three bore-holes. The water from receiving tanks is pumped to Skyline reservoir using two transfer pumps. The system is designed for continuous operation of three bore pumps. At the time of study all the three bore-pumps were operational. One transfer pump operates continuously, and the second transfer pump switched ON based on level switch in the receiver tank. Details of Tuvaruhu JICA pump station is presented below.

Name of the pump station	Tuvaruhu JICA
No. of transfer pumps	2 (2 Run + 1 ON-OFF)
No. of bore-hole pumps	3
Monthly electricity consumption	51,400 kWh (average of last 12 months)
Monthly water production	54,036 m^3 (based on onsite measurement)
Name and details of contact person	Livingston Kute, Plumber +677-7459172 Danny Titiri, Electrical and Mechanical Team Lead dtitiri@solomonwater.com.sb, +677-8876857
Annual working days	365

A detailed feasibility study of Tuvaruhu JICA pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Tuvaruhu JICA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station has a 100 m^3 water receiver tank, which receives water from three boreholes. The water from receiving tanks is pumped to Skyline reservoir using two transfer pumps. The pump station produces 1776.5 m^3 water daily consuming about 1638 kWh electrical energy. The existing specific energy consumption is 0.922 kWh per m^3. The study has identified four recommendations for energy conservation (**table**). These recommendations could save annually about 151,881 kWh of electricity. These recommendations have an estimated investment of US $ 51,441 and can yield a monetary savings of US $ 104,038 per year. The annual energy saving is estimated to be 24.6% of total energy consumption by the pump station (**figure**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 100.24 tonnes of CO_2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement transfer pump with EE pump	105,582	$ 72,324	$ 35,938	0.5	69.68
ECM-2	Replacement of borepump-1 (MJ-1)	11,339	$ 7,768	$ 7,956	1.0	7.48
ECM-3	Replacement of borepump-3 (MJ-3)	34,931	$ 23,928	$ 7,488	0.3	23.05
ECM-4	Replacement of FTL with LED lights	28	$ 19	$ 60	3.1	0.02
	Total	**151,881**	**$ 104,038**	**$ 51,441**	**0.5**	**100.24**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 26**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.922 kWh/m^3	0.688 kWh/m^3
Specific CO_2 emission	0.609 kg CO_2/m^3	0.454 kg CO_2/m^3

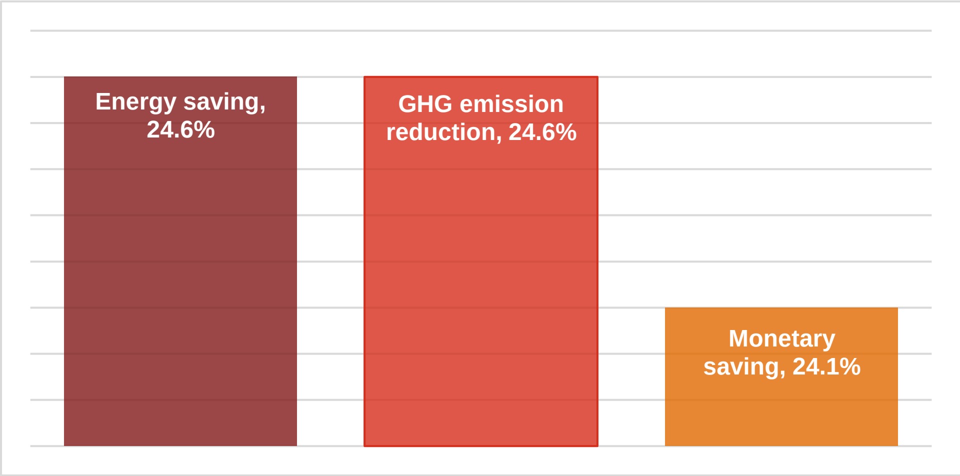
On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 97.8 kWp with an investment of US $ 340,393, it can replace conventional electrical energy equivalent to 151.1 MWh equivalent to GHG emission reduction of 99.7 tCO_2.

Funding options

The overall investment proposed for four energy conservation measures for Tuvaruhu JICA pump station is US$ 51,441. The simple payback on this investment is 6 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 5 months, which can be followed by transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Tuvaruhu JICA pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Identified saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m³	1,000 liters
1 USD	8 SBD

* *Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[1] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

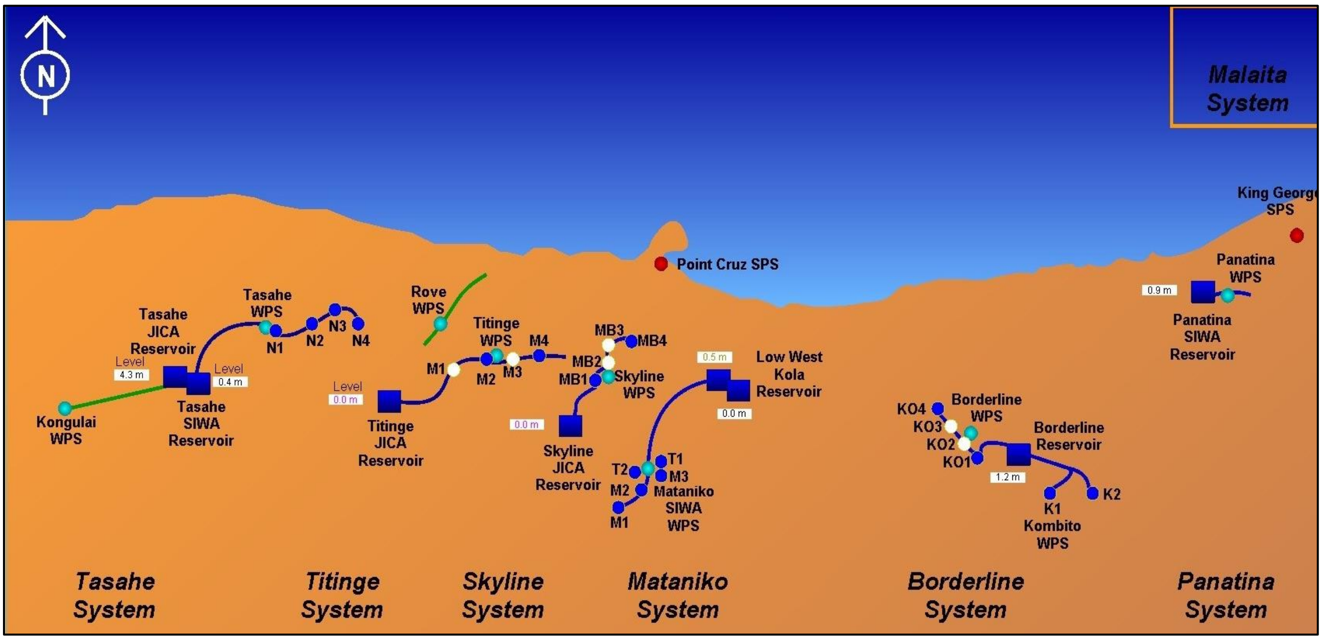


Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[1]

[1] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[2]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

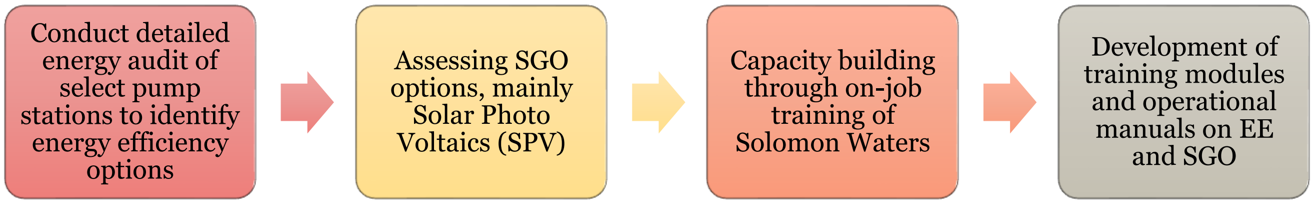


Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[2] *Response Plan, CTCN request ID: 2017000039*

Assessment of Energy Efficiency and RE options
- Field visit for measurement
- Identify energy conservation opportunities
- Identify self generation options

Capacity building through on-job training for Solomon Water
- Prepare training modules and operational modules
- On-the –job hands-on-mentoring on EE and RE implementation

Detail assessments of shortlisted EE and SGO options for Solomon Water
- Technical analysis
- Financial analysis

Monitoring of impact
- Monitoring and evaluation of Impacts
- Report on Gender co-benefits

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

Environmental Benefits
- Enhanced energy efficiency
- Improved energy security
- Lower dependence on imported fuels
- Contribution towards climate change mitigation

Economic Benefits
- Reduced operating (energy) cost for Solomon Water
- Increased investments in energy efficiency and renewable energy

Social Benefits
- Skill enhancement of Solomon Water professionals on EE and RE
- Enhanced profitability leading to availability of funds for increasing water coverage to un-serviced areas

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

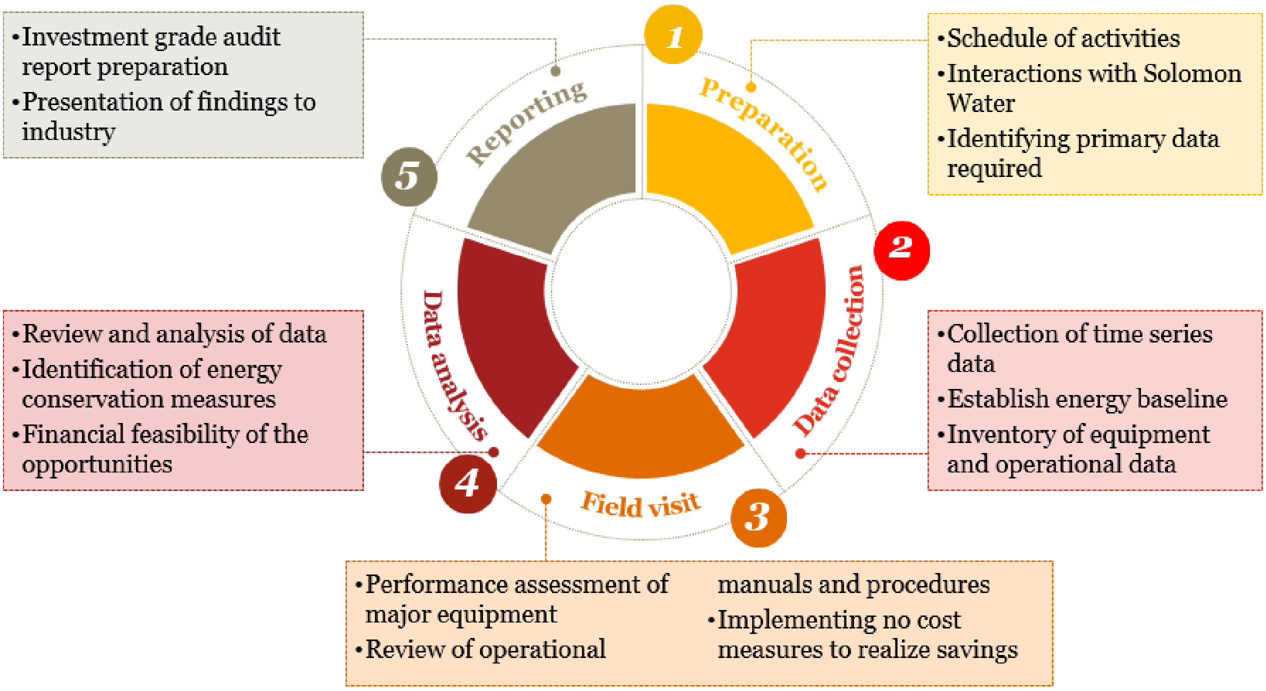


Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Tuvaruhu JICA pump station

2.1. About Tuvaruhu JICA pump station

Tuvaruhu JICA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station has a 100 m3 water receiver tank, which receives water from three bore-holes. The water from receiving tanks is pumped to Skyline reservoir using two transfer pumps. The system is designed for continuous operation of three bore pumps. At the time of study all the three bore-pumps were operational. One transfer pump operates continuously, and the second transfer pump switched ON based on level switch in the receiver tank. The overview of Tuvaruhu pump station as seen in Solomon Water SCADA system is shown in **Figure 6**.

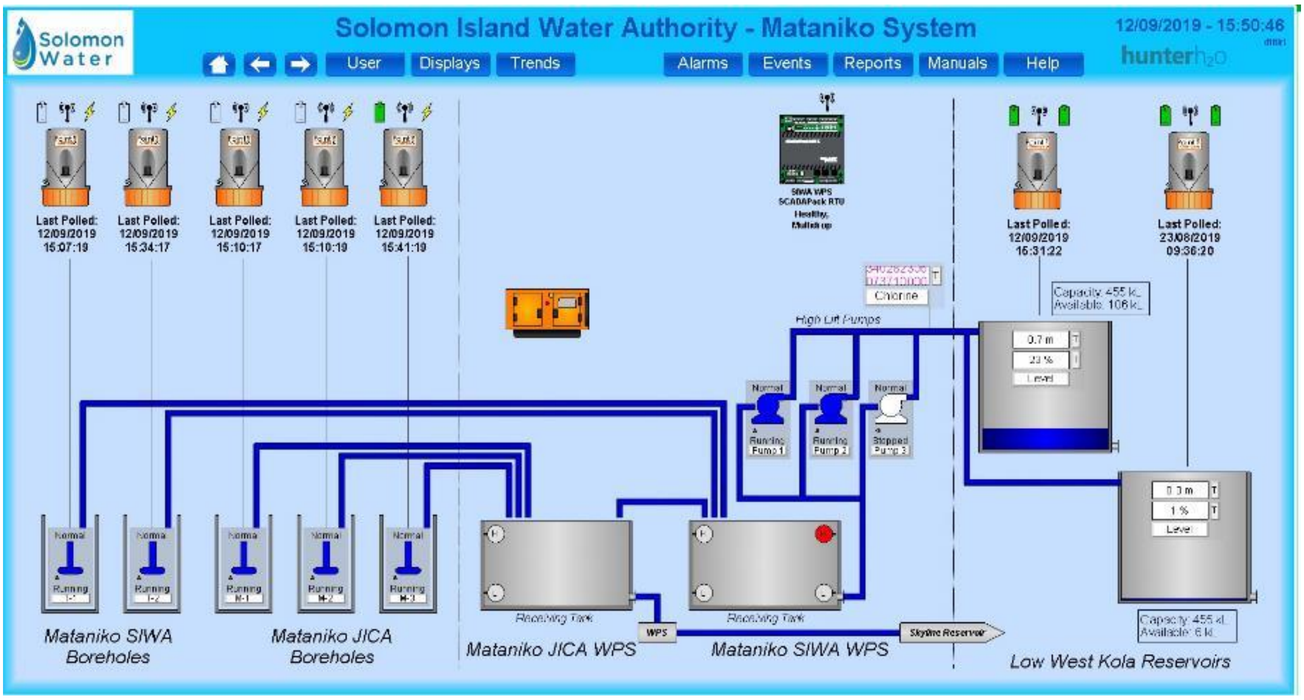


Figure 6 Tuvaruhu (JICA+SIWA) pump station overview - SCADA system

2.2. Transfer pumps

The Tuvaruhu pump station is equipped with two centrifugal end-suction pumps. These two pumps are connected to operate in parallel. Pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Skyline reservoir. Transfer pump 2 operates 24 x 7, with transfer pump switching ON and OFF depending on the level control of the JICA receiver tank. There is provision for third pump for standby, however it is not installed. Design details of transfer pumps, its corresponding motor is presented in **Table 2** and **Table 3** respectively. Pictorial view of transfer pumps is shown in **Figure 7**.

Table 2 Design details of transfer pumps

Particular	Unit	Pump 1	Pump 2
Make	-	Southern Cross	Southern Cross
Model	-	80X50-315 MHC16A-F-CC5CM	80X50-315 MHC16A-F-CC5CM
Design flow	m^3/h	62.0	62.0

Particular	Unit	Pump 1	Pump 2
Design head	m	110	110
Max. head	m	130	130
Pump speed	rpm	2975	2975
Recommended motor	kW	37.0	37.0
Pump efficiency	%	59.5	59.5

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor 1	Motor 2
Make	-	WEG	WEG
Power	kW	37	37
Voltage	V	415.0	415.0
Current	I	63.3	63.3
Power Factor	-	0.86	0.86
Motor speed	rpm	2965	2965
Frequency	Hz	50.0	50.0
Rating	-	EFF E2	EFF E2
Efficiency	%	92.5	92.5

Figure 7 Tuvaruhu JICA transfer pumps

2.3. Borehole pumps

The Tuvaruhu JICA pump station receives water from three borehole pumps. Water is extracted using submersible centrifugal pumps. As the pumps were underground, name plates could not be checked physically. The design details were collected from records available at Solomon Water maintenance office. The system was designed for 24 x 7 operation of three bore pumps. All three bore-pumps were operational during testing.

The design details of bore pumps is presented in **Table 4** and pictorial view of one borehole pump site is presented in **Figure 8**.

Table 4 Design details of borehole pumps

Particular	Unit	MJ-1	MJ-2	MJ-3
Make	-	Grundfos	Southern Cross	Southern Cross
Model	-	SP 46-6	SC series	SC series
Design flow	m^3/h	42.5	43.8	45.3
Design head	m	54	26.7	37
Pump depth	m	36	54	54
Pump efficiency	%	75.0	NA	NA

Figure 8 Typical borehole pump – Tuvaruhu

3. Energy consumption analysis

3.1. Energy source and tariff details

Tuvaruhu JICA pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Tuvaruhu JICA pump station is under Industrial I3 type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff for last 12 months was captured during feasibility study and same is presented in **Table 5**.

Table 5 Electricity tariff details – Last 12 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)			NAC (SBD/month)[3]
		I1[4]	I2[5]	I3[6]	
Aug-18	2.85	3.68	3.16	2.81	3,175.72
Sep-18	2.85	3.7	3.18	2.83	3,199.91
Oct-18	2.71	3.71	3.19	2.84	3,204.42
Nov-18	2.83	3.72	3.2	2.85	3,218.49
Dec-18	2.81	3.75	3.23	2.87	3,242.95
Jan-19	2.77	3.77	3.24	2.89	3,258.18
Feb-19	2.49	3.11	2.68	2.38	2,690.01
Mar-19	2.71	3.79	3.26	2.90	3,277.82
Apr-19	2.53	3.61	3.11	2.77	3121.85
May-19	2.64	3.85	3.31	2.95	3328.04
Jun-19	2.21	3.85	3.31	2.95	3,324.80
Jul-19	2.38	3.84	3.3	2.94	3,316.60
Average	**2.65**	**3.70**	**3.18**	**2.83**	**3,196.57**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 18 months for Tuvaruhu JICA pump station was analyzed. The average electricity tariff and consumption for last 12 months was evaluated. These 12-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 12 months (August 2018 to July 2019) was 616,800 kWh. The bill amount corresponding to this consumption was SBD 3.45 million i.e. USD 431,504.

The electricity consumption along with monthly energy charges is presented in **Table 6**. Variation of electricity consumption is presented in **Figure 9**.

---

[3] *I3 connection electricity consumption>6000 kWh*
[4] *First 1300 units of the monthly consumption*
[5] *Next 4700 units of the monthly consumption*
[6] *Remaining consumption of the month*

Table 6 Electricity consumption details

Month	Consumption	NAC	Fuel charge	Non-fuel charge			Total
	kWh	(SBD)	(SBD)	I1	I2	I3	(SBD)
Aug-18	55,200	3,176	157,320	4,784	14,852	138,252	**318,384**
Sep-18	54,560	3,200	155,496	4,810	14,946	137,425	**315,877**
Oct-18	54,480	3,204	147,641	4,823	14,993	137,683	**308,344**
Nov-18	52,560	3,218	148,745	4,836	15,040	132,696	**304,535**
Dec-18	52,720	3,243	148,143	4,875	15,181	134,086	**305,529**
Jan-19	51,520	3,258	142,710	4,901	15,228	131,553	**297,650**
Feb-19	46,800	2,690	116,532	4,043	12,596	97,104	**232,965**
Mar-19	40,760	3,278	110,460	4,927	15,322	100,804	**234,790**
Apr-19	53560	3,122	135,507	4,693	14,617	131,741	**289,680**
May-19	43,760	3,328	115,526	5,005	15,557	111,392	**250,808**
Jun-19	54,880	3,325	121,285	5,005	15,557	144,196	**289,368**
Jul-19	56,000	3,317	133,280	4,992	15,510	147,000	**304,099**
Average	**51,400**	**3,197**	**136,054**	**4,808**	**14,950**	**128,661**	**287,669**
Annual	**616,800**	**38,359**	**1,632,645**	**57,694**	**179,399**	**1,543,932**	**3,452,029**

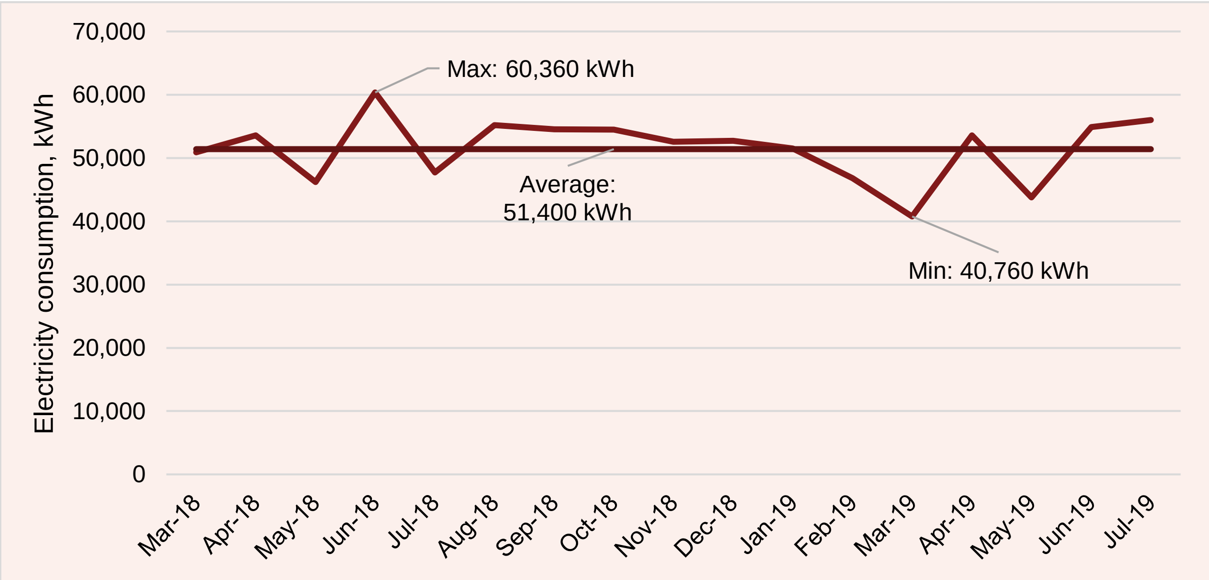


Figure 9 Electricity consumption profile March 2018 – July 2019 (18 months)

Key observations for the period August 2018 to July 2019:

- Monthly average consumption of electricity was 51,400kWh (varying between 60,360 to 40,760)
- Average electricity tariff (excluding fixed NAC) was SDB 5.53 per kWh (US$ 0.69 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.65 per kWh (US¢ 33.1 per kWh)

Average monthly electricity consumption of Tuvaruhu JICA Pump Station is 51,400 kWh

A sample electricity bill of Tuvaruhu JICA pump station is presented in **Figure 10**.

Solomon Islands Electricity Authority
trading as SOLOMON POWER

INVOICE / STATEMENT

Customer
SIWA- Tuvaruhu JICA Pump Station
P O Box 1407
Honiara

Date	06/January/2019
Customer Number	11165-05
Customer Type	**INDUSTRIAL**
Customer Category	**I3**

Location: Tuvaruhu JICA Pump Station
Tuvaruhu

Previous Month

Balance at Previous Account Date	$610,063.84
Payment Received to 19 Dec Thank you	($304,535.29)
Balance Prior to 6 Jan 19	$305,528.55

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$297,650.38	$305,528.55	$0.00	$0.00	$603,178.93

Month 06/January/2019

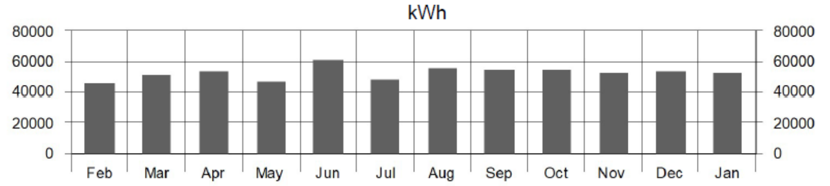
Readings from 6/Dec/2018 to 6/Jan/2019 **Days** 31

Usage

	Meter no.	Previous	Present	Multi	Units
1	216077978	16,732	18,020	40	51,520

Total **51,520.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 625600 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	I3	Days	31	3,258.18		3,258.18
Fuel	I1	kWh	51,520.00	2.7700	1.0000	142,710.40
Non-Fuel	I1	kWh	1,300.00	3.7700	1.0000	4,901.00
	I2	kWh	4,700.00	3.2400	1.0000	15,228.00
	I3	kWh	45,520.00	2.8900	1.0000	131,552.80
			51,520.00			151,681.80

TOTAL THIS PERIOD	**$297,650.38**
TOTAL DUE	**$603,178.93**
FINAL DATE FOR PAYMENT:	21/January/2019

No further notices will be issued. Unpaid accounts will have supply disconnected.
Previous month balances are payable immediately.

Figure 10 Sample electricity bill of Tuvaruhu JICA pump station

The total electricity consumption in the pump station can be categorized in four parts: (a) transfer pumps, (b) borehole pumps, (c) lighting system and (d) electrical system losses and miscellaneous. The average consumption by each category is presented in **Figure 11**.

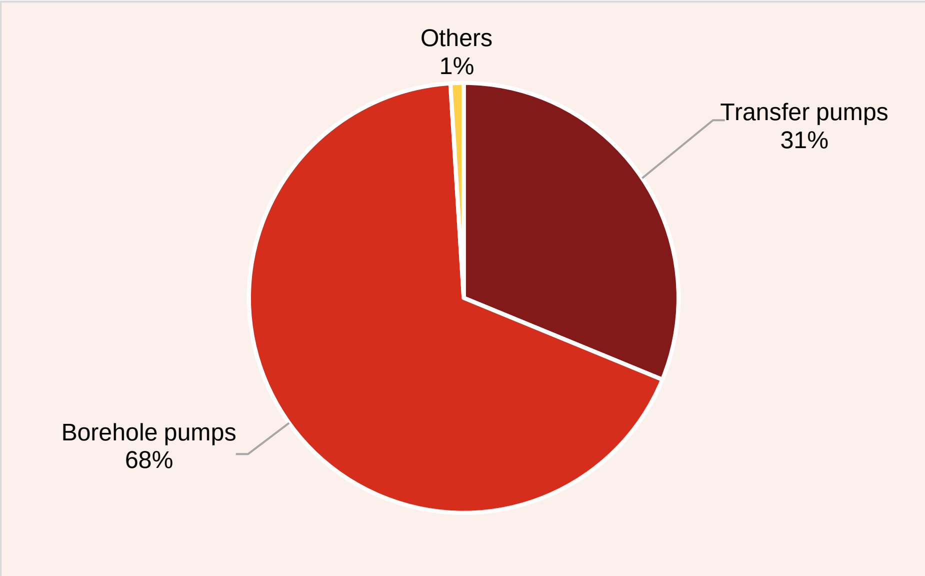


Figure 11 Electricity consumption share

3.3. Specific energy consumption

The daily water production from the bore-fields was 1776.5 m^3 and the daily energy consumption was 1638 kWh of electricity. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 12 months data, which was 1690 kWh. The specific energy consumption is presented in **Table 7**.

Table 7 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	1776.5
Daily electricity consumption	kWh	1638
Specific energy consumption	**kWh/m^3**	**0.922**

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with two transfer pumps. These are end-suction centrifugal pumps with stainless steel impeller. Pumps are of Southern Cross make and are driven by individual 37 kW motor. There is provision for third pump for standby, however it is not installed. During the site visit both pumps were operational and performance assessment test was conducted on pumps individually.

The performance assessment of transfer pumps was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump 2 operates 24 x 7, with transfer pump 1 switching ON and OFF depending on the level control of the JICA receiver tank. The daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current.

Figure 12 shows water flow measurement using non-intrusive ultrasonic water flow meter, pressure measurement and power measurement of the transfer pump.

Figure 12 Water flow, head and power measurement photograph

The measured data such as operating hours and flow are verified using system data available at Solomon Islands Water Authority. The performance assessment of transfer pumps is presented in **Table 8**.

Table 8 Performance assessment of transfer pumps 1 and 2

Particular	Unit	Pump 1	Pump 2
Operating flow	m^3/h	57.50	62.10
Suction head	m	-1.0	-1.0
Discharge head	m	107.0	107.0
Total head	m	106.0	106.0
Hydraulic power	kW	16.61	17.94
Motor input power	kW	38.37	39.45
Shaft power	kW	35.49	36.49
Pump efficiency	**%**	**46.80**	**49.16**

The operating efficiency of the transfer pumps 1 and 2 were 46.8% and 49.2%, which is less than design efficiency of the pump, 59.5%. The drop-in efficiency from design can be attributed to system duty point being away from design best efficiency point of the pump.

The actual duty point and best efficiency point of pump 1 and 2 are depicted in **Figure 13,** and **Figure 14.**

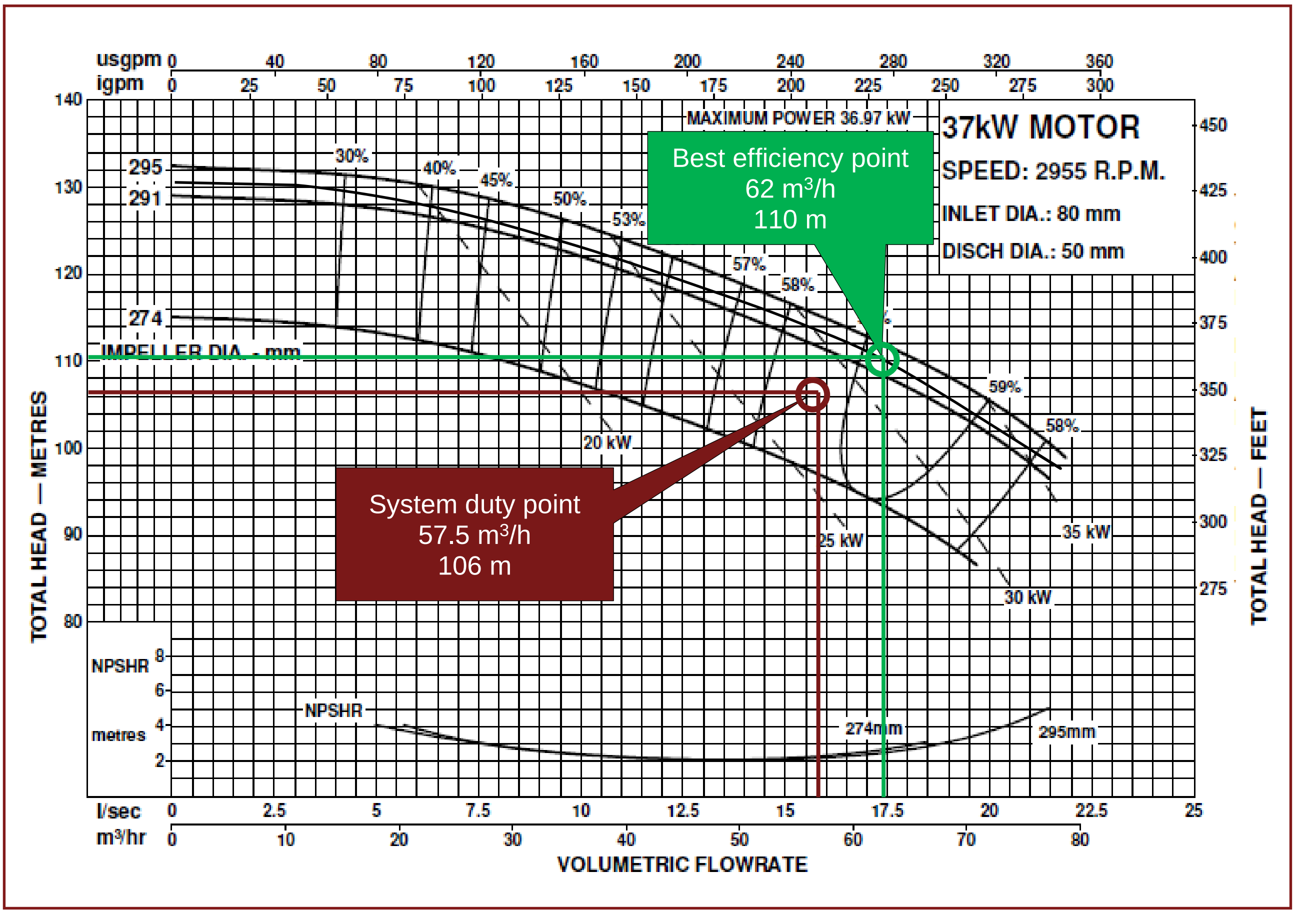


Figure 13 Transfer pump-1 duty point vs design

The system head of transfer pump-1 is close to design head however there is a drop in the flow rate, this can be attributed to wear in impeller due to ageing, as the pump is over a decade old.

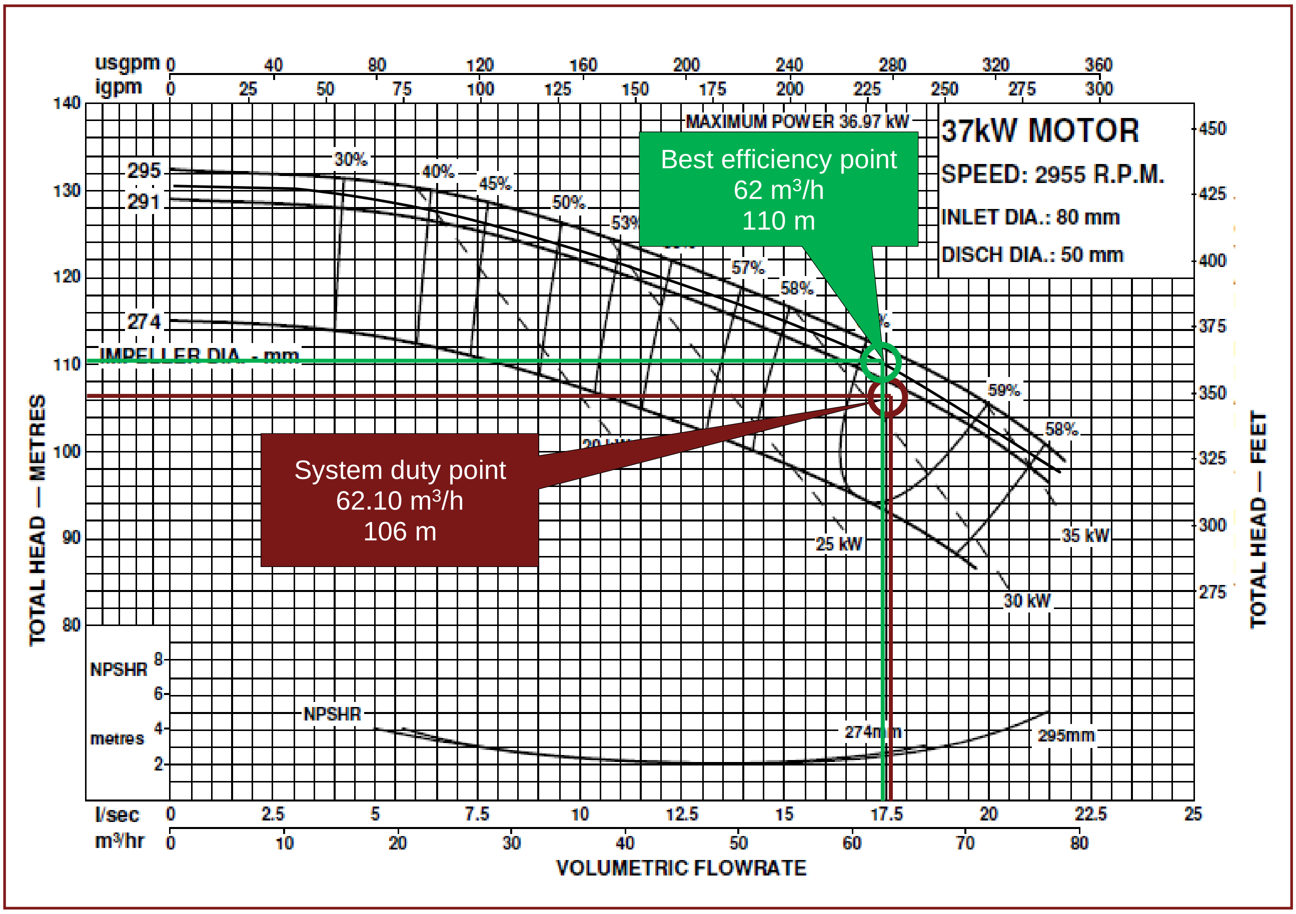


Figure 14 Transfer pump-2 duty point vs design

The system head of transfer pump-1 is close to design head however there is a drop in the flow rate, this can be attributed to wear in impeller due to ageing, as the pump is over a decade old.

The operating hours of the transfer pumps was recorded using power log taken by three-phase power analyser. The transfer pump 2 operates for 24 hours whereas the transfer pump 1 operates about five hours in a day (depending on receiver reservoir level). The total daily water pumped by transfer pumps was 1776.5 m^3.

The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 9**.

Table 9 Transfer pumps motor performance

Particular	Unit	Motor 1	Motor 2
Voltage	V	415.0	416.5
Current	I	65.1	65.1
Power factor	-	0.820	0.840
Power input	kW	38.37	39.45
Motor Efficiency	%	92.5	92.5
Power shaft	kW	35.49	36.49
Motor loading	**%**	**95.92**	**98.62**

Recommendation is given only for transfer pump 2 as it operates 24 hours. No recommendation is provided for transfer pump 1 as it operates only 4 to 5 hours a day.

4.1.2. Energy conservation measure

The flow rate of transfer pump 2 was 62.1 m3/h at a system head of 106 m. This resulted in a pump operating efficiency, 49.16%. Suspected reason for drop is in efficiency is wear in impeller due to ageing. Replacing impeller is expected to improve the flow rate, but as the pump is over decade old, we have recommended replacement of pump itself with an IE4 rated motor to achieve higher efficiency. The technical specification of proposed centrifugal vertical multistage pump is as follows (detailed specification is shown in **Appendix A**):

- Make and model: Grundfos CRN 64-5-1
- Flow rate: 64 m3/h
- Head: 108.5 m
- Pump Efficiency: 78.0 %
- Motor rating and efficiency: IE4, 94.5 %

The efficiency improvement and corresponding energy saving estimation is presented in **Table 10**.

Table 10 Transfer pump-1: Energy saving estimation

Particular	Unit		Value
Operating flow	m^3/h		64.0
Overall head	m		108.5
Hydraulic power	kW		18.92
Pump design efficiency	%		78.00
Shaft power required	kW		24.26
Standard motor size	kW		30.00
IE4 Motor efficiency	%		94.50
Overall power input	**kW**		**25.67**
Combined efficiency	%		73.71
Net daily water duty	m^3		1490.4
Total operating hours	h/day		23.29
Annual energy consumption – proposed	kWh/year		218205
Annual energy consumption – existing	kWh/year		323788
Annual energy saving	kWh/year		105582
Monetary saving	SBD/year		578592
	USD/year	**$**	**72,324**
Cost of new pump with IE4 motor	USD	$	28,000
Freight cost for pump-motor set	USD	$	250
Cost at port in Solomon Islands	USD	$	28,250
Import duty	%		10
GST on imported goods	%		15
Net landed cost of pump with IE4 motor	**USD**	$	35,938
Simple payback period	**years**		**0.5**
GHG emission reduction potential	**tCO_2/year**		**69.68**

The annual energy saving by replacing transfer pump-2 is 105,582 kWh equivalent to monetary saving of US $ 72,324. The investment required for new vertical centrifugal multistage pump with IE4 motor is US $ 28,000. The freight cost of shipping from Australia is US $ 250. Overall landed cost in Honiara inclusive of all applicable duties is US $ 35,938. The simple payback period of the recommendation is 0.5 years. The GHG emission reduction potential of the recommendation is 69.68 tCO_2 equivalent.

4.2. Borehole pumps

4.2.1. Performance assessment

The Tuvaruhu JICA pump station has three borehole pumps. The power measurement was taken using three-phase power analyser, flow was measured using ultrasonic water flow meter, head was measured using a water depth measurement instrument available with Solomon Water (Shaun, Hydrogeologist) and head from borehole surface level to receiver tank is measured using digital pressure meter.

The duty-point and best efficiency point of the bore-hole pump-1 is depicted in **Figure 15**.

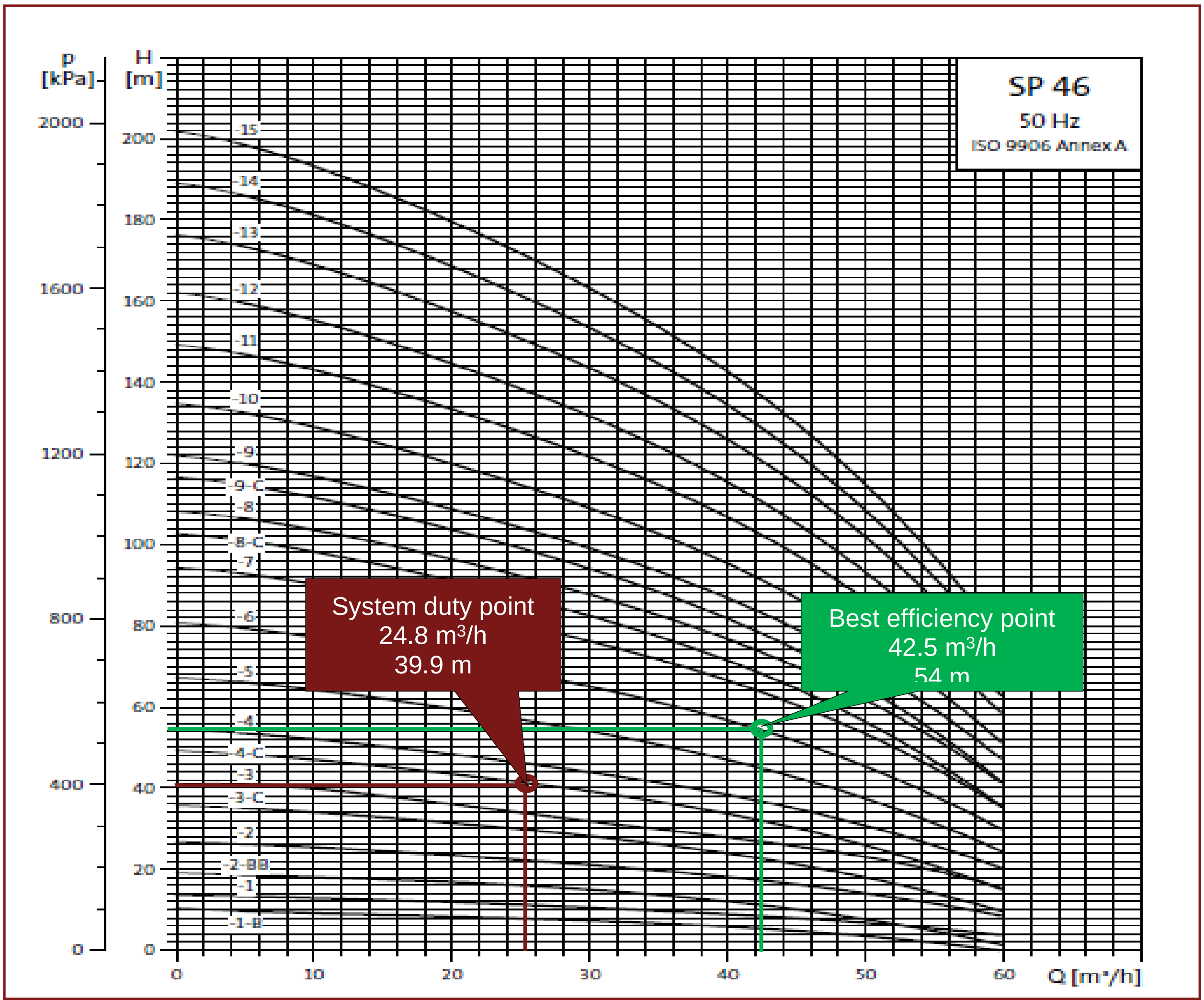


Figure 15 Borehole pump-1 duty point vs design

The borepump-1 was Grundfos SP46 series, model 6. The pump was operating away from design best efficiency point. The suspected reason for the less flow rate is slightly worn-out impeller. It is recommended to check the impeller during next maintenance and in case or wear and tear, repalce the impeller.

The performance curve of MJ-2 and MJ-3 (Southern Cross make) were not available, hence team was unable to plot the operating and design duty points. The flow rate of MJ-2 was about 72% less than design. It appreas the screens for drawing water are blocked and unable to draw water in. The MJ-3 was operating away from design best efficiency point. The suspected reason for the less flow rate is slightly worn-out impeller.

The valve on the discharge pipe coming out of well was throttled, leading to a head of 7.8, 6.9 and 4.4 m respectively for MJ-1, MJ-2 and MJ-3, which is close to the actual head estimated from this point till reservoir. Hence the throttling has minimum effect on system head.

The performance assessment of borehole pumps is presented in **Table 11**.

Table 11 Performance assessment of borehole pumps

Particular	Unit	Bore-pump 1	Bore-pump 2	Bore-pump 3
Operating flow	m^3/h	24.80	12.10	38.90
Well depth to water level	m	32.10	28.10	25.72
Head from surface to reservoir	m	7.80	6.90	4.40
Total head	m	39.90	35.00	30.12
Hydraulic power	kW	2.70	1.15	3.19
Motor power	kW	7.77	3.77	10.82
Shaft power	kW	6.26	3.03	8.87
Pump efficiency	**%**	**43.09**	**38.08**	**36.00**

The operating hours of the bore-hole pumps was taken from the SCADA system. The measured flow rate of water was then converted to arrive at daily water production from borefields, same is presented in **Table 12**.

Table 12 Production from bore-fields

Bore-field	Flow rate (m^3/h)	Operating hours (h)	Daily production (m^3)
Bore-pump 1 (MJ-1)	24.8	23.2	574.6
Bore-pump 2 (MJ-2)	12.1	23.2	280.4
Bore-pump 3 (MJ-3)	38.9	23.7	921.5
Total			**1776.5**

4.2.2. Energy conservation measure

The borehole pump-1 and 3 were operating inefficiently. The recommendation would be to replace the pumps with new submersible pump with a higher efficiency motor. The pump specification of the existing bore pump, system duty-point and recommended submersible pump is presented in **Table 13**.

Table 13 Technical specification of existing pump, system duty point and recommended pump

Particular	Unit	Existing Pump	System duty point	Proposed pump
Bore-hole pump MJ-1				
Model	-	Grundfos SP 46-6	-	Grundfos SP 30-6
Flow rate	m^3/h	42.0	24.8	29.2
Total head	m	53.8	39.9	45.0
Bore-hole pump MJ-3				
Model	-	Southern Cross SC	-	Grundfos SP 46-3
Flow rate	m^3/h	45.3	38.9	42.5
Total head	m	37.0	30.1	32.0

The recommendation for MJ-2 is not provided as, it will lead to negligible energy savings. The proposed submersible pump as replacement for bore pumps is capable of handling head variation of ± 5 m, without substantial difference in discharge head. Detailed technical specification of the recommended submersible pump is provided in **Appendix A**. ***The energy saving is estimated considering the sustainable daily water production for the bore field shared by Solomon Water Hydrogeologist***. Detailed saving estimation is presented in **Table 14**.

The annual energy saving by replacing borehole pump-1 and 3 is 46,271 kWh equivalent to monetary saving of US $ 31,695. The investment required for installation of pump is US $ 10,855. The freight cost of shipping from Australia is US $ 500. Overall landed cost in Honiara inclusive of all applicable duties is US $ 15,444. The simple payback period of the recommendation is six months. The GHG emission reduction potential of the recommendation is 30.54 tCO_2 equivalent.

Table 14 Borehole pumps energy saving estimation

Particular	Unit	MJ-1	MJ-3
Net daily water duty	m^3	700	1020
Proposed pump flow rate	m^3/h	29.2	42.5
Proposed annual energy consumption	kWh/year	53502	57317
Existing annual energy consumption	kWh/year	64841	92248
Annual energy saving	kWh/year	11339	34931
Monetary saving	SBD/year	62140	191422
	USD/year	$ 7,768	$ 23,928
Cost of new bore-pump	USD	$ 5,615	$ 5,240
Freight cost	USD	$ 250	$ 250
Cost at port in Solomon Islands	USD	$ 5,865	$ 5,490
Import duty	%	10	10
GST	%	15	15
Net landed cost of bore-pump	USD	$ 7,956	$ 7,488
Simple payback period	**years**	**1.0**	**0.3**
GHG emission reduction	**tCO_2/year**	**7.48**	**23.05**

4.3. Electrical system

4.3.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel and bore-pumps panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current.

The logging of total power for 24 hours is shown in **Figure 16**.

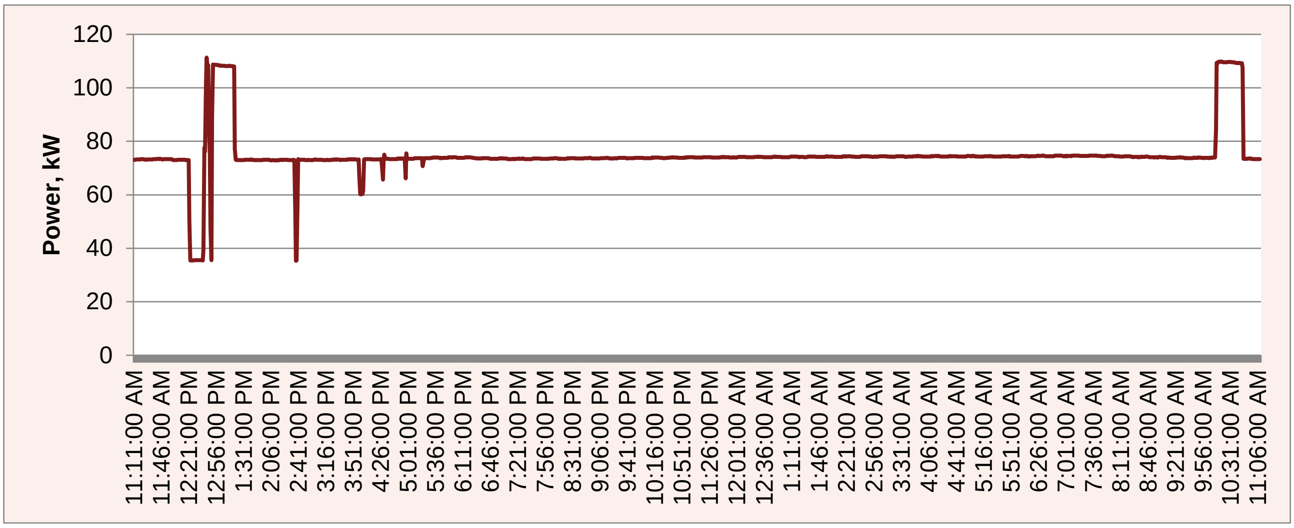


Figure 16 Tuvaruhu JICA pump station total power log 24 hours

The power factor (PF) at the main incomer of pump station was varying between 0.706 – 0.811, with an average PF 0.770. The PF variation over 24 hours is presented in **Figure 17**.

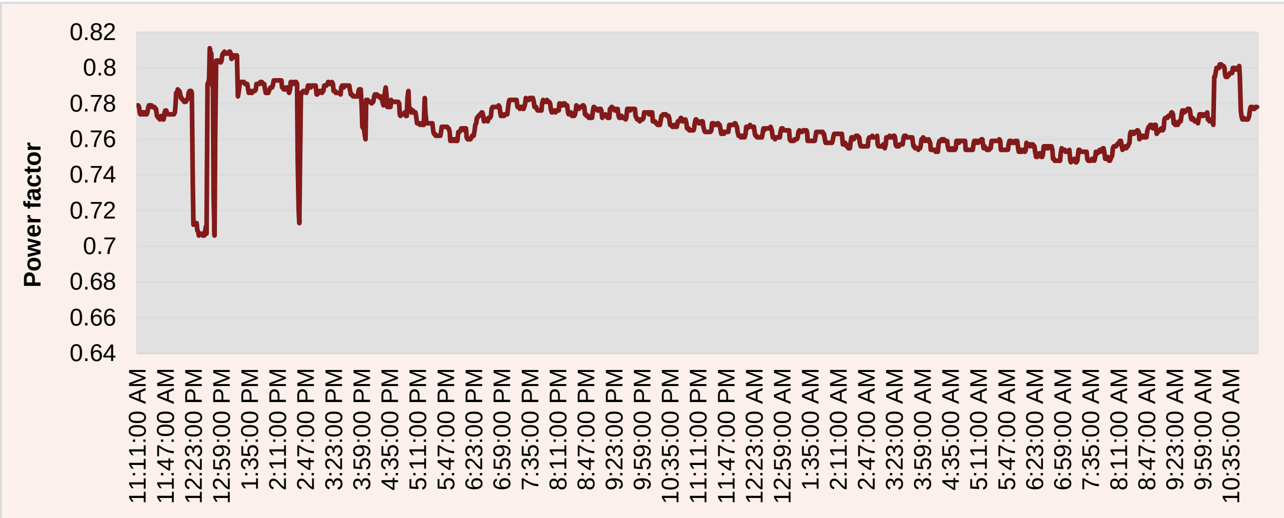


Figure 17 Power factor variation over 24 hours

4.3.2. Automatic Power Factor Correction

The average PF is 0.77 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install a 80 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 30+30+10+5+2+2+1 kVAr.

Figure 18 APFC panel

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 15** and **Table 18**. The pictorial view of APFC panel is presented is **Figure 18**.

Table 15 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.770
Average daily reactive power	kVAr	61.8
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.170
Annual charge for PF	US$/year	$ 7,927
Capacitor bank requirement	**kVAr**	**80**
Investment cost	US$	$ 4,000
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 4,250
Import duty	%	10
GST	%	15
Net landed cost of APFC system	USD	$ 5,938
Simple payback period	**years**	**0.7**

Table 16 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.770
Power factor tariff as % of fuel charge	%	5.00
Annual fuel charge	US$/year	204081
Annual charge for PF	US$/year	$ 10,204
Capacitor bank requirement	**kVAr**	**80**
Investment cost	US$	$ 4,000
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 4,250
Import duty	%	10
GST	%	15
Net landed cost of APFC system	USD	$ 5,938
Simple payback period	**years**	**0.6**

4.4. Lighting system

4.4.1. Performance assessment

The pump station was equipped with 4 six feet fluorescent tube lights (FTL) of 36 W rating (T8). The details of the existing system are provided in **Table 17**.

Table 17 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	4	176
Total			**4**	**176**

4.4.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 6 LED tube pump room and 6 in DG room. Details of the present lighting system are given in **Table 18**. The pictorial view of FTL tube and LED tube is shown in **Figure 19.**

Figure 19 LED tube vs florescent tube

Table 18 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	4	3
Total rating	W	176	63
Operating hours	h/year	250	250
Annual consumption	kWh/year	44	15.75
Annual saving	kWh/year		28.25
Monetary saving	SBD/year		156
	USD/year		$ 19
Investment cost	USD		$ 60
Simple payback	**Years**		**3.1**
GHG emission reduction	**tCO_2/year**		**0.02**

The estimated annual energy savings with new LED lighting system is 28.25 kWh of electricity, effectively equivalents to a monetary savings of US $ 19. The investment requirement is US $ 60. The simple payback period of the recommendation is 3.1 years. The annual reduction in GHG emission is estimated to be 0.02 tCO_2.

5. Self-generation option

5.1. Renewable energy assessment

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic. Detailed feasibility analysis for solar is presented in this chapter.

5.2. Site description

Tuvaruhu JICA pump station is in Mataniko area of Honiara city in Guadalcanal province. The Tuvaruhu JICA and SIWA pump stations are in one compound. The compound also houses a ware-house and a medical centre. Multiple roof area is available which includes: JICA pump station, SIWA pump station, JICA water reservoir, SIWA water reservoir, medical centre and ware-house. The total projected roof area as seen from the top, over the pump house is about 774 m^2. About ⅓ of medical centre's roof is shaded due to presence of a tree. There are no buildings nearby to cause shading. The net area available for solar panel installation is 611 m^2. Roof is made of concrete or sheet metal and support installation of solar roof top PV modules. In some cases, maty require additional support structure. The coordinates of Tuvaruhu pump station are as follows: Latitude -9.45°, Longitude +159.96°. The layout of the pump station is presented in **Figure 20**.

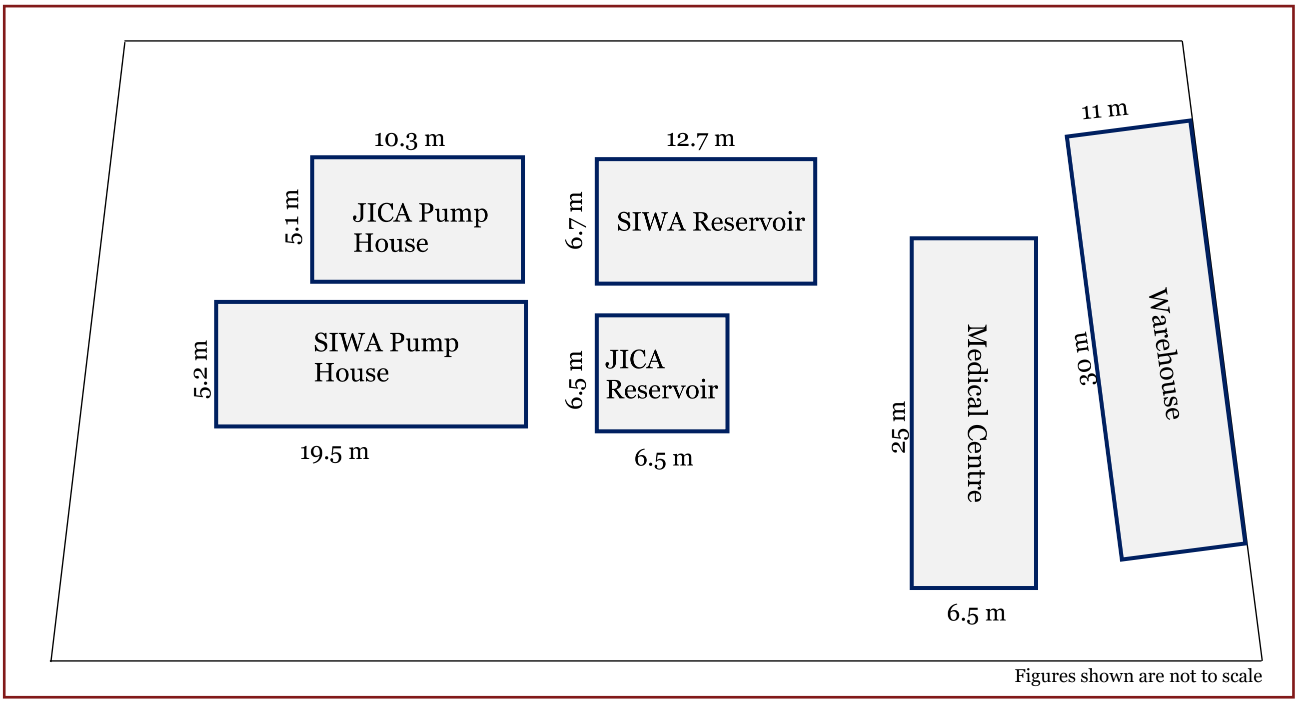


Figure 20 Layout of the Tuvaruhu pump station

5.3. Solar resource assessment

The solar data source i.e. Global Horizontal Irradiance (GHI) for Honiara, is derived from a Japan International Cooperation Agency (JICA) report on Pilot Survey for Disseminating SME's Technologies for Introduction of Utility Interactive Grid-Connected Photovoltaic Generation System Possessed in Okinawa Prefecture for Small Island Regions, 2015. These values are an estimation of the solar resource on a horizontal surface. Solar data for Honiara is presented in **Table 19**.

Table 19 Daily Global Horizontal Irradiation at site location

Daily Global Horizontal Irradiation in kWh/m²/day											
Latitude -9.45⁰, Longitude 159.96⁰											
Jan	**Feb**	**Mar**	**Apr**	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

The roof orientation yields optimum results when the tilt angle is equal to the latitude which in this case is 9.4⁰. The sun elevation diagram for the pump station is presented in **Figure 21**.

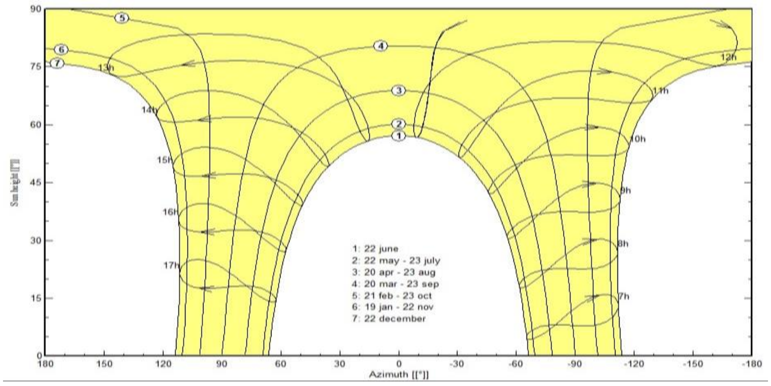


Figure 21 Sun elevation diagram for the site

5.4. System sizing and cost benefit

The effective area available for solar-roof PV installation is 611 m². Capacity for PV systems is measured at Standard Testing Conditions, of 1000 W/m², AM 1.5 and 25°C cell temperature. These conditions may not be the same on site. Site specific capacity varies intermittently with changing irradiance, ambient temperature, wind speed and air mass with respect to time, calendar day and other effects like cloud cover. The Polycrystalline technology generally has efficiency of ~ 16%. Monocrystalline Silicon technology can achieve ~20% although they are more expensive. The power delivered at the interconnection will be further reduced due to inverter efficiency, transformer efficiency, module fouling and cabling losses.

The system sizing along with cost benefit considering thin film and monocrystalline technology is presented in **Table 20**. This is considering there is no standby charges fees and the utility i.e. SIEA pays fuel charges to Solomon Water for imported energy to grid which is SBD 2.65 per kWh.

Table 20 Cost benefit of solar roof PV - Thin film and monocrystalline[7]

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m²	774	774
Utilization area	m²	611	611
Nominal power	kWp	61.1	97.8
Average global horizontal irradiance	kWh/m²/day	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	94386	151079
Avg fuel charges	SBD/kWh	2.65	2.65
Monetary saving	SBD/year	249964	400107
	USD/year	$ 31,246	$ 50,013
Module cost	USD	$ 57,129	$ 91,406
Supports cost	USD	$ 69,898	$ 69,898
Inverter and wiring cost	USD	$ 21,507	$ 21,507
Transport and mounting cost	USD	$ 61,110	$ 89,003
Cost at port in Solomon Islands	USD	$ 209,644	$ 271,814

[7] *This recommendation is common for Tuvaruhu JICA and Tuvaruhu SIWA pump station*

Particular	Unit	Thin-film	Monocrystalline
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost	USD	$ 262,680	$ 340,393
Simple payback period	**years**	**8.4**	**6.8**

The cost benefit considering present tariff structure is presented in **Table 21**. With present regulation we have considered the standby changes in addition with cost system.

Table 21 Cost benefit of solar roof PV with present tariff

Particular	Unit	Thin-film	Monocrystalline
Nominal power	kWp	61.1	97.8
Annual solar yield	kWh/year	94386	151079
Monetary saving by avoided energy consumption	SBD/year	267268	427804
	USD/year	$ 33,409	$ 53,476
Annual standby charges	USD/year	$ 41,531	$ 66,478
Net landed cost	USD	$ 304,211	$ 406,870
Simple payback period	**years**	9.1	7.6

The detailed analysis for Solar roof PV system sizing was performed on PVSyst software. PVSyst software provides possibility of complex simulation input and output parameters of PV plant and is also commercially to calculate the total production of electricity. As per the PVSyst simulation results, the estimated energy generation for the first year is 94.4 MWh/year, with Specific Energy Yield of 1545 kWh/kW$_p$/year for thin film technology-based modules. The simulation was run considering monocrystalline cell modules and the estimated energy generation for the first year is 151.1 MWh/year. The detailed results of PVSyst are presented in **Appendix C** – PVSYST simulation results.

5.5. Regulatory framework

The policies, processes and forms for solar system connection to SIEA grid are available in Solar Manual of SIEA. Some of the key highlights are:

- Inverter energy systems that have a continuous rating of no more than 30 kVA for three-phase systems.
- The installation should as a minimum comply with Australian Standards AS3000, AS4777 and AS5033 and all other relevant Australian Standards and Solomon Islands statutory requirements.
- All energy consumed from the grid at the premises will be metered by an import-only meter and billed to the customer under the applicable tariff(s). It is only any 'excess' energy will be exported to the SIEA grid. This energy will be metered but will NOT be paid for by SIEA.

The process for solar grid connection as provided by SIEA is presented in **Figure 22**.

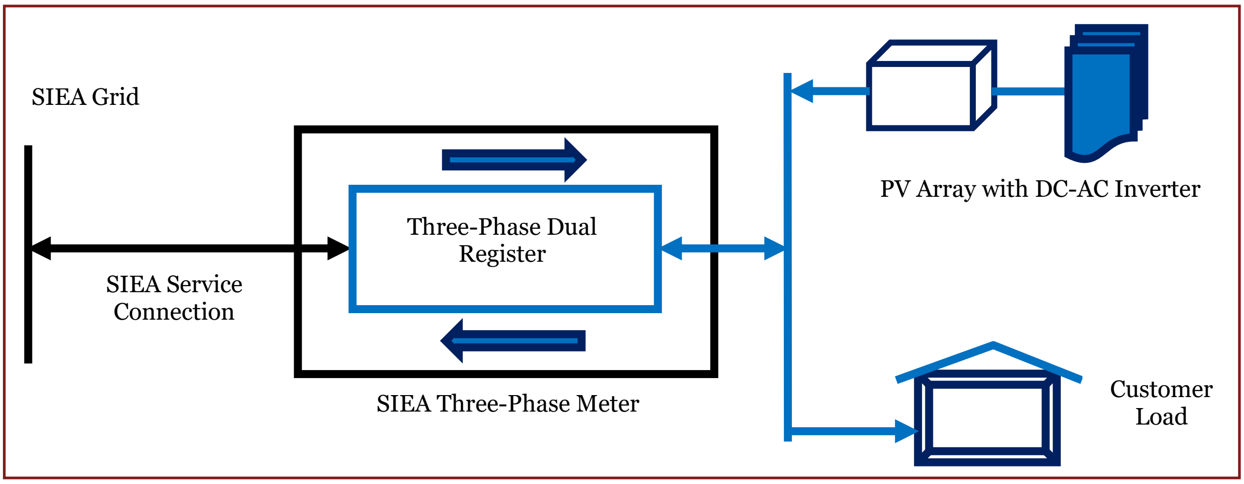


Figure 22 Schematics of solar PV interconnection with SIEA grid

Net metering is a utility billing mechanism that offers a credit to customers who are making excess electricity with their solar panel systems and sending it back to the grid. Solomon Islands at present does not have provision for net metering. However, SIEA is in process of reviewing and restructuring its electricity tariff. It may introduce the net metering option for solar roof top.

On a LT connection of 400 V the maximum allowed capacity of solar roof top PV plant is 30 kVA (~30 kWp). The proposed solar roof top system is cumulative continuous rating of 97.8 kWp. Hence, as the proposed plant is higher than allowed, it will require a special agreement with SIEA.

*Solar PV option for the pump station is **technically feasible**. But, the financially feasibility is dependent on future SIEA tariff structure. With present tariff structure and regulatory elements, the solar PV is not feasible.*
*The Solomon Water can **take a strategic call** if to invest in solar PV now or to wait for favorable regulatory regime.*

5.6. Other grid-connected solar initiatives in Solomon Islands

The World Bank is implementing a scaling-up of renewable energy project in Solomon Islands in the period 2018 to 2023. The Project intends to improve lifestyle and increase shared prosperity for the low-income household through scaling-up off and on-grid renewable energy projects.

The project is being implemented in four components, which are presented in **Table 22**.

Table 22 Components of WB Scaling-up RE project

Component – 1	Renewable energy hybrid mini-grids – Supply, installation and initial maintenance
Component – 2	Electricity connections in low income areas – Households, micro enterprise and community infrastructure
Component – 3	Grid-connected solar power - Supply, installation and initial maintenance
Component – 4	Enabling environment and project management – including gender related activities, technical assistance and training activities

The third component deals with grid connected solar power. World Bank intendeds to support supply, implementation and initial maintenance of grid-connected solar power projects. The project financing and source of funding for the gird connected solar power is presented in **Table 23**.

Table 23 Project financing and source of funding

Source of Fund	Project financing (US$ million)	Share of financing
International Development Association (IDA) financing credits	3.5	**70%**
IDA financing grant	0.55	**11%**
Trust funds GEF	0.95	**19%**
Total	**5.0**	**100%**

The reason for the solar power project being financially feasible as compared to solar power project proposed at pumps station are as follows:

- About 30% of the total funding for the project is through grant or funds, thus, reducing financing burden
- The remaining cost of project is also in terms of IDA financing credits, which has very low interest charge and repayments been stretched over long term
- The economy of scale, the solar power supported by World Bank is of MW capacity, however, the pump station projects capacity is in kW size
- One component of the World Bank project is on reducing regulatory barriers for solar project while creating the conditions for future replication. (This is in progress)

In case, the solar power project proposed for pump station can be financed through similar mechanism i.e. close to 30% grant/funds, the project finances will improve. Moreover, a further strengthened regulatory regime will be an advantage. The sensitivity analysis of grid connected solar power project with and without grant funding is presented in **Table 24**.

Table 24 Sensitivity analysis - Solar power project with and without grant

Particular	Unit	Without grant	With grant
Solar rooftop plant capacity for Tuvaruhu Pump Station	kWp	97.8	97.8
Monetary savings	US $	50013	50013
Investment	US $	340393	238275
Simple payback period	**Years**	**6.8**	**4.8**

6. Conclusion

6.1. Summary of study

Tuvaruhu JICA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station has a 100 m³ water receiver tank, which receives water from three bore-holes. The water from receiving tanks is pumped to Skyline reservoir using two transfer pumps. The pump station produces 1776.5 m³ water daily consuming about 1638 kWh electrical energy. The existing specific energy consumption is 0.922 kWh per m³. The study has identified four recommendations for energy conservation (**Table 25**). These recommendations could save annually about 151,881 kWh of electricity. These recommendations have an estimated investment of US $ 51,441 and can yield a monetary savings of US $ 104,038 per year. The annual energy saving is estimated to be 24.6% of total energy consumption by the pump station (**Figure 23**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 100.24 tonnes of CO_2.

Table 25 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement transfer pump with EE pump	105,582	$ 72,324	$ 35,938	0.5	69.68
ECM-2	Replacement of borepump-1 (MJ-1)	11,339	$ 7,768	$ 7,956	1.0	7.48
ECM-3	Replacement of borepump-3 (MJ-3)	34,931	$ 928	$ 7,488	0.3	23.05
ECM-4	Replacement of FTL with LED lights	28	$ 19	$ 60	3.1	0.02
	Total	**151,881**	**$ 104,038**	**$ 51,441**	**0.5**	**100.24**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 26**.

Table 26 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.922 kWh/m³	0.688 kWh/m³
Specific CO_2 emission	0.609 kg CO_2/m³	0.454 kg CO_2/m³

On renewable side, there is potential of solar photovoltaic plant. The pump station can either utilize entire roof space for a SPV plant of 97.8 kWp with an investment of US $ 340,393, it can replace conventional electrical energy equivalent to 151.1 MWh equivalent to GHG emission reduction of 99.7 tCO_2.

6.2. Funding options

The overall investment proposed for four energy conservation measures for Tuvaruhu JICA pump station is US$ 51,441. The simple payback on this investment is 6 months. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 5 months, which can be followed by transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Tuvaruhu JICA pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

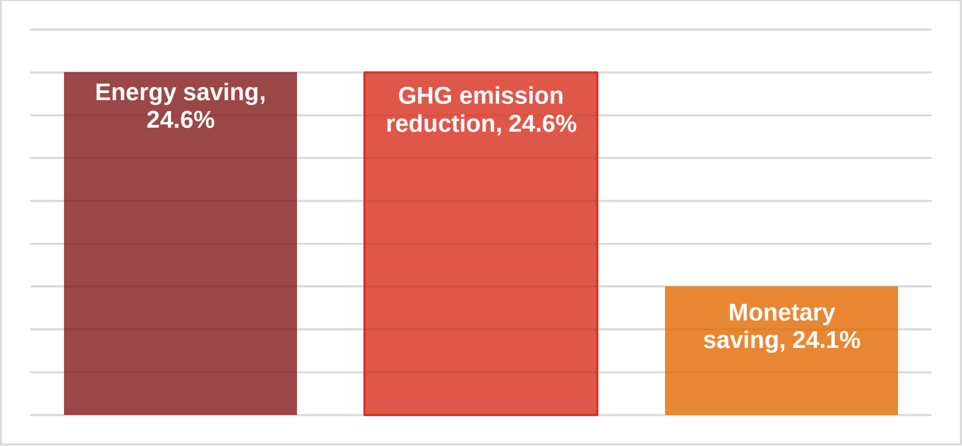


Figure 23 Identified saving potential

A collage of select pictures taken during the detailed feasibility study is presented in **Appendix D**.

Appendix

Appendix A – Proposed pump technical specification

Transfer pump-2

Position	Qty.	Description
	1	**CRN 64-5-1 A-F-A-V-HQQV**

Product No.: On request

Vertical, multistage centrifugal pump with inlet and outlet ports on same the level (inline). Pump materials in contact with the liquid are in high-grade stainless steel. A cartridge shaft seal ensures high reliability, safe handling, and easy access and service. Power transmission is via a rigid split coupling. Pipe connection is via DIN flanges.

The pump is fitted with a 3-phase, fan-cooled asynchronous motor.

Further product details

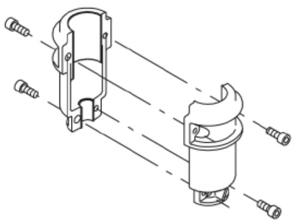
Steel, cast iron and aluminium components have an epoxy-based coating made in a cathodic electro-deposition (CED) process. CED is a high-quality dip-painting process where an electrical field around the products ensures deposition of paint particles as a thin, well-controlled layer on the surface. An integral part of the process is a pretreatment. The entire process consists of these elements:

1) Alkaline-based cleaning.
2) Zinc phosphating.
3) Cathodic electro-deposition.
4) Curing to a dry film thickness 18-22 my m.

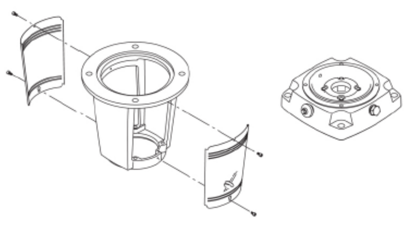
The colour code for the finished product is NCS 9000/RAL 9005.

Pump

A long split coupling connects the pump and motor shaft. It is enclosed in the motor stool by means of two coupling guards. The long coupling makes it possible to replace the shaft seal without removing the motor from the pump.



The motor stool connects the pump head and motor. The pump head has a combined 1/2" priming plug and vent screw.



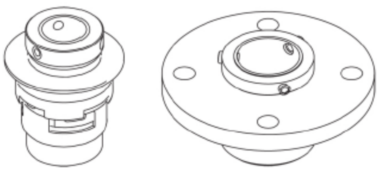
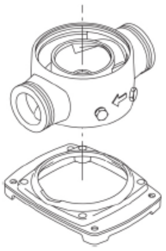
The pump is fitted with a balanced O-ring seal unit with a rigid torque-transmission system. This seal type is assembled in a cartridge unit which makes replacement safe and easy. Due to the balancing, this seal type is suitable for high-pressure applications. The cartridge construction also protects the pump shaft from possible wear from a dynamic O-ring between pump shaft and shaft seal.

Primary seal:

- Rotating seal ring material: silicon carbide (SiC)
- Stationary seat material: silicon carbide (SiC)

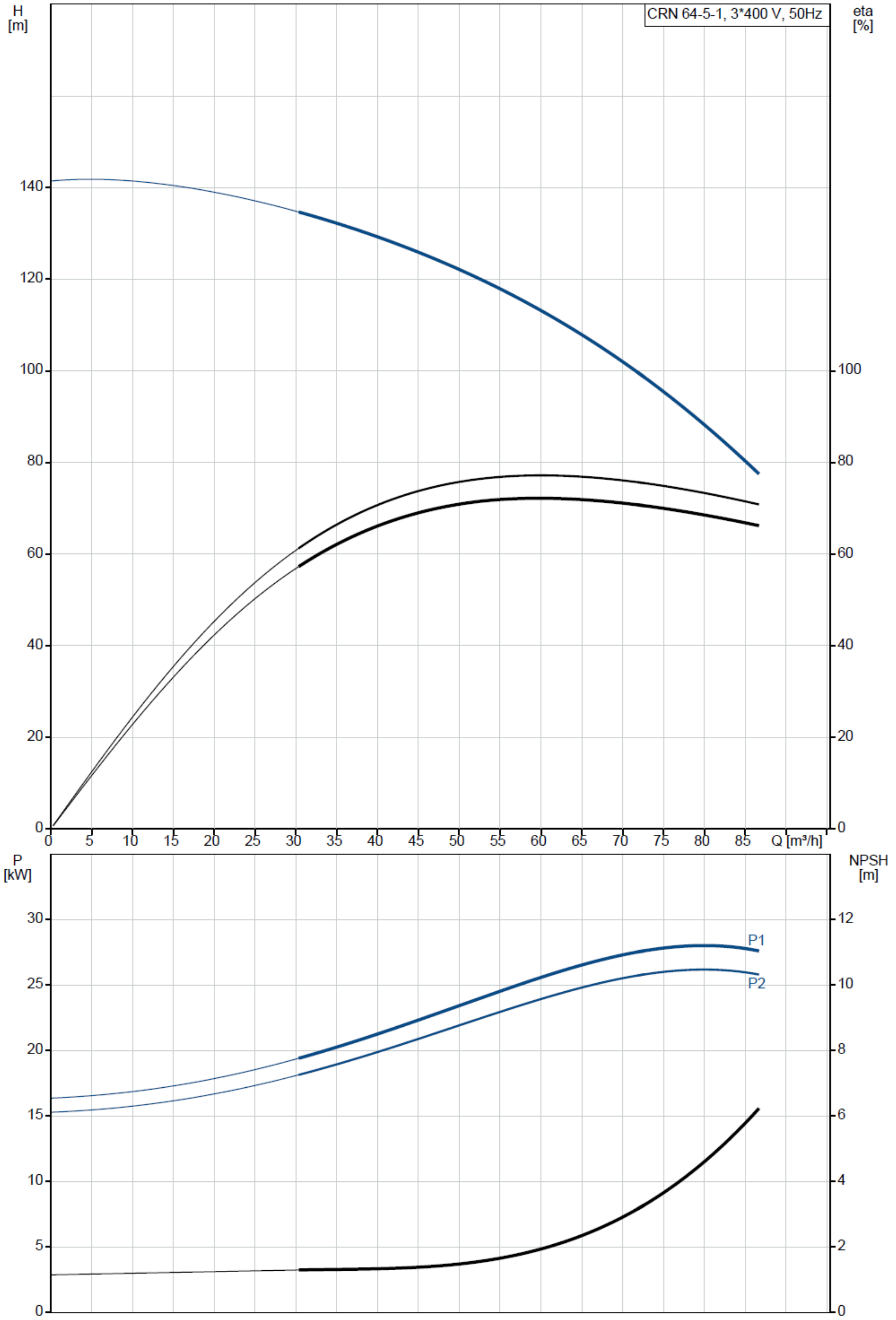
This material pairing is used where higher corrosion resistance is required. The high hardness of this material pairing offers good resistance against abrasive particles.

Secondary seal material: FKM (fluorocarbon rubber)

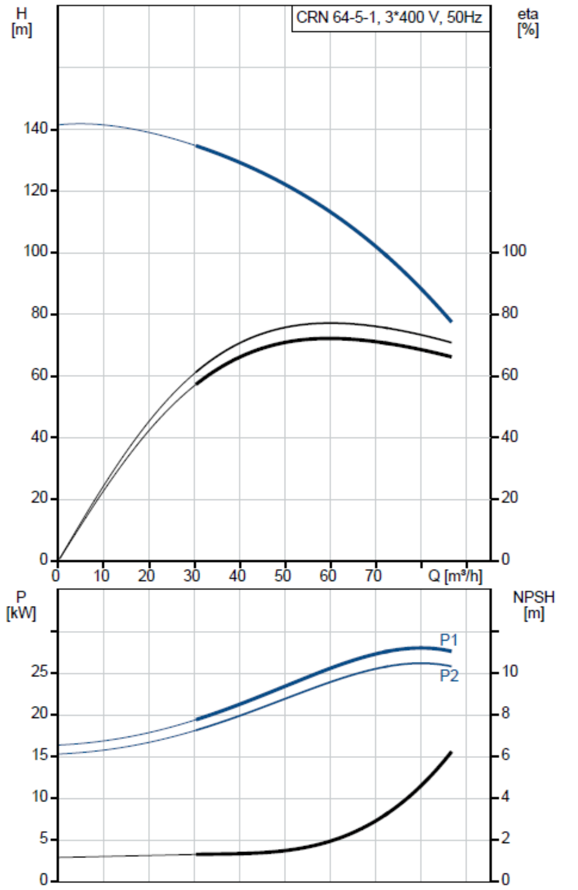
Position	Qty.	Description
		FKM has excellent resistance to oils and chemicals. Above 90 °C, FKM should only be used in media without water.  The shaft seal is retained in the pump head by a cover and screws. It can be replaced without removing the motor. The chambers and impellers are made of stainless-steel sheet. The chambers are provided with a PTFE neck ring offering improved sealing and high efficiency. The impellers have smooth surfaces, and the shape of the blades ensure a high efficiency. The pump has a stainless-steel base mounted on a separate base plate. The base and base plate are kept in position by the tension of the staybolts which hold the pump together. Both the inlet and the outlet side of the base have two pressure gauge tappings. The pump is secured to the foundation by four bolts through the base plate. The flanges are fastened to the base by means of locking rings.  **Motor** The motor is a totally enclosed, fan-cooled motor with principal dimensions to IEC and DIN standards. The motor is flange-mounted with free-hole flange (FF). Motor-mounting designation in accordance with IEC 60034-7: IM B 5 (Code I) / IM 3001 (Code II). Electrical tolerances comply with IEC 60034. The motor efficiency is classified as IE3 in accordance with IEC 60034-30-1. The motor has thermistors (PTC sensors) in the windings in accordance with DIN 44081/DIN 44082. The protection reacts to both slow- and quick-rising temperatures, e.g. constant overload and stalled conditions. Thermal switches must be connected to an external control circuit in a way which ensures that the automatic reset cannot cause accidents. The motors must be connected to a motor-protective circuit breaker according to local regulations. The motor can be connected to a variable speed drive for adjustment of pump performance to any duty point. Grundfos CUE offers a range of variable speed drives. Please find more information in Grundfos Product Center. **Technical data** **Controls:** Frequency converter: NONE **Liquid:** Pumped liquid: Water Liquid temperature range: -20 .. 90 °C Liquid temperature during operation: 20 °C Density: 998.2 kg/m³ **Technical:** Rated flow: 64 m³/h Rated head: 108.5 m Pump orientation: Vertical Shaft seal arrangement: Single

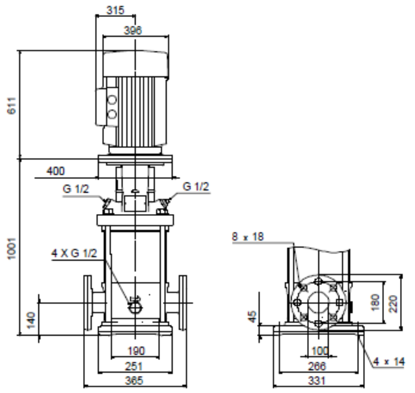
Position	Qty.	Description	
		Code for shaft seal:	HQQV
		Approvals on nameplate:	CE, EAC
		Curve tolerance:	ISO9906:2012 3B
		Materials:	
		Base:	Stainless steel EN 1.4408 AISI 316
		Impeller:	Stainless steel EN 1.4401 AISI 316
		Bearing:	SIC
		Support bearing:	Graflon
		Installation:	
		Maximum ambient temperature:	55 °C
		Maximum operating pressure:	16 bar
		Max pressure at stated temp:	16 bar / 90 °C 16 bar / -20 °C
		Type of connection:	DIN
		Size of inlet connection:	DN 100
		Size of outlet connection:	DN 100
		Pressure rating for pipe connection:	PN 16
		Flange size for motor:	FF350
		Electrical data:	
		Motor standard:	IEC
		Motor type:	SIEMENS
		IE Efficiency class:	IE3
		Rated power - P2:	30 kW
		Power (P2) required by pump:	30 kW
		Mains frequency:	50 Hz
		Rated voltage:	3 x 380-420D/660-725Y V
		Rated current:	56,0-51,0/32,0-29,5 A
		Starting current:	660-660 %
		Cos phi - power factor:	0.86
		Rated speed:	2955 rpm
		Efficiency:	IE3 93,3%
		Motor efficiency at full load:	93.3-93.3 %
		Motor efficiency at 3/4 load:	93.6-93.6 %
		Motor efficiency at 1/2 load:	93.4-93.4 %
		Number of poles:	2
		Enclosure class (IEC 34-5):	55 Dust/Jetting
		Insulation class (IEC 85):	F
		Others:	
		Minimum efficiency index, MEI ≥:	0.7
		Net weight:	333 kg
		Gross weight:	371 kg
		Shipping volume:	0.805 m³

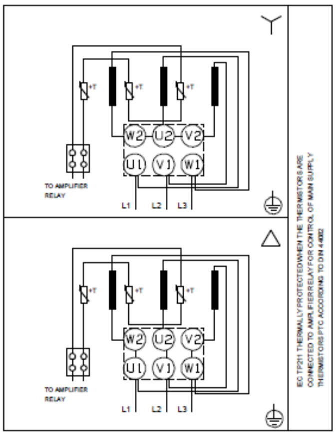
On request CRN 64-5-1 A-F-A-V-HQQV 50 Hz



Description	Value
General information:	
Product name:	CRN 64-5-1 A-F-A-V-HQQV
Product No:	On request
EAN number:	On request
Technical:	
Rated flow:	64 m³/h
Rated head:	108.5 m
Stages:	5
Impellers:	5
Number of reduced-diameter impellers:	1
Low NPSH:	N
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQV
Approvals on nameplate:	CE, EAC
Curve tolerance:	ISO9906:2012 3B
Pump version:	A
Model:	B
Materials:	
Base:	Stainless steel
	EN 1.4408
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Material code:	A
Code for rubber:	V
Bearing:	SIC
Support bearing:	Graflon
Installation:	
Maximum ambient temperature:	55 °C
Maximum operating pressure:	16 bar
Max pressure at stated temp:	16 bar / 90 °C
	16 bar / -20 °C
Type of connection:	DIN
Size of inlet connection:	DN 100
Size of outlet connection:	DN 100
Pressure rating for pipe connection:	PN 16
Flange size for motor:	FF350
Connect code:	F
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-20 .. 90 °C
Liquid temperature during operation:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor standard:	IEC
Motor type:	SIEMENS
IE Efficiency class:	IE3
Rated power - P2:	30 kW
Power (P2) required by pump:	30 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-420D/660-725Y V
Rated current:	56,0-51,0/32,0-29,5 A
Starting current:	660-660 %
Cos phi - power factor:	0.86
Rated speed:	2955 rpm
Efficiency:	IE3 93,3%
Motor efficiency at full load:	93.3-93.3 %
Motor efficiency at 3/4 load:	93.6-93.6 %
Motor efficiency at 1/2 load:	93.4-93.4 %
Number of poles:	2
Enclosure class (IEC 34-5):	55 Dust/Jetting







Borehole pump MJ-1

Company name:
Created by:
Phone:

Date: 09/02/2020

Qty.	Description
1	**SP 30-6**

Note! Product picture may differ from actual product

Product No.: 13A01906

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 5.5 kW MS4000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	29.44 m³/h
Resulting head of the pump:	45.71 m
Shaft seal for motor:	HM/CER
Approvals on nameplate:	CE,EAC
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

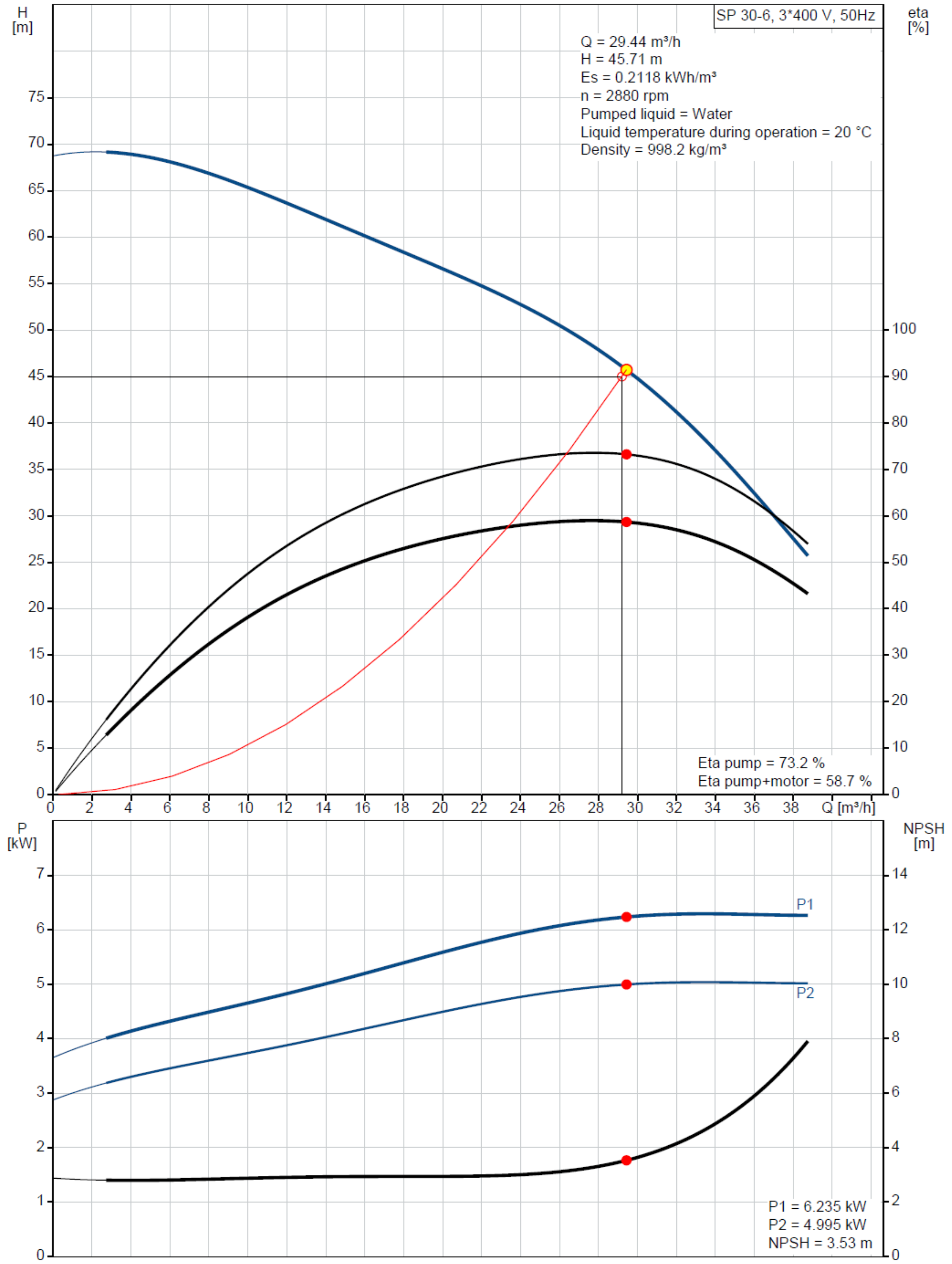
Installation:

Pump outlet:	RP3
Motor diameter:	4 inch

Company name:
Created by:
Phone:

Date: 09/02/2020

13A01906 SP 30-6 50 Hz

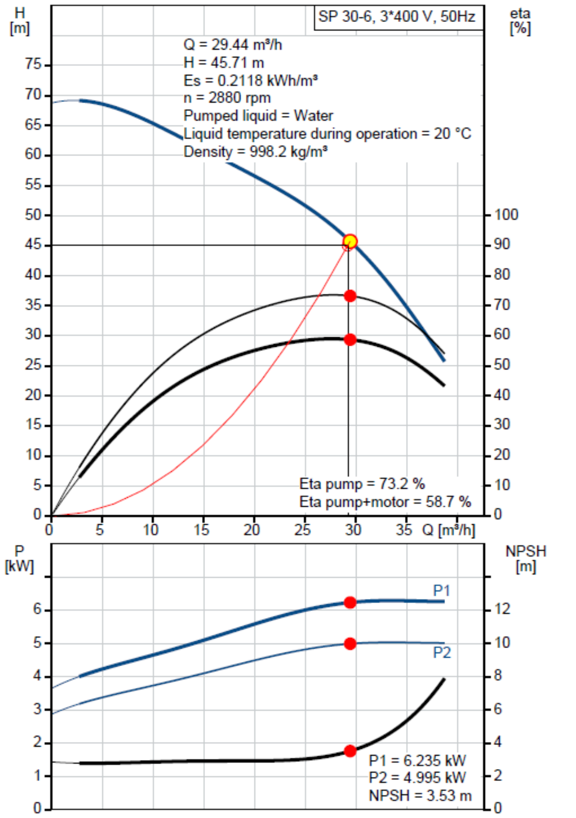


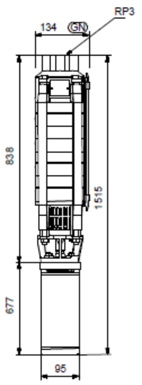
GRUNDFOS

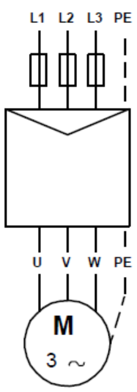
Company name:
Created by:
Phone:

Date: 09/02/2020

Description	Value
General information:	
Product name:	SP 30-6
Product No:	13A01906
EAN number:	5700390381103
	5700390381103
Technical:	
Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	29.44 m³/h
Resulting head of the pump:	45.71 m
Stages:	6
Impeller reduc.:	NONE
Shaft seal for motor:	HM/CER
Approvals on nameplate:	CE,EAC
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP3
Motor diameter:	4 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS4000
Applic. motor:	GRUNDFOS
Rated power - P2:	5.5 kW
Power (P2) required by pump:	5.5 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-400-415 V
Rated current:	13.0-13.0-13.4 A
Starting current:	480-530-550 %
Cos phi - power factor:	0.85-0.81-0.76
Rated speed:	2850-2860-2870 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	79195511
Others:	
Minimum efficiency index, MEI â‰¥:	0.50
ErP status:	EuP Standalone/Prod.







Borehole pump MJ-3

GRUNDFOS

Company name:
Created by:
Phone:

Date: 09/02/2020

Qty.	Description
1	**SP 46-3**

Note! Product picture may differ from actual product

Product No.: 15A21903

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 5.5 kW MS4000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	43.75 m³/h
Resulting head of the pump:	26.5 m
Shaft seal for motor:	HM/CER
Approvals on nameplate:	CE,EAC
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP3
Motor diameter:	4 inch

Company name:
Created by:
Phone:

Date: 09/02/2020

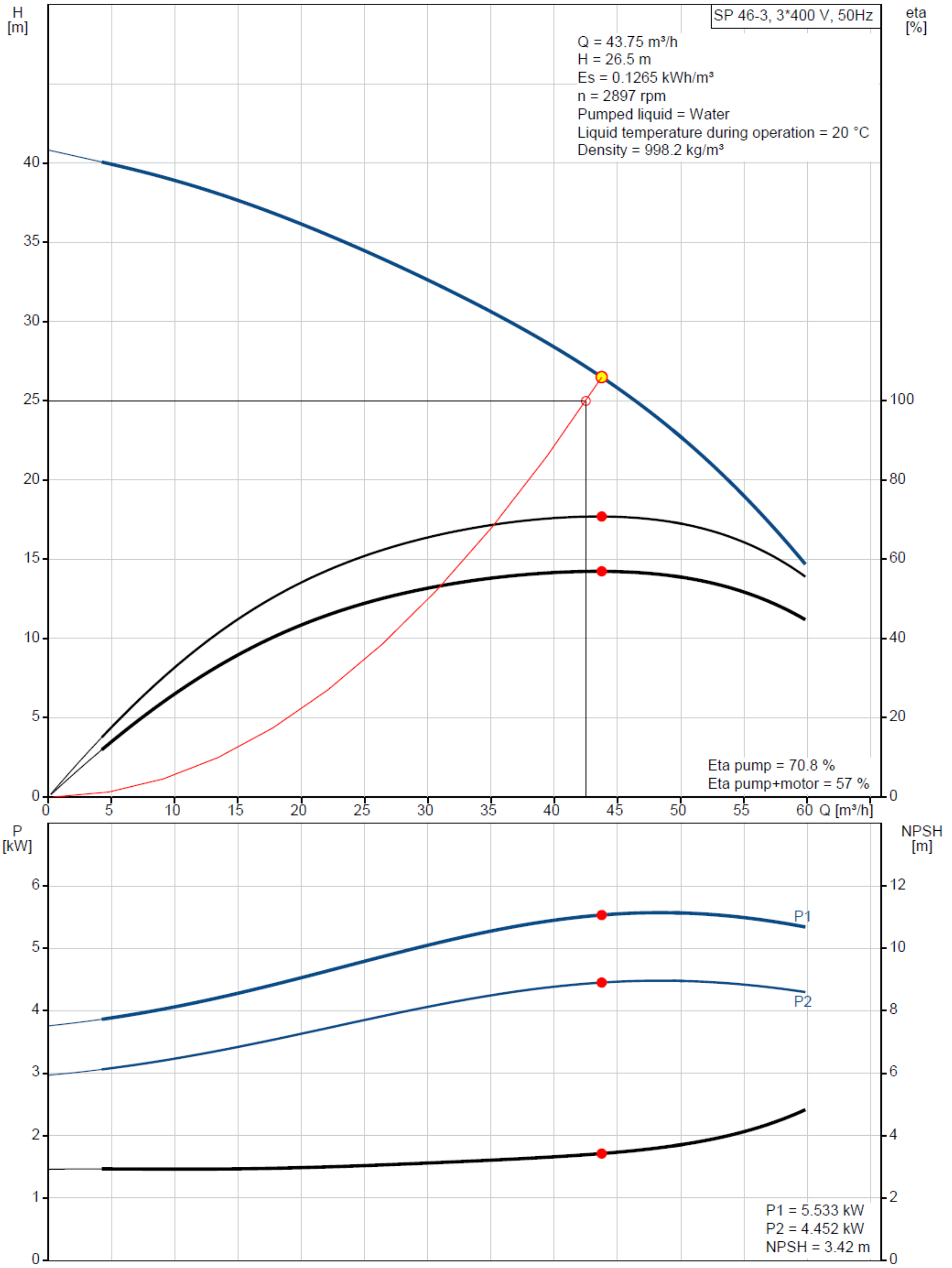
Qty.	Description	
	Electrical data:	
	Motor type:	MS4000
	Rated power - P2:	5.5 kW
	Power (P2) required by pump:	5.5 kW
	Mains frequency:	50 Hz
	Rated voltage:	3 x 380-400-415 V
	Rated current:	13.0-13.0-13.4 A
	Starting current:	480-530-550 %
	Cos phi - power factor:	0.85-0.81-0.76
	Rated speed:	2850-2860-2870 rpm
	Start. method:	direct-on-line
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	79195511
	Others:	
	Minimum efficiency index, MEI â‰¥:	0.40
	ErP status:	EuP Standalone/Prod.
	Net weight:	38.9 kg
	Gross weight:	43.3 kg
	Shipping volume:	0.052 m³
	Danish VVS No.:	388462003

GRUNDFOS

Company name:
Created by:
Phone:

Date: 09/02/2020

15A21903 SP 46-3 50 Hz

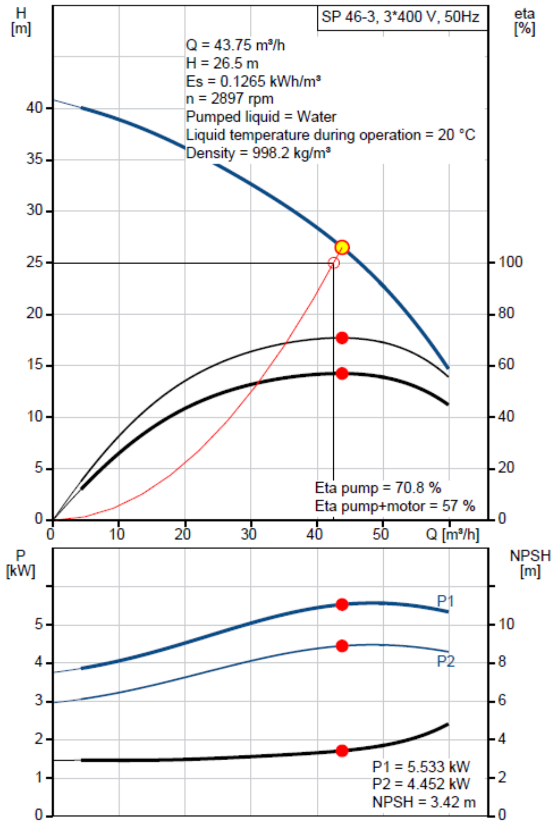


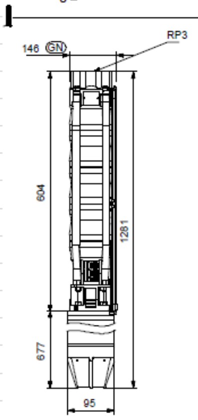
GRUNDFOS

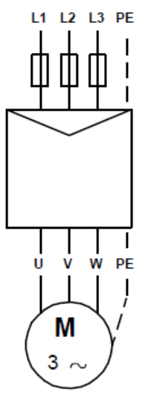
Company name:
Created by:
Phone:

Date: 09/02/2020

Description	Value
General information:	
Product name:	SP 46-3
Product No:	15A21903
EAN number:	5700391151019
	5700391151019
Technical:	
Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	43.75 m³/h
Resulting head of the pump:	26.5 m
Stages:	3
Impeller reduc.:	NONE
Shaft seal for motor:	HM/CER
Approvals on nameplate:	CE,EAC
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP3
Motor diameter:	4 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS4000
Applic. motor:	GRUNDFOS
Rated power - P2:	5.5 kW
Power (P2) required by pump:	5.5 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-400-415 V
Rated current:	13.0-13.0-13.4 A
Starting current:	480-530-550 %
Cos phi - power factor:	0.85-0.81-0.76
Rated speed:	2850-2860-2870 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	79195511
Others:	
Minimum efficiency index, MEI â‰¥:	0.40
ErP status:	EuP Standalone/Prod.







Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
9/6/2019	11:11:00 AM	50.000	418.9	419.7	418.9	131.2	128.4	127.8	73.10	0.779
9/6/2019	11:12:00 AM	50.000	419.0	419.8	419.0	131.3	128.5	127.7	73.09	0.779
9/6/2019	11:13:00 AM	50.000	418.9	419.7	419.1	131.3	128.2	127.9	73.09	0.778
9/6/2019	11:14:00 AM	50.000	420.6	421.5	420.7	131.5	128.7	128.1	73.21	0.775
9/6/2019	11:15:00 AM	50.000	421.0	421.8	420.8	131.5	129.1	127.8	73.25	0.774
9/6/2019	11:16:00 AM	50.000	420.9	421.7	420.8	131.6	128.9	127.9	73.25	0.774
9/6/2019	11:17:00 AM	50.000	420.9	421.5	420.9	131.8	128.6	128.1	73.28	0.775
9/6/2019	11:18:00 AM	50.000	420.7	421.5	420.7	131.7	128.7	128.0	73.24	0.775
9/6/2019	11:19:00 AM	49.990	421.2	421.7	421.1	132.0	128.6	127.9	73.24	0.774
9/6/2019	11:20:00 AM	50.000	421.1	421.7	420.9	131.9	128.9	127.9	73.28	0.775
9/6/2019	11:21:00 AM	50.000	421.2	421.6	420.9	132.1	128.8	127.7	73.28	0.775
9/6/2019	11:22:00 AM	50.000	421.1	421.6	421.0	132.0	128.6	128.1	73.29	0.774
9/6/2019	11:23:00 AM	50.000	421.2	421.9	421.4	132.0	128.5	128.4	73.31	0.774
9/6/2019	11:24:00 AM	50.000	420.6	421.4	420.8	131.6	128.6	128.3	73.28	0.775
9/6/2019	11:25:00 AM	50.000	419.2	420.3	419.4	131.0	128.6	128.2	73.16	0.778
9/6/2019	11:26:00 AM	49.990	419.0	419.7	418.9	131.4	128.5	127.7	73.15	0.779
9/6/2019	11:27:00 AM	50.000	419.1	419.8	419.2	131.5	128.3	128.0	73.16	0.778
9/6/2019	11:28:00 AM	50.000	419.1	419.7	419.1	131.7	128.3	127.7	73.17	0.779
9/6/2019	11:29:00 AM	50.000	419.0	420.0	419.1	131.2	128.7	127.9	73.19	0.779
9/6/2019	11:30:00 AM	50.000	419.1	420.0	419.0	131.1	128.8	127.8	73.16	0.778
9/6/2019	11:31:00 AM	50.000	419.2	420.2	419.1	131.0	128.9	127.9	73.21	0.778
9/6/2019	11:32:00 AM	50.000	419.2	420.2	419.3	131.2	128.6	128.1	73.20	0.778

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
9/6/2019	11:33:00 AM	50.010	419.4	420.5	419.8	131.3	128.4	128.4	73.26	0.778
9/6/2019	11:34:00 AM	50.000	419.6	420.7	420.0	131.3	128.4	128.5	73.24	0.777
9/6/2019	11:35:00 AM	50.000	419.5	420.6	419.7	131.2	128.7	128.3	73.21	0.777
9/6/2019	11:36:00 AM	50.000	421.3	422.5	421.7	131.4	128.9	128.8	73.34	0.773
9/6/2019	11:37:00 AM	50.000	421.7	422.8	421.8	131.5	129.2	128.6	73.38	0.773
9/6/2019	11:38:00 AM	50.000	421.6	422.9	422.0	131.4	129.0	129.0	73.39	0.772
9/6/2019	11:39:00 AM	50.000	421.8	423.0	422.2	131.5	129.0	129.0	73.37	0.772
9/6/2019	11:40:00 AM	50.000	422.0	423.1	422.3	131.7	128.9	128.8	73.38	0.771
9/6/2019	11:41:00 AM	50.000	422.0	422.9	422.3	131.9	128.8	128.9	73.41	0.772
9/6/2019	11:42:00 AM	50.000	421.6	422.8	421.9	131.5	129.0	128.9	73.40	0.773
9/6/2019	11:43:00 AM	50.000	421.8	422.9	422.2	131.7	128.9	128.9	73.37	0.772
9/6/2019	11:44:00 AM	50.000	422.3	423.2	422.3	131.9	129.1	128.6	73.40	0.771
9/6/2019	11:45:00 AM	50.000	422.5	423.2	422.3	132.1	129.3	128.3	73.44	0.771
9/6/2019	11:46:00 AM	50.000	420.8	421.5	420.8	131.8	128.8	128.2	73.30	0.775
9/6/2019	11:47:00 AM	50.000	420.1	421.0	420.0	131.3	128.9	128.1	73.24	0.776
9/6/2019	11:48:00 AM	50.000	419.9	421.1	419.8	131.0	129.2	128.1	73.24	0.776
9/6/2019	11:49:00 AM	50.000	420.7	422.0	420.7	131.1	129.3	128.4	73.31	0.775
9/6/2019	11:50:00 AM	50.000	420.8	422.0	421.0	131.3	129.0	128.6	73.32	0.774
9/6/2019	11:51:00 AM	50.000	421.1	422.0	421.3	131.8	128.8	128.5	73.36	0.774
9/6/2019	11:52:00 AM	50.000	421.1	422.1	421.3	131.6	128.8	128.6	73.34	0.774
9/6/2019	11:53:00 AM	50.000	420.9	422.0	421.1	131.4	129.0	128.5	73.31	0.774
9/6/2019	11:54:00 AM	50.010	420.7	421.9	420.9	131.3	129.0	128.6	73.35	0.774
9/6/2019	11:55:00 AM	49.990	420.8	421.9	420.8	131.4	129.1	128.3	73.30	0.774
9/6/2019	11:56:00 AM	50.000	420.8	421.8	421.0	131.5	128.9	128.5	73.31	0.774

Appendix C – PVSYST simulation results

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude -9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt: 10°		Azimuth 0°

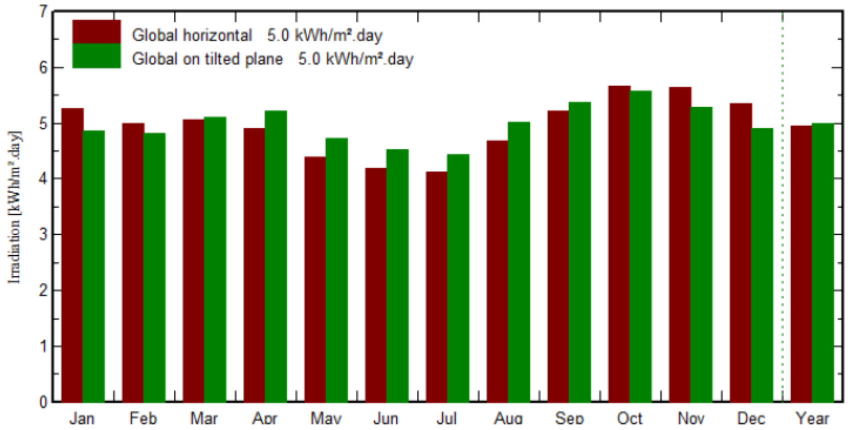
PV Installation main features

Module Type	Standard
Technology	Thin film
Mounting method	Flat roof
Back ventilation properties	Free Standing

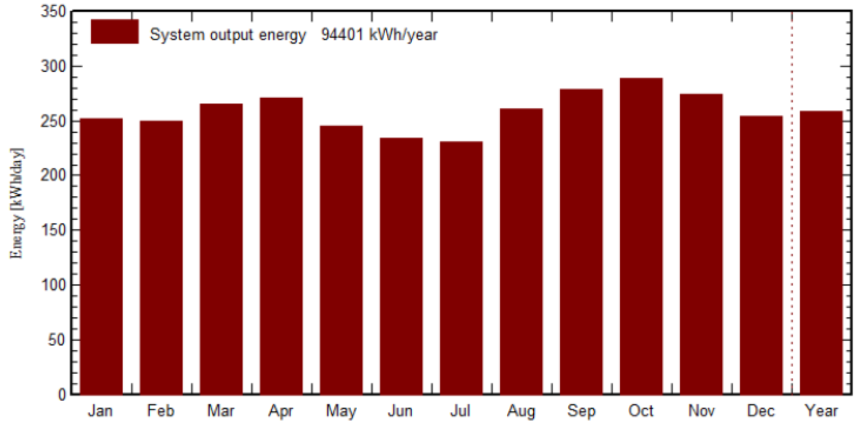
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	61.1 kWp		
Collector Area	Acoll	611 m²		
Annual energy yield	Eyear	94.4 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	252.3	7821
Feb	4.99	249.7	6992
Mar	5.05	264.8	8208
Apr	4.91	270.4	8112
May	4.39	245.0	7595
June	4.19	234.3	7030
Jul	4.12	230.1	7133
Aug	4.67	260.7	8083
Sept	5.21	279.0	8369
Oct	5.67	288.8	8954
Nov	5.64	274.1	8224
Dec	5.35	254.2	7882
Year	4.95	258.6	94401

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude -9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt:10°		Azimuth: 0°

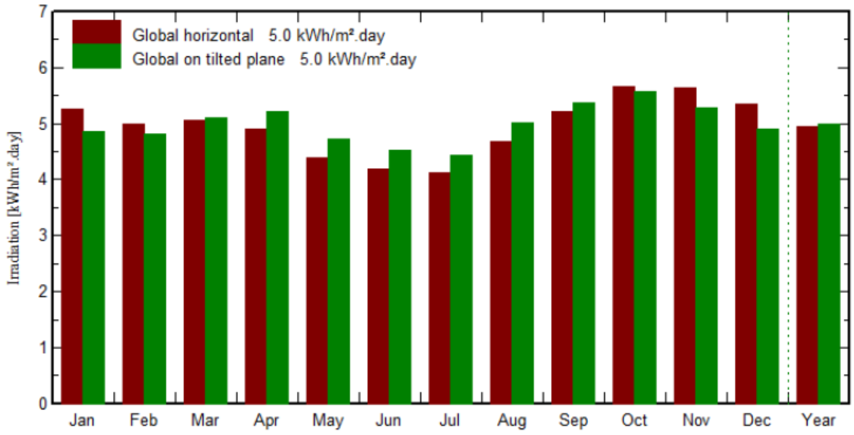
PV Installation main features

Module Type	Standard
Technology	Monocrystalline cell
Mounting method	Flat roof
Back ventilation properties	Free Standing

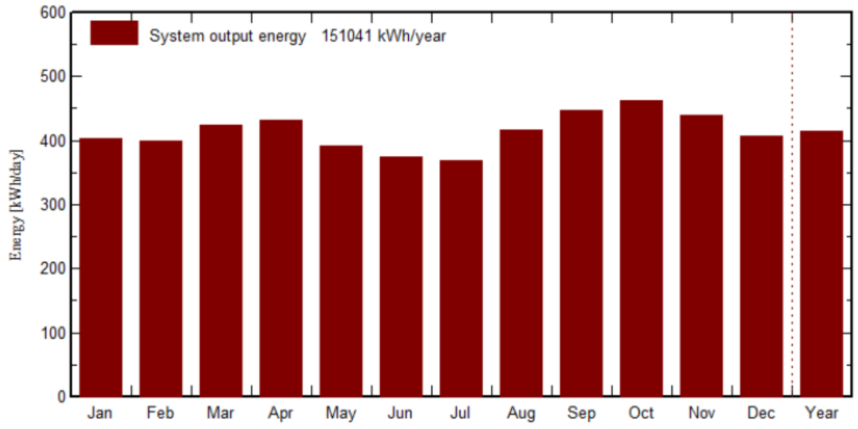
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	97.8 kWp		
Collector Area	Acoll	611 m²		
Annual energy yield	Eyear	151 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	403.7	12514
Feb	4.99	399.5	11187
Mar	5.05	423.6	13133
Apr	4.91	432.6	12978
May	4.39	392.0	12152
June	4.19	374.9	11248
Jul	4.12	368.2	11413
Aug	4.67	417.2	12932
Sept	5.21	446.3	13390
Oct	5.67	462.1	14326
Nov	5.64	438.6	13159
Dec	5.35	406.8	12610
Year	4.95	413.8	151041

Definition of Geographical Site

Geographical Site **Honiara** Country **Solomon Islands**

File New.SIT of 01/10/19 12h40

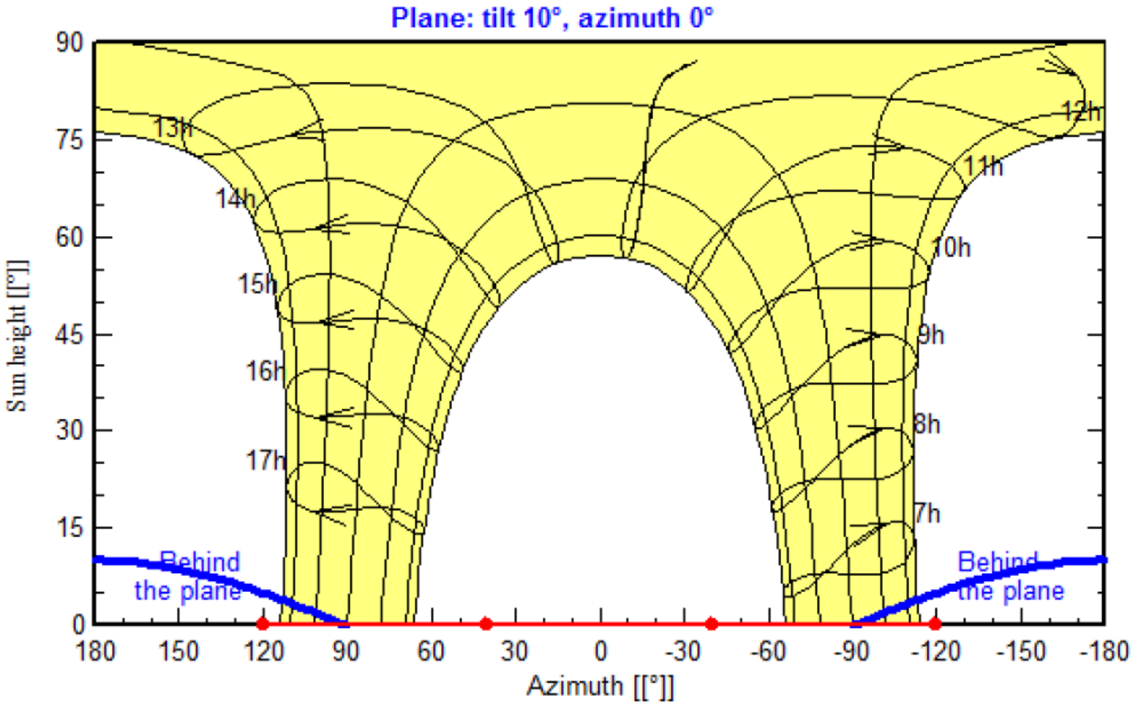
Situation Latitude: -9.45° S Longitude: 159.96° E

Time defined as Legal Time Time zone UT+11 Altitude: 10 m

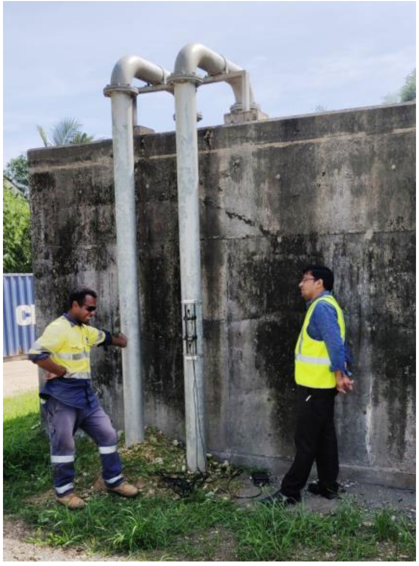
Monthly Meteo values

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m² day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m² day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

Solar paths at Honiara, (Lat. -9.45° S, long. 159.96° E, alt. 10 m) - Legal Time



Appendix D – Photographs taken during the study



DISCLAIMER

The report has been prepared based on study done at the Tuvaruhu JICA Pump Station of Solomon Island Water Authority. Our assessment and recommendations are based on the facts and details provided during our visit. If any of these facts or details provided is incomplete or inaccurate, the subsequent analysis might change, causing us to change our opinion. The conclusions drawn and recommendations made are based on the information available at the time of writing this report and PricewaterhouseCoopers will not be responsible to rework any such conclusion or recommendation if new or updated information is made available.

The recipient must conduct its own analysis of the information contained in this document and is advised to carry out its own investigation into the proposed project, the legislative and regulatory regime which applies thereto and by all matters pertinent to the proposed project and to seek its own professional advice on the legal, financial, regulatory and taxation consequences of entering into any agreement or arrangement relating to the proposed project.

Detailed Feasibility Report
Tuvaruhu SIWA Pump Station

Prepared for
UNIDO – CTCN

Under the project
Technical Assistance to Solomon Water for Energy Efficiency and Self-Generation Plan

DRAFT

Prepared by

pwc

Acknowledgement

PricewaterhouseCoopers (PwC) places on record its sincere thanks to Climate Technology Centre & Network (CTCN) and United Nations Development Organization (UNIDO) for vesting its confidence in PwC for carrying out this prestigious “technical assistance to Solomon Water on Energy Efficiency and Self-Generation Plan”.

The study team is indebted to Mr. Ian Gooden, Chief Executive Officer, Solomon Island Water Authority for showing keen interest in the study and thankful to the progressive management of Solomon Water for their wholehearted support and cooperation for the study and preparation of Detailed Feasibility Report. It is well worthy to mention that the efforts being taken, and the enthusiasm shown by all the personnel towards energy efficiency was admirable. A special thanks to Mr. Mark Waite (Strategic Projects Management Advisor), Mr. Shaun Kies-Ryan (Hydrogeologist), Mr. Noel Orudiana (Project Manager) and Mr. Danny Titiri (Electrical and Mechanical Team Lead) for coordinating the field visits. We would like to thank all the staff for support including technicians, electricians i.e. Mr. Livingston, Mr. Sam and Mr. Moffat.

PwC is grateful to Mr. Hudson Kauhiona, Director Climate Change for his committed support from Ministry of Environment, Climate Change, Disaster Management and Meteorology for executing the technical assistance.

Last but not the least, our sincere thanks to Mr. Adam Searancke, Project Manager, Solomon Island Water Authority for his full cooperation and support during entire technical assistance.

Executive Summary

Brief about the project

Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets. The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements.

Brief about the industry

Tuvaruhu SIWA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station has a 200 m^3 water receiver tank, which receives water from two bore-holes. The water from receiving tanks is pumped to Low West Kola reservoirs using two transfer pumps. The system is designed for continuous operation of two bore pumps. At the time of study both the bore-pumps were operational. Both transfer pumps were operating in parallel ON-OFF mode, based on level switch in the receiver tank. Details of Tuvaruhu SIWA pump station is presented below.

Name of the pump station	Tuvaruhu SIWA
No. of transfer pumps	2 (Both operational)
No. of bore-hole pumps	2 (Both operational)
Monthly electricity consumption	19,557 kWh (average of last 17 months)
Monthly water production	43,057 m^3 (based on onsite measurement)
Name and details of contact person	Livingston Kute, Plumber +677-7459172 Danny Titiri, Electrical and Mechanical Team Lead dtitiri@solomonwater.com.sb, +677-8876857
Annual working days	365

A detailed feasibility study of Tuvaruhu SIWA pump station was conducted in September 2019 to identify the preliminary areas for energy efficiency improvement and renewable energy potential and techno-economic feasibility. A detailed performance study was undertaken in the identified areas with the use of the sophisticated handheld instruments. Energy consumption pattern and water production data were collated to estimate the specific energy consumption (SEC) of the pump station. The pump station level baseline was estimated using the historical data.

Summary of study

Tuvaruhu SIWA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station is over a decade old. The pump station has a 200 m3 water receiver tank, which receives water from two boreholes. The pump station produces 1416 m3 water daily consuming about 652 kWh electrical energy. The existing specific energy consumption is 0.454 kWh per m3. The study has identified four recommendations for energy conservation **(table**). These recommendations could save annually about 67,294 kWh of electricity. These recommendations have an estimated investment of US $ 51,318 and can yield a monetary savings of US $46,097 per year. The annual energy saving is estimated to be 28.7%of total energy consumption by the pump station (**figure**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 44.41 tonnes of CO_2.

Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement transfer pump with EE pump + VFD	34,949	$ 23,940	$ 43,750	1.8	23.07
ECM-2	Replacement of borepump-2 with efficient pump	32,311	$ 22,133	$ 7,488	0.3	21.33
ECM-3	Replacement of FTL with LED lights	34	$ 23	$ 80	3.4	0.02
	Total	**67,294**	**$ 46,097**	**$ 51,318**	**1.1**	**44.41**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table**.

Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.454 kWh/m^3	0.324 kWh/m^3
Specific CO_2 emission	0.300 kg CO_2/m^3	0.214 kg CO_2/m^3

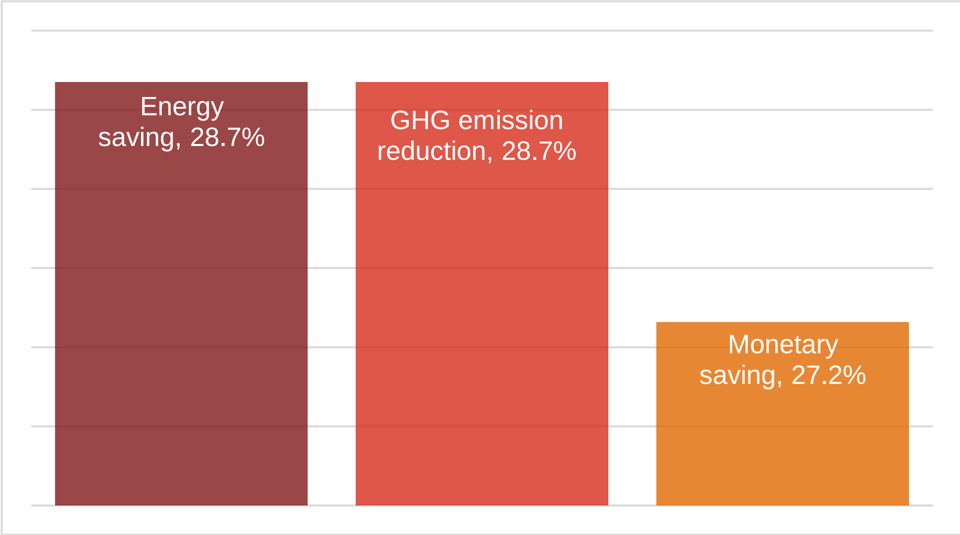
On renewable side, there is potential of solar photovoltaic plant. The pump station can utilize entire roof space for a SPV plant of 97.8 kWp with an investment of US $ 340,393, it can replace conventional electrical energy equivalent to 151.1 MWh equivalent to GHG emission reduction of 99.7 tCO_2.

Funding options

The overall investment proposed for four energy conservation measures for Tuvaruhu SIWA pump station is US$ 51,318. The simple payback on this investment is one year. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 3 months, which can be followed by transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Tuvaruhu SIWA pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.



Identified saving potential

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Conversion tables

Unit	Conversion factor
1 kWh	0.66 kg CO_{2e}*
1 kWh	860 kcal
1 m^3	1,000 liters
1 USD	8 SBD

* *Source: http://documents.worldbank.org/curated/en/772871531020654750/pdf/Solomon-Islands-Electricity-PAD-06132018.pdf*

Abbreviations

APFC	Automatic power factor correction
BEP	Best efficiency point
CO_2	Carbon Dioxide
CTCN	Climate Technology Centre & Network
DG	Diesel generator
ECM	Energy Conservation Measures
EE	Energy efficiency
FTL	Fluorescent Tube light
GHG	Greenhouse gas
GHI	Global Horizontal Irradiance
Hz	Hertz
kVA	Kilovolt ampere
kVAr	Kilovolt ampere-reactive
kW	Kilo Watt
kWp	Kilowatt-peak
kWh	Kilowatt hour
LED	Light emitting diode
m	meter
m^3	Cubic meter
MW	Megawatt
NDE	National Designated Entity
rpm	Revolution per minute
SBD	Solomon Island Dollar
SCE	Specific Carbon dioxide emission
SEC	Specific Energy Consumption
SPP	Simple Payback Period
SPV	Solar Photovoltaic
TA	Technical Assistance
tCO_2e	tonne of carbon dioxide equivalent
toe	tonne of oil equivalent
UNIDO	United Nations Industrial Development Organization
VFD	Variable Frequency Drive

1. Introduction

1.1. Background

Solomon Islands comprise hundreds of islands; of these, the main islands include Honiara (capital of Solomon Islands) and provincial urban centers of Auki, Noro and Tulagi. Solomon Islands Water Authority (SW), a state-owned enterprise, is mandated to operate as the provider of municipal water and wastewater services in Solomon Islands under the SIWA Act and State-Owned Enterprise Act. SW supplies and manages water only in these four main islands. It provides water services to an estimated population of about 100,000 in Honiara and over 8,000 in the provincial centers. The municipal wastewater services are provided to about 30,000 people in Honiara.[1] The Solomon Waters body reports to Minister of Mines, Energy and Rural Electrification and to the Minister of Finance of Solomon Islands.

The water pumping facilities of Solomon Island Water Authority comprise of the following:

- Borehole pumps (Honiara and Auki)
- Raw water supply and pumping stations (in all four islands)
- Waste water collection facilities (Honiara)

Typical view of pump stations located in Honiara is presented in **Figure 1**.

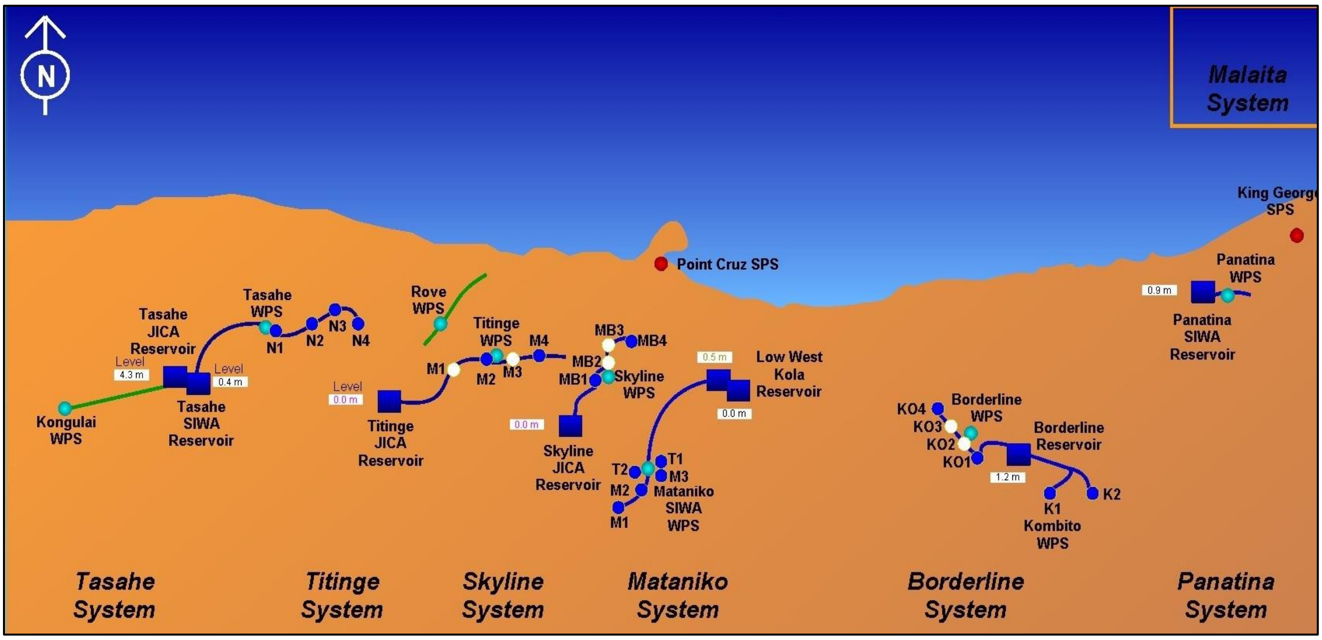

Figure 1 Pump stations in Honiara

About 95% of total installed capacity of electricity generation in Solomon Islands is based on fossil fuels, and the balance 5% is through renewable energy sources. The electricity tariff of Solomon Islands is one of the highest in the Pacific (and the World), since a major share of electricity in the Islands is met through fossil fuels (diesel generators).

Solomon Water is using diesel-based electricity generators to meet its electricity requirements in its various facilities. In addition, most of the equipment and system installed in various facilities of SW have not incorporated energy efficiency options.[1]

[1] *Terms of Reference, CTCN request ref: 2017000039*

1.2. Problem statement

The expense towards energy consumption were more than 35% in year 2013-14 for Solomon Water. The total energy consumption of Solomon Water is almost 10% of total energy consumption of Solomon Islands. The energy consumption is further expected to increase to cater the projected escalation of demand pertaining to the increasing population and to reach out to un-serviced population. The main source of electricity generation in the island is fossil fuel and the increase in fuel cost would directly affect the operation cost and GHG footprint of Solomon Water. This in turn put upward pressure and wrongly influence the expansion plans of its services. In addition, low importance is provided to efficiency in selection of equipment related to water services. Therefore, it is vital for Solomon Water to explore sustainable energy solutions that would help reducing energy consumption and contribute towards national GHG emission reduction targets.[2]

1.3. Objective of the technical assistance

The objective of the technical assistance is to support the planning and implementation of Energy Efficiency (EE) measures and Self-Generation Options (SGO) through renewable energy to reduce the reliance of Solomon Water on fossil fuel for energy requirements. **Figure 2** presents the objectives of technical assistance:

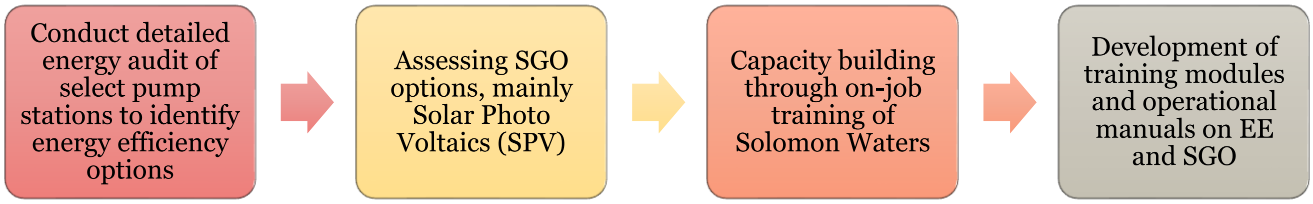

Figure 2 Objectives of the technical assistance

The assistance would lead to preparation of detailed feasibility reports covering technical and economic feasibility for EE and SGO options as well as support for selection of equipment and system by preparing tender specifications for procurement of energy efficient equipment/systems and implementation by Solomon Water.

1.4. Scope of work

The scope of work is divided in five parts:

- Output 1: Implementation plan and communication documents for the projects
- Output 2: Assessment of EE and renewable energy options
- Output 3: Detail assessments of shortlisted EE and SGO options for Solomon Water
- Output 4: Capacity building through on-job training of Solomon Water on EE and RE implementation
- Output 5: Monitoring of impacts

The output 1 is mainly the CTCN communication documents such as monitoring & evaluation plan, impact description and closure & data collection reports. **Figure 3** presents the details of output 2 to 5. The study focused on seen pump stations, 6 in Honiara and one in Auki. The list of pump station is presented in **Table 1**.

Table 1 List of pump stations covered

Borderline pump station – Honiara	Tuvaruhu JICA pump station – Honiara
Skyline pup station – Honiara	Tuvaruhu SIWA pump station – Honiara
Tasahe pump station – Honiara	Kwaibala pump station - Auki
Titinge pump station – Honiara	

[2] *Response Plan, CTCN request ID: 2017000039*

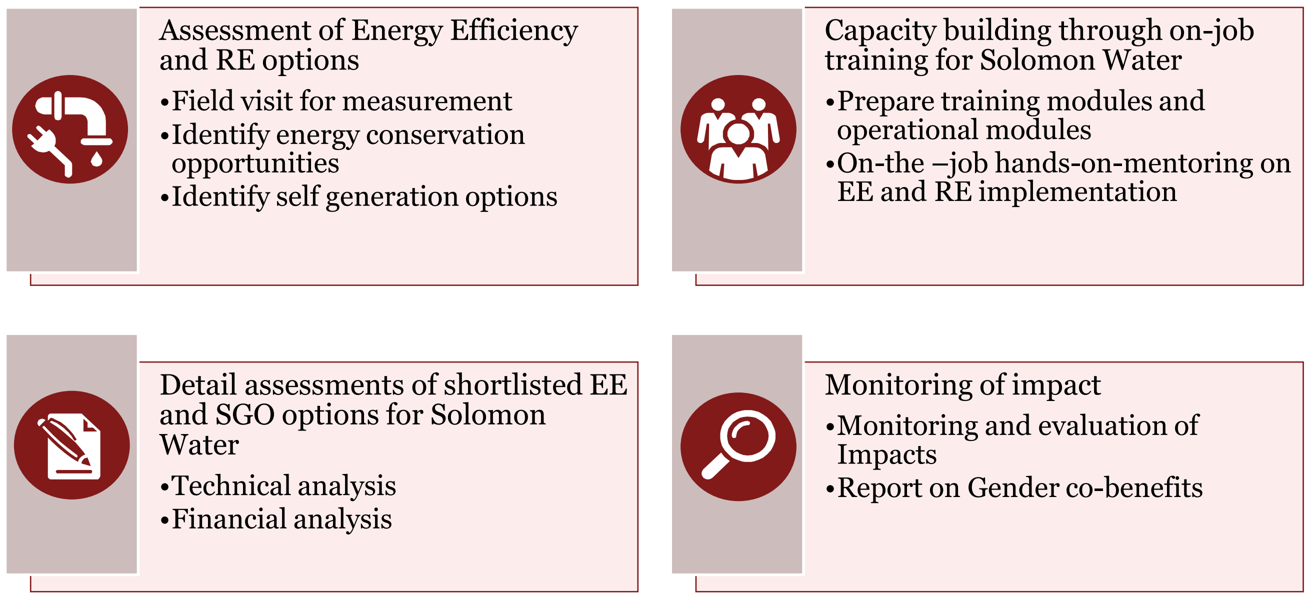

Figure 3 Scope of work

1.5. Expected benefits

The proposed technical assistance is expected to expedite the uptake of energy efficiency and renewable energy by Solomon Water in Solomon Islands. **Figure 4** presents some of anticipated environmental, economic and social benefits of technical assistance.

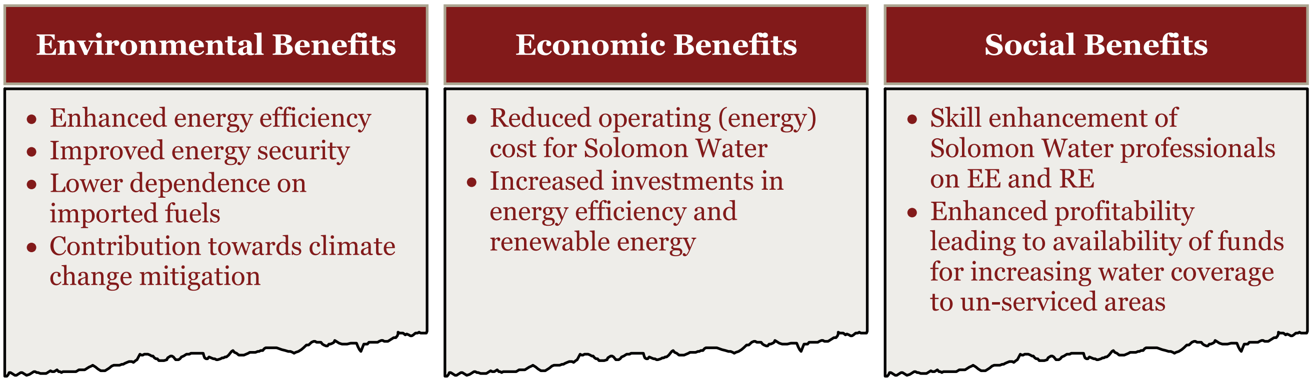

Figure 4 Expected benefits from the assignment

1.6. Detailed feasibility study methodology

The project team conducted a comprehensive energy audit and renewable energy potential assessment at the 7 pump stations following the methodology depicted in **Figure 5**. The steps in the detailed feasibility assessment included establishment of baseline, energy and water balance, performance assessment of equipment, estimation of operating efficiency, identifying energy conservation measures, solar potential assessment and sizing of potential system.

PwC team developed a structured questionnaire to capture basic information about pump station, its energy consumption and water pumped. The field assessment of pump station starts with opening meeting, wherein Solomon Water explains the layout and specifics of the pump station. This is followed by in-site measurements and trials on transfer pumps and bore pumps. Team carries-out number of trails to assess performance of electrical system, pump and motors. Aspects of solar feasibility is assessed such as resource availability, potential of generation, shading and net roof availability. Project team used sophisticated portable hand-held instruments for water flow, head and power measurements.

The technical and financial feasibility analysis of all potential energy efficiency and renewable energy recommendation is conducted. Draft detailed feasibility report is submitted to Solomon Water for comments and feedback. The comments are incorporated to finalize the detailed feasibility report.

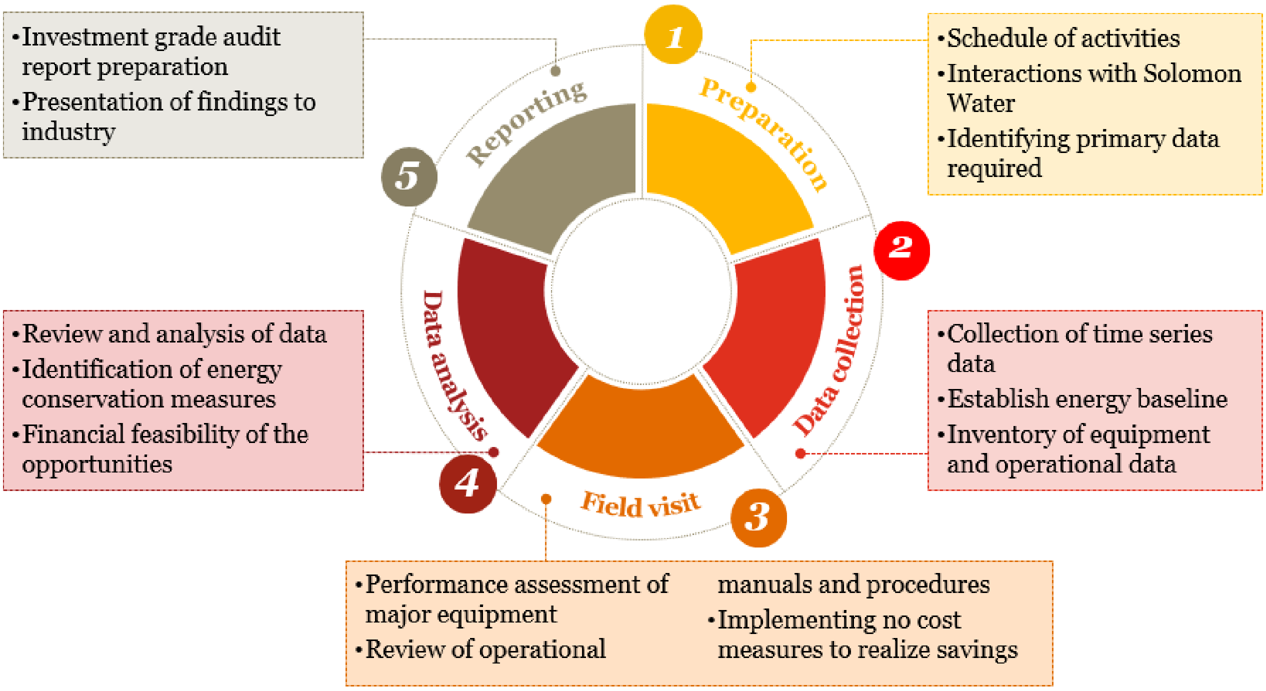

Figure 5 Detailed EE and RE feasibility study methodology

2. Overview of Tuvaruhu SIWA pump station

2.1. About Tuvaruhu SIWA pump station

Tuvaruhu SIWA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station has a 200 m³ water receiver tank, which receives water from two bore-holes. The water from receiving tanks is pumped to Low West Kola reservoirs using two transfer pumps. The system is designed for continuous operation of two bore pumps. At the time of study both the bore-pumps were operational. Both transfer pumps were operating in parallel ON-OFF mode, based on level switch in the receiver tank. The overview of Tuvaruhu pump station as seen in Solomon Water SCADA system is shown in **Figure 6**.

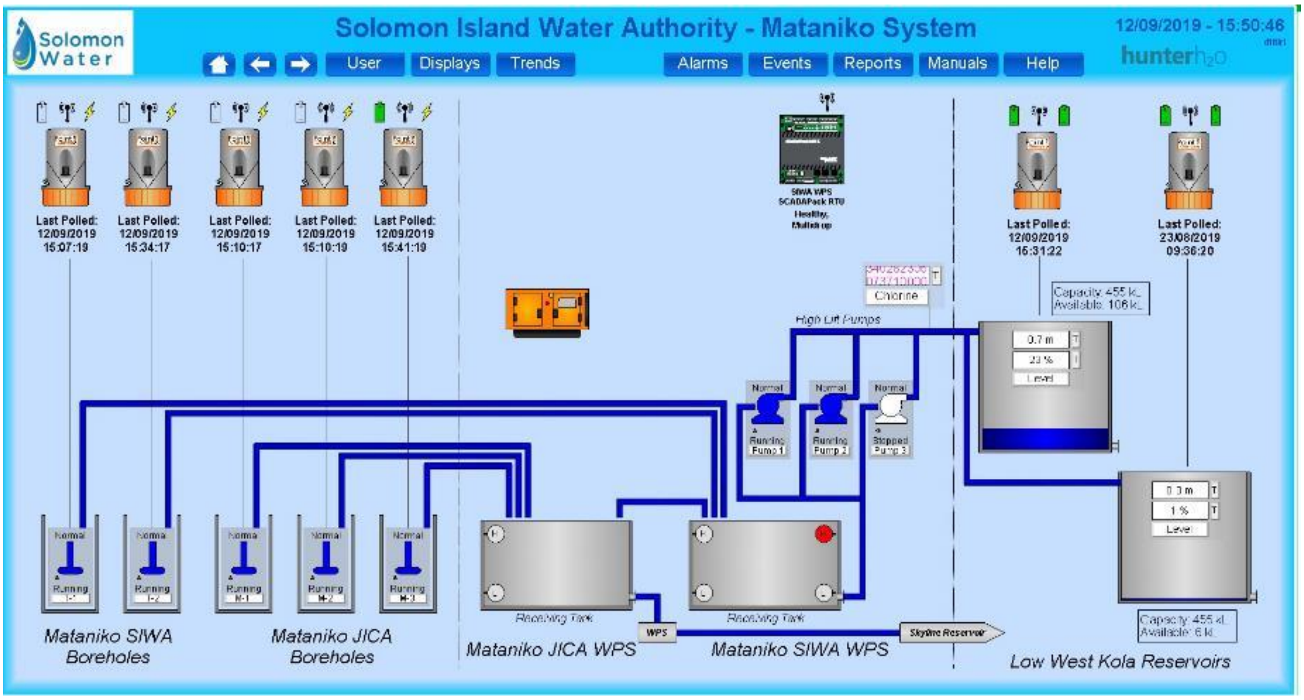

Figure 6 Tuvaruhu (JICA+SIWA) pump station overview - SCADA system

2.2. Transfer pumps

The Tuvaruhu pump station is equipped with two centrifugal end-suction pumps. These two pumps are connected to operate in parallel. Pumps have a common suction header drawing water from receiver tank and a common discharge header supplying water to Low West Kola reservoirs. Both transfer pumps operate in parallel, they switch ON and OFF depending on the level control of the SIWA receiver tank. Design details of transfer pumps, its corresponding motor is presented in **Table 2** and **Table 3** respectively. Pictorial view of transfer pumps is shown in **Figure 7**.

Table 2 Design details of transfer pumps

Particular	Unit	Pump 1	Pump 2
Make	-	Southern Cross	Southern Cross
Model	-	80X50-200 MFC13A-F-CC5CM	80X50-200 MFC13A-F-CC5CM
Design flow	m^3/h	70.0	70.0
Design head	m	62	62

Particular	Unit	Pump 1	Pump 2
Max. head	m	72	72
Pump speed	rpm	2950	2950
Recommended motor	kW	18.5	18.5
Pump efficiency	%	75.0	75.0

Table 3 Design details of motors suppling power to transfer pumps

Particular	Unit	Motor 1	Motor 2
Make	-	Monarch	Monarch
Power	kW	18.5	18.5
Voltage	V	415.0	415.0
Current	I	32.6	35.5
Power Factor	-	0.89	0.90
Motor speed	rpm	2940	2935
Frequency	Hz	50.0	50.0
Rating	-	MEPS 2006 Compliant	MEPS Compliant
Efficiency	%	90.8	89.3

Figure 7 Tuvaruhu SIWA transfer pumps

2.3. Borehole pumps

The Tuvaruhu SIWA pump station receives water from two borehole pumps. Water is extracted using submersible centrifugal pumps. As the pumps were underground, name plates could not be checked physically. The design details were collected from records available at Solomon Water maintenance office. The system was designed for 24 x 7 operation of two bore pumps. Both bore-pumps were operational during testing.

The design details of bore pumps is presented in **Table 4** and pictorial view of one borehole pump site is presented in **Figure 8**.

Table 4 Design details of borehole pumps

Particular	Unit	T-1	T-2
Make	-	Southern Cross	Southern Cross
Model	-	SC 50-5	SC 46-8
Design flow	m^3/h	46.2	47.9
Design head	m	42.4	24.5
Pump depth	m	33.5	42
Pump efficiency	%	NA	NA

Figure 8 Typical borehole pump – Tuvaruhu

3. Energy consumption analysis

3.1. Energy source and tariff details

Tuvaruhu SIWA pump station of Solomon Water receives power from 415 V low tension connection of Solomon Island Electricity Authority (SIEA). Tuvaruhu SIWA pump station is under Industrial I3 type electricity connection. The electricity tariff is three-part type, which are (a) Network access changes – NAC, (b) Fuel charge and (c) Non-fuel charges. The tariff varies every month.

The monthly variation in tariff for last 12 months was captured during feasibility study and same is presented in **Table 5**.

Table 5 Electricity tariff details – Last 12 months

Month	Fuel charge (SBD/unit)	Non-fuel charge (SBD/unit)			NAC (SBD/month)[3]
		I1[4]	I2[5]	I3[6]	
Aug-18	2.85	3.68	3.16	2.81	3,175.72
Sep-18	2.85	3.7	3.18	2.83	3,199.91
Oct-18	2.71	3.71	3.19	2.84	3,204.42
Nov-18	2.83	3.72	3.2	2.85	3,218.49
Dec-18	2.81	3.75	3.23	2.87	3,242.95
Jan-19	2.77	3.77	3.24	2.89	3,258.18
Feb-19	2.49	3.11	2.68	2.38	2,690.01
Mar-19	2.71	3.79	3.26	2.90	3,277.82
Apr-19	2.53	3.61	3.11	2.77	3121.85
May-19	2.64	3.85	3.31	2.95	3328.04
Jun-19	2.21	3.85	3.31	2.95	3,324.80
Jul-19	2.38	3.84	3.3	2.94	3,316.60
Average	**2.65**	**3.70**	**3.18**	**2.83**	**3,196.57**

3.2. Analysis of electricity consumption

The monthly electricity consumption of last 18 months for Tuvaruhu SIWA pump station was analyzed. The average electricity tariff and consumption for last 12 months was evaluated. These 12-month average are considered as energy baseline and are used for comparison with proposed saving. The average electricity tariff is used for computing equivalent monetary saving, corresponding to an energy saving resulting from energy efficiency recommendation.

The total electricity consumption in last 12 months (August 2018 to July 2019) was 234,680 kWh. The bill amount corresponding to this consumption was SBD 1.36 million i.e. USD 169,744.

The electricity consumption along with monthly energy charges is presented in **Table 6**. Variation of electricity consumption is presented in **Figure 9**.

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[3] *I3 connection electricity consumption>6000 kWh*
[4] *First 1300 units of the monthly consumption*
[5] *Next 4700 units of the monthly consumption*
[6] *Remaining consumption of the month*

Table 6 Electricity consumption details

Month	Consumption	NAC (SBD)	Fuel charge (SBD)	Non-fuel charge			Total (SBD)
	kWh			I1	I2	I3	
Aug-18	13,280	3,176	37,848	4,784	14,852	20,457	**81,117**
Sep-18	23,280	3,200	66,348	4,810	14,946	48,902	**138,206**
Oct-18	23,200	3,204	62,872	4,823	14,993	48,848	**134,740**
Nov-18	22,440	3,218	63,505	4,836	15,040	46,854	**133,454**
Dec-18	20,240	3,243	56,874	4,875	15,181	40,869	**121,042**
Jan-19	19,560	3,258	54,181	4,901	15,228	39,188	**116,757**
Feb-19	19,640	2,690	48,904	4,043	12,596	32,463	**100,696**
Mar-19	17,320	3,278	46,937	4,927	15,322	32,828	**103,292**
Apr-19	21600	3,122	54,648	4,693	14,617	43,212	**120,292**
May-19	17,680	3,328	46,675	5,005	15,557	34,456	**105,021**
Jun-19	18,080	3,325	39,957	5,005	15,557	35,636	**99,480**
Jul-19	18,360	3,317	43,697	4,992	15,510	36,338	**103,854**
Average	**19,557**	**3,197**	**51,871**	**4,808**	**14,950**	**38,338**	**113,163**
Annual	**234,680**	**38,359**	**622,446**	**57,694**	**179,399**	**460,052**	**1,357,950**

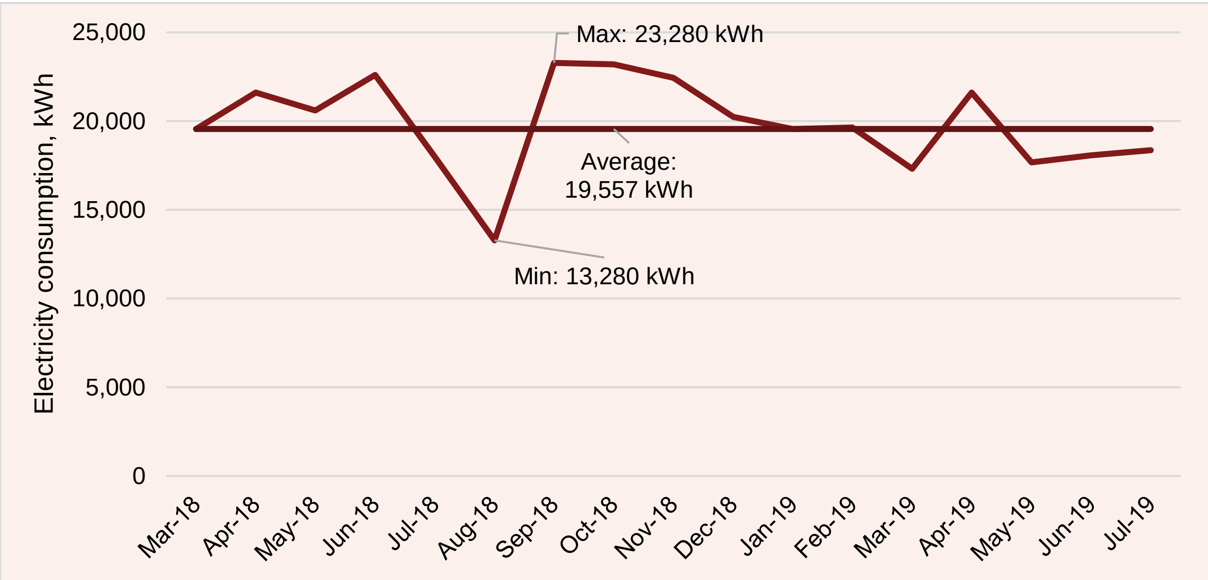


Figure 9 Electricity consumption profile March 2018 – July 2019 (18 months)

Key observations for the period August 2018 to July 2019:

- Monthly average consumption of electricity was 19,557kWh (varying between 13,280 to 23,280)
- Average electricity tariff (excluding fixed NAC) was SDB 5.62 per kWh (US$ 0.70 per kWh)
- Average fuel tariff considered for solar calculation was SBD 2.65 per kWh (US¢ 33.1 per kWh)

Average monthly electricity consumption of Tuvaruhu SIWA Pump Station is 19,557 kWh

A sample electricity bill of Tuvaruhu SIWA pump station is presented in **Figure 10**.

Solomon Islands Electricity Authority
trading as SOLOMON POWER

INVOICE / STATEMENT

Customer

SIWA - Tuvaruhu SIWA Pump Stn.
P O Box 1407
Honiara

Date	06/January/2019
Customer Number	11165-01
Customer Type	**INDUSTRIAL**
Customer Category	**I3**

Location: Water Unit
Tuvaruhu SIWA Pump Stn.
Tuvaruhu

Previous Month

Balance at Previous Account Date	$254,495.84
Payment Received to 19 Dec Thank you	($133,453.69)
Balance Prior to 6 Jan 19	$121,042.15

Aged Debts

Current	30 days	60 days	90 days & over	TOTAL
$116,756.78	$121,042.15	$0.00	$0.00	$237,798.93

Month 06/January/2019

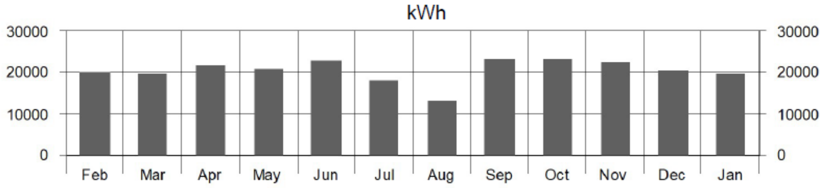
Readings from 6/Dec/2018 to 6/Jan/2019 **Days** 31

Usage

	Meter no.	Previous	Present	Multi	Units
1	216077962	6,547	7,036	40	19,560

Total **19,560.00** kWh/month

CONSUMPTION - kWh / month



Total Consumption for the Past 12 months 244080 kWh

	Category	UNITS	Amount	Rate - $/Unit	Factor	Charge
NAC	I3	Days	31	3,258.18		3,258.18
Fuel	I1	kWh	19,560.00	2.7700	1.0000	54,181.20
Non-Fuel	I1	kWh	1,300.00	3.7700	1.0000	4,901.00
	I2	kWh	4,700.00	3.2400	1.0000	15,228.00
	I3	kWh	13,560.00	2.8900	1.0000	39,188.40
			19,560.00			59,317.40

TOTAL THIS PERIOD	**$116,756.78**
TOTAL DUE	**$237,798.93**
FINAL DATE FOR PAYMENT:	21/January/2019

No further notices will be issued. Unpaid accounts will have supply disconnected.
Previous month balances are payable immediately.

Figure 10 Sample electricity bill of Tuvaruhu SIWA pump station

The total electricity consumption in the pump station can be categorized in four parts: (a) transfer pumps, (b) borehole pumps, (c) lighting system and (d) electrical system losses and miscellaneous. The average consumption by each category is presented in **Figure 11**.

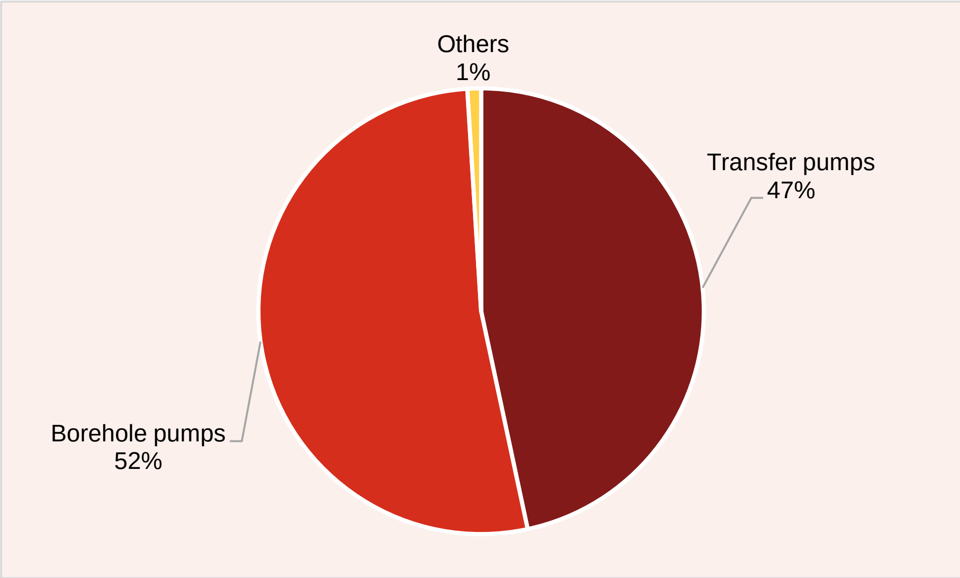


Figure 11 Electricity consumption share

3.3. Specific energy consumption

The daily water production from the bore-fields was 1415.6 m^3 and the daily energy consumption was 652 kWh of electricity. The water production is estimated using field measurement of flow and operating hours. The electricity consumption is measured using three-phase power analyzer for 24 hours. Same was verified using the daily average electricity consumption arrived from last 12 months data. The specific energy consumption is presented in **Table 7**.

Table 7 Specific energy consumption

Particular	Unit	Value
Daily water production	m^3	1415.6
Daily electricity consumption	kWh	651.9
Specific energy consumption	**kWh/m^3**	**0.454**

4. Energy efficiency performance assessment

4.1. Transfer pumps

4.1.1. Performance assessment

The pump station is equipped with two transfer pumps. These are end-suction centrifugal pumps with stainless steel impeller. Pumps are of Southern Cross make and are driven by individual 18.5 kW motor. During the site visit both pumps were operational and performance assessment test was conducted on pumps individually and in parallel operation of two pumps.

The performance assessment of transfer pumps was conducted by measuring following three parameters simultaneously:

- Water flow rate of pump, m^3/h
- Differential head developed (suction and discharge), m
- Power absorbed by motor, kW

The performance assessment test help us achieve the following:

- Determination of pump efficiency during the operating condition
- Determination of system resistance and the operating duty point of pump compared to the design best efficiency duty point.

The transfer pump 2 operates 24 x 7, with transfer pump 1 switching ON and OFF depending on the level control of the SIWA receiver tank. The daily operating hours of the transfer pumps were recorded by installing a three-phase power analyser for 24 hours to record power parameters for every one-minute interval. The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current.

Figure 12 shows water flow measurement using non-intrusive ultrasonic water flow meter and power measurement of the transfer pump.

Figure 12 Water flow and power measurement photograph

The measured data such as operating hours and flow are verified using system data available at Solomon Islands Water Authority. The performance assessment of transfer pumps is presented in **Table 8**.

Table 8 Performance assessment of transfer pumps 1 and 2

Particular	Unit	Pump 1	Pump 2
Operating flow	m^3/h	64.60	62.90
Suction head	m	1.00	1.00
Discharge head	m	46.00	46.00
Total head	m	47.0	47.0
Hydraulic power	kW	8.27	8.06
Motor input power	kW	16.39	16.78
Shaft power	kW	14.88	14.99
Pump efficiency	**%**	**55.61**	**53.75**

The operating efficiency of the transfer pumps 1 and 2 were 55.6% and 53.8%, which is less than design efficiency of the pump, 75%. The drop-in efficiency from design can be attributed to system duty point being away from design best efficiency point of the pump.

The actual duty point and best efficiency point of pump 1 and 2 are depicted in **Figure 13**, and **Figure 14.**

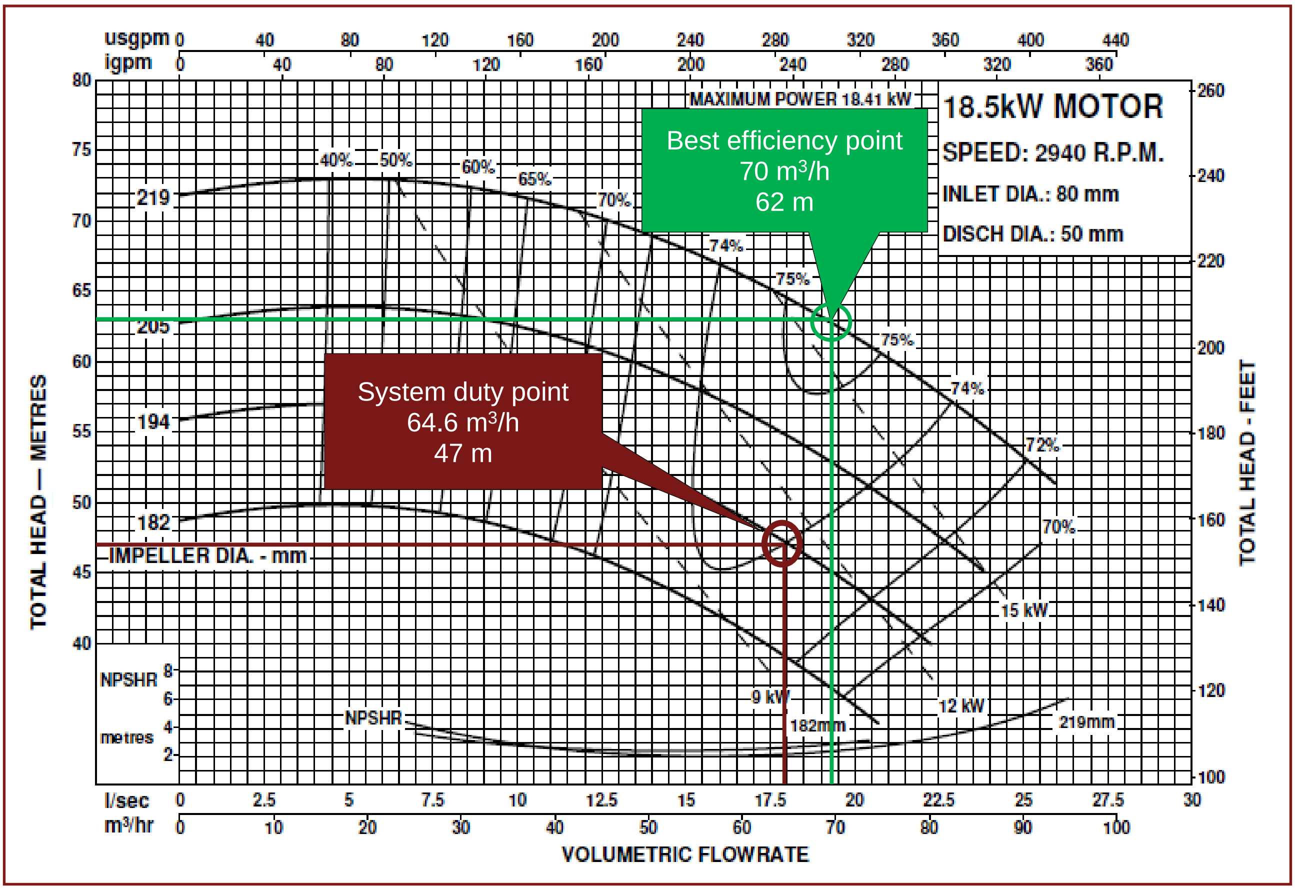


Figure 13 Transfer pump-1 duty point vs design

The system head of transfer pump-1 is lesser than the design head which should correspond to a higher flow rate than design. But in actual the flow is less than design. This drop in the flow rate can be attributed to wear in impeller due to ageing, as the pump is over a decade old.

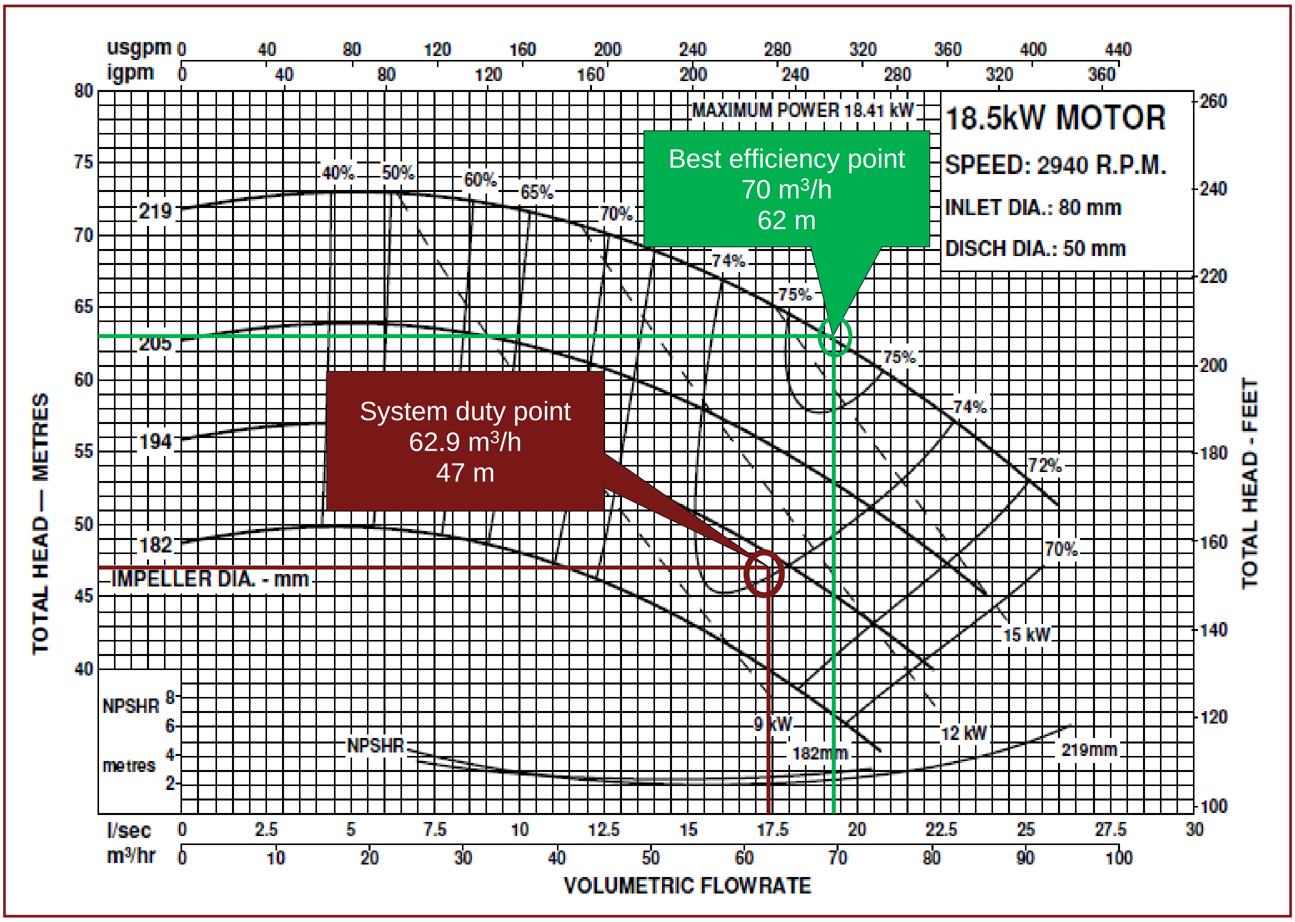


Figure 14 Transfer pump-2 duty point vs design

The system head of transfer pump-1 is lesser than the design head which should correspond to a higher flow rate than design. But in actual the flow is less than design. This drop in the flow rate can be attributed to wear in impeller due to ageing, as the pump is over a decade old.

The operating hours of the transfer pumps was recorded using power log taken by three-phase power analyser. Both transfer pumps operate for 11.1 hours in a day. They go ON-OFF depending on receiver reservoir level. The total daily water pumped by transfer pumps was 1415.6 m^3.

The performance of the motor was assessed by measuring input power parameter and arriving at motor loading using design efficiency, same is presented in **Table 9**.

Table 9 Transfer pumps motor performance

Particular	Unit	Motor 1	Motor 2
Voltage	V	417.60	416.70
Current	I	26.10	26.70
Power factor	-	0.868	0.871
Power input	kW	16.39	16.78
Motor Efficiency	%	90.8	89.3
Power shaft	kW	14.88	14.99
Motor loading	**%**	**80.42**	**81.02**

The energy conservation measure for the transfer pumps 1 and 2 is presented in next section.

4.1.2. Energy conservation measure

The flow rate of transfer pumps was 62.6 and 62.9 m3/h respectively at a system head of 47 m. This resulted in a pump operating efficiency, 55.6 and 53.8% respectively. Suspected reason for drop is in efficiency is wear in impeller due to ageing. Replacing impeller is expected to improve the flow rate, but as the pump is over decade old, we have recommended replacement of pump itself with a vertical multistage centrifugal pump with IE4 rated motor to achieve higher efficiency.

The proposed pump is of higher capacity than actual system requirement, hence it is recommended to install a variable frequency drive (VFD) to operate the pump at lower speed and meet system requirement efficiently.

The technical specification of proposed vertical multistage centrifugal pump is as follows (detailed specification is presented in **Appendix A**):

- Make and model: Grundfos CRN 64-3-1
- Design flow rate: 64 m3/h
- Design head: 59.8 m
- Pump eficiency: 77.4 %
- Motor rating and efficiency: IE4, 93.3 %

The duty point calculation with VFD is presented in **Table 10** and saving estimation is shown in **Table 11**.

Table 10 Duty point estimation with VFD

Parameter	Unit	Design	Proposed with VFD
F – Frequency	Hz	50.00	43.9
N – Speed	Rpm	2950	2634
Q – Flow	m^3/h	64.0	57.1
H – Head	m	59.8	47.7
P – Power	kW	14.4	10.8

Table 11 Transfer pumps: Energy saving estimation

Particular	Unit	Pump-1	Pump-1
Operating flow	m^3/h	57.1	57.1
Net daily water duty	m^3	707.8	707.8
Total operating hours	h/day	12.39	12.39
Annual energy consumption – proposed	kWh/year	48799	48799
Annual energy consumption – existing	kWh/year	65478	67070
Annual energy saving	kWh/year	16679	18271
Monetary saving	SBD/year	91400	102735
	USD/year	**$ 11,425**	**$ 12,515**
Cost of new pump with IE4 motor	USD	$ 16,500	$ 16,500
Freight cost for pump-motor set	USD	$ 500	$ 500
Cost at port in Solomon Islands	USD	$ 17,000	$ 17,000
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost of pump with IE4 motor	**USD**	$ 21,875	$ 21,875
Simple payback period	**years**	**1.9**	**1.7**
GHG emission reduction potential	**tCO_2/year**	**11.01**	**12.06**

The annual energy saving by replacing transfer pumps 1 and 2 is 34,949 kWh equivalent to monetary saving of US $ 23,940. The investment required for new vertical multistage centrifugal pump with IE4 motor is US $ 33,000. The freight cost of shipping from Australia is US $ 1000. Overall landed cost in Honiara inclusive of all applicable duties is US $ 43,750. The simple payback period of the recommendation is 1.8 years. The GHG emission reduction potential of the recommendation is 23.07 tCO_2 equivalent.

4.2. Borehole pumps

4.2.1. Performance assessment

The Tuvaruhu SIWA pump station has two borehole pumps. The power measurement was taken using three-phase power analyser, flow was measured using ultrasonic water flow meter, head was measured using a water depth measurement instrument available with Solomon Water (Shaun, Hydrogeologist) and head from borehole surface level to receiver tank is measured using digital pressure meter.

The borehole pump T-1 was Southern Cross SP series, model 50-5. The flow rate was measured as 18.3 m^3/h, which was lower than design and this could be due to clogged inlet screen or worn impeller. However, the performance of the pump could not be assessed as the team was unable to measure the depth of water.

The borehole pump T-2 was Southern Cross SP series, model 46-8. The pump was operating at a high head as compared to design and as a result the flow was less than design. The operating efficiency of pump was estimated 36.4%, which is not satisfactory and less than best available pumps in market.

The performance curve of borehole pump 1 and 2 were not available, hence the team was unable to plot the operating and design duty points.

The valve on the discharge pipe coming out of well was throttlled, leading to a head of 2.5 m, which is close to the actual head estimated from this point till reservoir. Hence throttling has minimum effect on system head.

The measured data such as operating hours and flow are verified using system data available at Solomon Islands Water Authority. The performance assessment of borehole pump T-2 is presented in **Table 12**.

Table 12 Performance assessment of borehole pumps

Particular	Unit	Bore-pump T-2
Operating flow	m^3/h	42.20
Well depth to water level	m	27.50
Head from surface to reservoir	m	2.50
Total head	m	30.0
Hydraulic power	kW	3.45
Motor power	kW	11.77
Shaft power	kW	9.48
Pump efficiency	**%**	**36.40**

The operating hours of the bore-hole pumps was taken from the SCADA system. The measured flow rate of water was then converted to arrive at daily water production from borefields, same is presented in **Table 13**.

Table 13 Production from bore-fields

Bore-field	Flow rate (m^3/h)	Operating hours (h)	Daily production (m^3)
Bore-pump 1 (T-1)	18.3	23.0	420.9
Bore-pump 2 (T-2)	42.2	23.6	994.7
Total			**1415.6**

4.2.2. Energy conservation measure

The borehole pump T-2 was operating inefficiently. The recommendation would be to replace the pumps with new submersible pump with a higher efficiency motor. The pump specification of the existing bore pump, system duty-point and recommended submersible pump is presented in **Table 14**.

Table 14 Technical specification of existing pump, system duty point and recommended pump

Particular	Unit	Existing Pump	System duty point	Proposed pump
Bore-hole pump T-2				
Model	-	Southern Cross SP 46-8	-	Grundfos SP 46-4
Flow rate	m^3/h	47.9	42.2	49.7
Total head	m	24.5	30.0	33.0

The proposed submersible pump as replacement for bore pumps is capable of handling head variation of ± 3 m, without substantial difference in discharge head. Detailed technical specification of the recommended submersible pump is provided in **Appendix A**. ***The energy saving is estimated considering the sustainable daily water production for the bore field shared by Solomon Water Hydrogeologist***. Detailed saving estimation is presented in **Table 15**.

The annual energy saving by replacing borehole pump T-2 is 32,311 kWh equivalent to monetary saving of US $ 22,133. The investment required for installation of submersible pump is US $ 5,240. The freight cost of shipping from Australia is US $ 250. Overall landed cost in Honiara inclusive of all applicable duties is US $ 7,488. The simple payback period of the recommendation is four months. The GHG emission reduction potential of the recommendation is 21.33 tCO_2 equivalent.

Table 15 Borehole pumps energy saving estimation

Particular	Unit	T-2
Net daily water duty	m^3	1192
Proposed pump flow rate	m^3/h	49.7
Proposed annual energy consumption	kWh/year	67555
Existing annual energy consumption	kWh/year	99911
Annual energy saving	kWh/year	32311
Monetary saving	SBD/year	177064
	USD/year	$ 22,133
Cost of new bore-pump	USD	$ 5,240
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 5,490
Import duty	%	10
GST	%	15
Net landed cost of bore-pump	USD	$ 7,488
Simple payback period	**years**	**0.3**
GHG emission reduction	**tCO_2/year**	**21.33**

4.3. Electrical system

4.3.1. Performance assessment

The pump station receives power from SIEA 415 V LT connection at the main receiving panel. The connection is routed to transfer pump panel and bore-pumps panel. The electrical parameters were studied by installing three-phase power analyzer for 24 hours. The sample snapshot of recording is presented in **Appendix B.** The power analyser recorded the following parameters: voltage, current, power factor, power of all three phases along with current and voltage harmonics, reactive and apparent power and unbalance in voltage and current.

The logging of total power for 24 hours is shown in **Figure 15**.

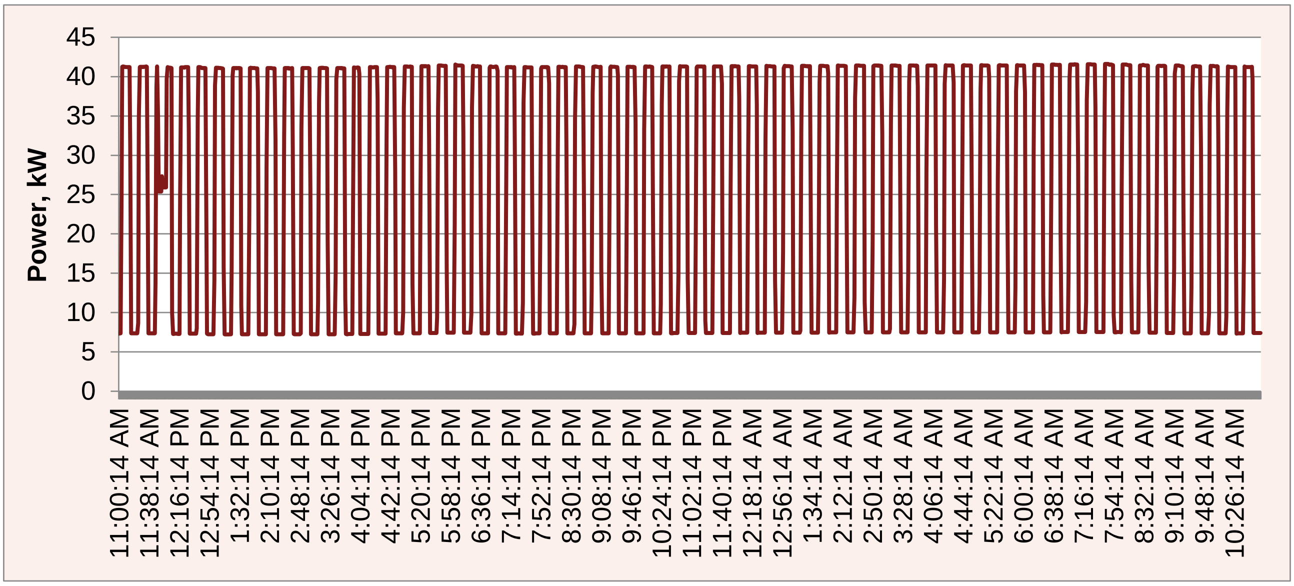


Figure 15 Tuvaruhu SIWA pump station total power log 24 hours

The power factor (PF) at the main incomer of pump station was varying between 0.69 – 0.86, with an average PF 0.783. The PF variation over 24 hours is presented in **Figure 16**.

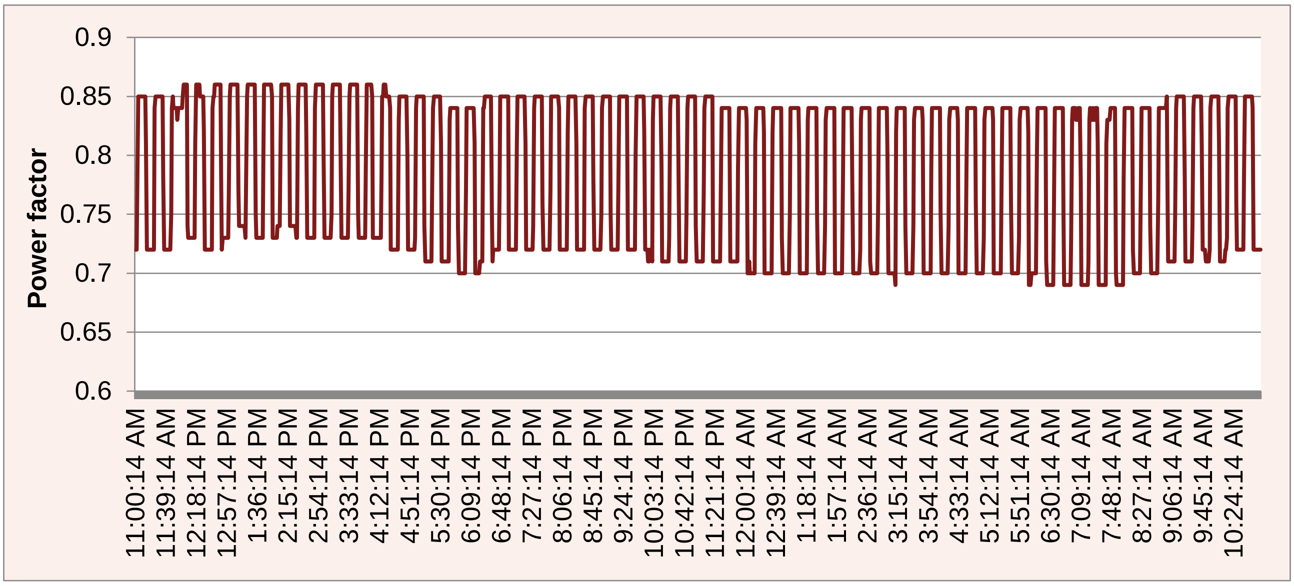


Figure 16 Power factor variation over 24 hours

4.3.2. Automatic Power Factor Correction

The average PF is 0.783 and there is a substantial scope for improvement of PF. The present tariff structure does not encourage the consumers to maintain better PF. However, SIEA is in process of reviewing and restructuring its electricity tariff. It is likely that in future a tariff on PF may be introduced. It is recommended to install 30 kVAr capacity automatic power factor correction (APFC) panel. The panel is PLC controlled which senses the reactive power requirement and switches the modules of capacitor banks to meet required kVAr demand. The sizing of capacitor banks recommended is 10+10+5+2+2+1 kVAr. All the banks recommended are detuned capacitors.

Figure 17 APFC panel

For the assessment, we have considered two scenarios for a PF tariff (a) PF tariff of Australia and (b) PF tariff of India. The cost benefit of these scenarios is presented in **Table 16** and **Table 17**. The pictorial view of APFC panel is presented is **Figure 17**.

Table 16 Cost benefit of APFC considering Australian PF tariff

Particular	Unit	Value
Average power factor	-	0.783
Average daily reactive power	kVAr	17.36
Power factor tariff	AU¢/kVAr/day	52.226
	US¢/kVAr/day	35.17
Annual charge for PF	US$/year	$ 2,228
Capacitor bank requirement	**kVAr**	30
Investment cost	US$	$ 1,500
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 1,750
Import duty	%	10
GST	%	15
Net landed cost of APFC system	USD	$ 2,813
Simple payback period	**years**	**1.3**

Table 17 Cost benefit of APFC considering Indian PF tariff

Particular	Unit	Value
Average power factor	-	0.783
Power factor tariff as % of fuel charge	%	5.00
Annual fuel charge	US$/year	77806
Annual charge for PF	US$/year	$ 3,890
Capacitor bank requirement	**kVAr**	30
Investment cost	US$	$ 1,500
Freight cost	USD	$ 250
Cost at port in Solomon Islands	USD	$ 1,750
Import duty	%	10
GST	%	15
Net landed cost of APFC system	USD	$ 2,813
Simple payback period	**years**	**0.7**

4.4. Lighting system

4.4.1. Performance assessment

The pump station was equipped with 5 six feet fluorescent tube lights (FTL) of 36 W rating (T8). The details of the existing system are provided in **Table 18**.

Table 18 Design details of lighting

Type of light	Area	Rating (W)	No. of fixtures	Total power (W)
FTL T8	Pump room	36+8	4	176
FTL T8	Office room	36+8	1	44
Total			**4**	**220**

4.4.2. Energy conservation measure

The fluorescent tube lights have a luminous efficacy 50-60 lumen per watt. Replacing FTL with LED tube will not only improve lighting but also result in energy saving. LED tube has luminous efficacy of 130 lumen per watt. It is recommended to install 3 LED tube pump room and 1 in office room.

Details of the present lighting system are given in **Table 19**. The pictorial view of FTL tube and LED tube is shown in **Figure 18.**

Figure 18 LED tube vs florescent tube

Table 19 LED lighting system savings estimation

Particular	Unit	Existing	Proposed
Type	-	FTL T8	LED
Rating	W	36	21
Ballast rating	W	8	0
No. of lights	no.	5	4
Total rating	W	220	84
Operating hours	h/year	250	250
Annual consumption	kWh/year	55	21
Annual saving	kWh/year		34
Monetary saving	SBD/year		186
	USD/year		$ 23
Investment cost	USD		$ 80
Simple payback	**Years**		**3.43**
GHG emission reduction	**tCO_2/year**		**0.02**

The estimated annual energy savings with new LED lighting system is 34 kWh of electricity, effectively equivalents to a monetary savings of US $ 23. The investment requirement is US $ 80. The simple payback period of the recommendation is 3.4 years. The annual reduction in GHG emission is estimated to be 0.02 tCO_2.

5. Self-generation option

5.1. Renewable energy assessment

The project team assessed feasibility of renewable energy options at the pump site. The following resources were considered: Solar, Wind, Small Hydro and Biomass. The pump station was in a small valley surrounded by hills; thus, wind energy potential was negligible at pump station. There was no source of small hydra near pump station. No biomass potential existed at pump site. Only feasible solution for self-generation was solar photovoltaic. Detailed feasibility analysis for solar is presented in this chapter.

5.2. Site description

Tuvaruhu SIWA pump station is in Mataniko area of Honiara city in Guadalcanal province. The Tuvaruhu SIWA and JICA pump stations are in one compound. The compound also houses a ware-house and a medical centre. Multiple roof area is available which includes: JICA pump station, SIWA pump station, JICA water reservoir, SIWA water reservoir, medical centre and ware-house. The total projected roof area as seen from the top, over the pump house is about 774 m². About ⅓ of medical centre's roof is shaded due to presence of a tree. There are no buildings nearby to cause shading. The net area available for solar panel installation is 611 m². Roof is made of concrete or sheet metal and support installation of solar roof top PV modules. In some cases, maty require additional support structure. The coordinates of Tuvaruhu pump station are as follows: Latitude -9.45°, Longitude +159.96°. The layout of the pump station is presented in **Figure 19**.

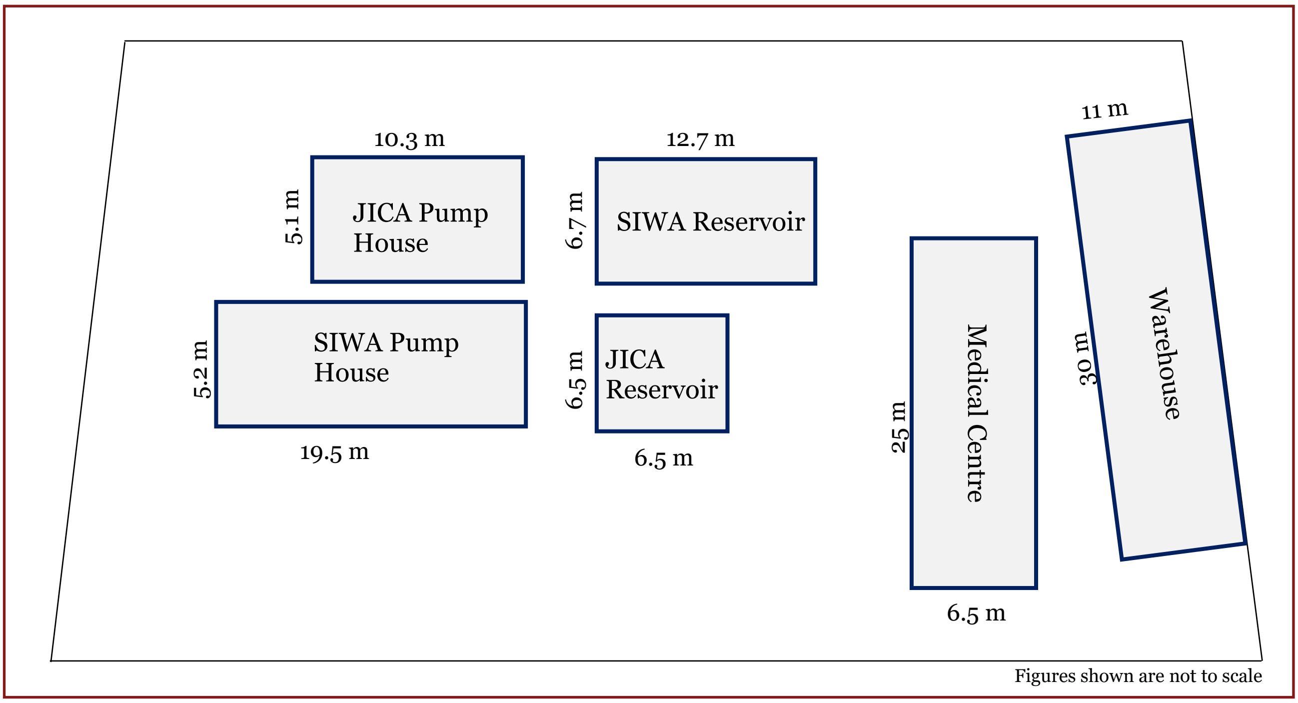


Figure 19 Layout of the Tuvaruhu pump station

5.3. Solar resource assessment

The solar data source i.e. Global Horizontal Irradiance (GHI) for Honiara, is derived from a Japan International Cooperation Agency (JICA) report on Pilot Survey for Disseminating SME's Technologies for Introduction of Utility Interactive Grid-Connected Photovoltaic Generation System Possessed in Okinawa Prefecture for Small Island Regions, 2015. These values are an estimation of the solar resource on a horizontal surface. Solar data for Honiara is presented in **Table 20**.

Table 20 Daily Global Horizontal Irradiation at site location

Daily Global Horizontal Irradiation in kWh/m²/day											
Latitude -9.45⁰, Longitude 159.96⁰											
Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35

The roof orientation yields optimum results when the tilt angle is equal to the latitude which in this case is 9.4⁰. The sun elevation diagram for the pump station is presented in **Figure 20**.

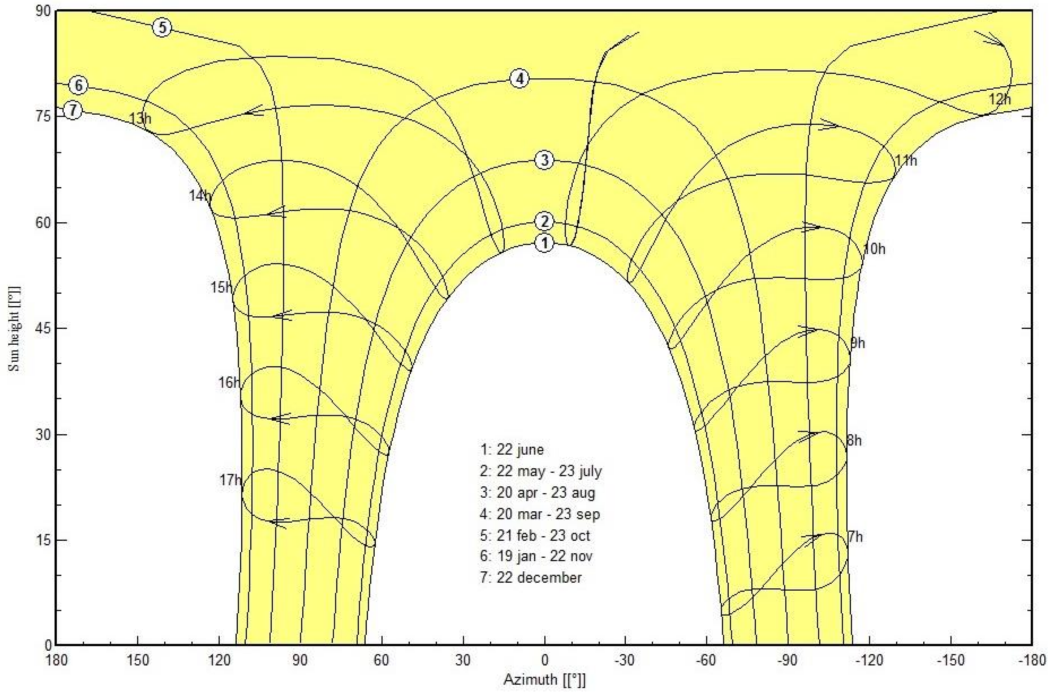


Figure 20 Sun elevation diagram for the site

5.4. System sizing and cost benefit

The effective area available for solar-roof PV installation is 611 m². Capacity for PV systems is measured at Standard Testing Conditions, of 1000 W/m², AM 1.5 and 25°C cell temperature. These conditions may not be the same on site. Site specific capacity varies intermittently with changing irradiance, ambient temperature, wind speed and air mass with respect to time, calendar day and other effects like cloud cover. The Polycrystalline technology generally has efficiency of ~ 16%. Monocrystalline Silicon technology can achieve ~20% although they are more expensive. The power delivered at the interconnection will be further reduced due to inverter efficiency, transformer efficiency, module fouling and cabling losses.

The system sizing along with cost benefit considering thin film and monocrystalline technology is presented in **Table 21**. This is considering there is no standby charges fees and the utility i.e. SIEA pays fuel charges to Solomon Water for imported energy to grid which is SBD 2.65 per kWh.

Table 21 Cost benefit of solar roof PV - Thin film and monocrystalline[7]

Particular	Unit	Thin-film	Monocrystalline
Available roof area	m²	774	774
Utilization area	m²	611	611
Nominal power	kWp	61.1	97.8

[7] *This recommendation is common for Tuvaruhu JICA and Tuvaruhu SIWA pump station*

Particular	Unit	Thin-film	Monocrystalline
Average global horizontal irradiance	kWh/m²/day	4.95	4.95
Proposed tilt angle	degree	10	10
Annual solar yield	kWh/year	94386	151079
Avg fuel charges	SBD/kWh	2.65	2.65
Monetary saving	SBD/year	249964	400107
	USD/year	$ 31,246	$ 50,013
Module cost	USD	$ 57,129	$ 91,406
Supports cost	USD	$ 69,898	$ 69,898
Inverter and wiring cost	USD	$ 21,507	$ 21,507
Transport and mounting cost	USD	$ 61,110	$ 89,003
Cost at port in Solomon Islands	USD	$ 209,644	$ 271,814
Import duty	%	10	10
GST on imported goods	%	15	15
Net landed cost	USD	$ 262,680	$ 340,393
Simple payback period	**years**	**8.4**	**6.8**

The cost benefit considering present tariff structure is presented in **Table 22**. With present regulation we have considered the standby changes in addition with cost system.

Table 22 Cost benefit of solar roof PV with present tariff

Particular	Unit	Thin-film	Monocrystalline
Nominal power	kWp	61.1	97.8
Annual solar yield	kWh/year	94386	151079
Monetary saving by avoided energy consumption	SBD/year	267268	427804
	USD/year	$ 33,409	$ 53,476
Annual standby charges	USD/year	$ 41,531	$ 66,478
Net landed cost	USD	$ 304,211	$ 406,870
Simple payback period	**years**	9.1	7.6

The detailed analysis for Solar roof PV system sizing was performed on PVSyst software. PVSyst software provides possibility of complex simulation input and output parameters of PV plant and is also commercially to calculate the total production of electricity. As per the PVSyst simulation results, the estimated energy generation for the first year is 94.4 MWh/year, with Specific Energy Yield of 1545 kWh/kW$_p$/year for thin film technology-based modules. The simulation was run considering monocrystalline cell modules and the estimated energy generation for the first year is 151.1 MWh/year. The detailed results of PVSyst are presented in **Appendix C** – PVSYST simulation results.

5.5. Regulatory framework

The policies, processes and forms for solar system connection to SIEA grid are available in Solar Manual of SIEA. Some of the key highlights are:

- Inverter energy systems that have a continuous rating of no more than 30 kVA for three-phase systems.
- The installation should as a minimum comply with Australian Standards AS3000, AS4777 and AS5033 and all other relevant Australian Standards and Solomon Islands statutory requirements.

- All energy consumed from the grid at the premises will be metered by an import-only meter and billed to the customer under the applicable tariff(s). It is only any 'excess' energy will be exported to the SIEA grid. This energy will be metered but will NOT be paid for by SIEA.

The process for solar grid connection as provided by SIEA is presented in **Figure 21**.

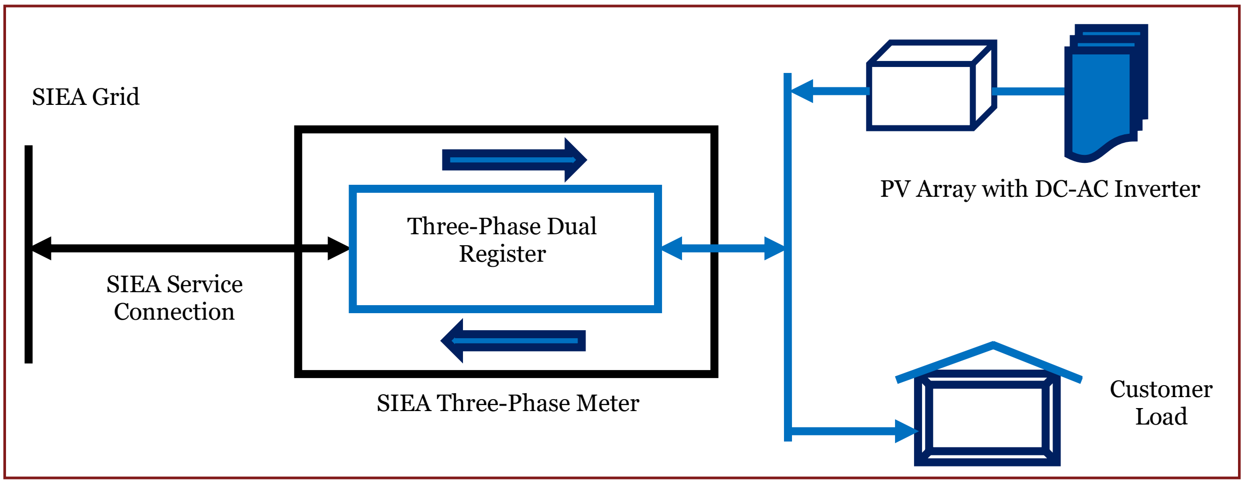


Figure 21 Schematics of solar PV interconnection with SIEA grid

*Solar PV option for the pump station is **technically feasible**. But, the financially feasibility is dependent on future SIEA tariff structure. With present tariff structure and regulatory elements, the solar PV is not feasible.*
*The Solomon Water can **take a strategic call** if to invest in solar PV now or to wait for favorable regulatory regime.*

Net metering is a utility billing mechanism that offers a credit to customers who are making excess electricity with their solar panel systems and sending it back to the grid. Solomon Islands at present does not have provision for net metering. However, SIEA is in process of reviewing and restructuring its electricity tariff. It may introduce the net metering option for solar roof top.

On a LT connection of 400 V the maximum allowed capacity of solar roof top PV plant is 30 kVA (~30 kWp). The proposed solar roof top system is cumulative continuous rating of 97.8 kWp. Hence, as the proposed plant is higher than allowed, it will require a special agreement with SIEA.

6. Conclusion

6.1. Summary of study

Tuvaruhu SIWA pump station is in Mataniko area of Honiara city in Guadalcanal province. The pump station is over a decade old. The pump station is over a decade old. The pump station has a 200 m³ water receiver tank, which receives water from two bore-holes. The pump station produces 1416 m³ water daily consuming about 652 kWh electrical energy. The existing specific energy consumption is 0.454 kWh per m³. The study has identified four recommendations for energy conservation **(Table 23)**. These recommendations could save annually about 67,294 kWh of electricity. These recommendations have an estimated investment of US $ 51,318 and can yield a monetary savings of US $46,097 per year. The annual energy saving is estimated to be 28.7%of total energy consumption by the pump station (**Figure 22**). The total annual reduction in GHG emission by implementation of recommendations is estimated to be equivalent to 44.41 tonnes of CO_2.

Table 23 Summary of energy conservation measures

ID	Particular	Energy Saving	Monetary Saving	Investment	Simple Payback	GHG Emission Reduction
		kWh/year	USD/year	USD	years	tCO_2/year
ECM-1	Replacement transfer pump with EE pump + VFD	34,949	$ 23,940	$ 43,750	1.8	23.07
ECM-2	Replacement of borepump-2 with efficient pump	32,311	$ 22,133	$ 7,488	0.3	21.33
ECM-3	Replacement of FTL with LED lights	34	$ 23	$ 80	3.4	0.02
	Total	**67,294**	**$ 46,097**	**$ 51,318**	**1.1**	**44.41**

The potential improvement in key performance indicators i.e. the specific energy consumption and specific GHG emissions are presented in **Table 24**.

Table 24 Key performance indicators of the plant

Key Performance Indicator	Existing	Proposed
Specific energy consumption	0.454 kWh/m³	0.324 kWh/m³
Specific CO_2 emission	0.300 kg CO_2/m³	0.214 kg CO_2/m³

On renewable side, there is potential of solar photovoltaic plant. The pump station can utilize entire roof space for a SPV plant of 97.8 kWp with an investment of US $ 340,393, it can replace conventional electrical energy equivalent to 151.1 MWh equivalent to GHG emission reduction of 99.7 tCO_2.

6.2. Funding options

The overall investment proposed for four energy conservation measures for Tuvaruhu SIWA pump station is US$ 51,318. The simple payback on this investment is one year. Solomon Water can fund the project through internal funds. It is recommended to implement the bore-hole pump recommendation first, as the payback is under 4 months, which can be followed by transfer pumps. The replacement in lighting system is recommended on failure of existing lights.

Alternatively, Solomon Water can combine the recommendations of seven pump stations including Tuvaruhu SIWA pump station and develop a funding proposal which could be submitted to either ADB or World Bank to seek funds for implementation.

Solomon Water can get the recommendations implemented by an ESCO (Energy Service Company) in shared saving model, wherein the ESCO will invest upfront and collect from Solomon Water's monthly saving over a predetermined timeframe.

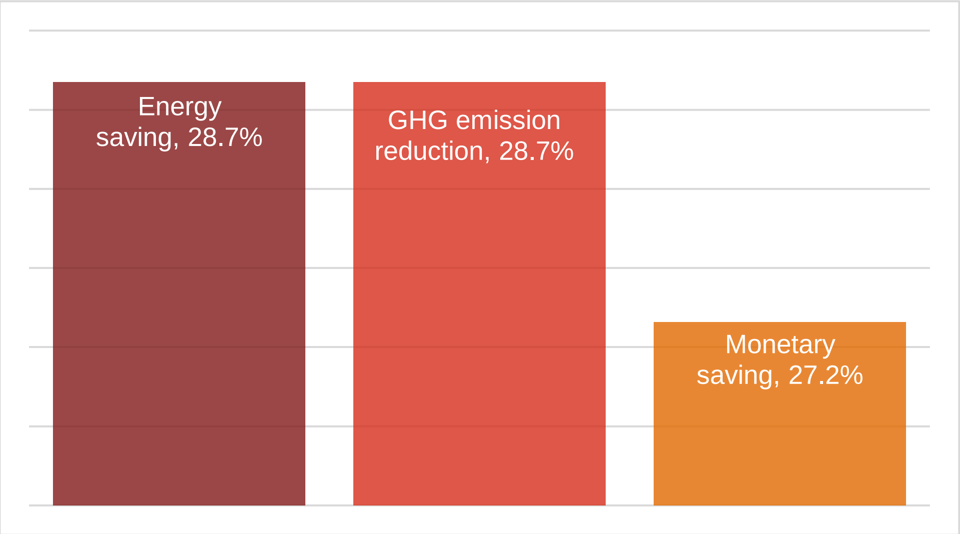


Figure 22 Identified saving potential

A co llage of select pictures taken during the detailed feasibility study is presented in **Appendix D**.

Appendix

Appendix A – Proposed pump technical specification

Transfer pump

Company name:
Created by:
Phone:

Date: 10/31/2019

Count	Description
1	**CRN 64-3-1 A-F-A-E-HQQE**

Product No.: 96123736

Vertical, multistage centrifugal pump with inlet and outlet ports on same the level (inline). Pump materials in contact with the liquid are in high-grade stainless steel. A cartridge shaft seal ensures high reliability, safe handling, and easy access and service. Power transmission is via a rigid split coupling. Pipe connection is via DIN flanges.

The pump is fitted with a 3-phase, fan-cooled asynchronous motor.

Controls:
Frequency converter: NONE

Liquid:
Pumped liquid: Drinking water
Liquid temperature range: 233 .. 393 K
Density: 998.2 kg/m³

Technical:
Rated pump speed: 2923 rpm
Actual calculated flow: 57 m³/h
Resulting head of the pump: 47 m
Pump orientation: Vertical
Shaft seal arrangement: Single
Code for shaft seal: HQQE
Approvals on nameplate: CE, EAC,ACS
Curve tolerance: ISO9906:2012 3B

Materials:
Base: Stainless steel
EN 1.4408
AISI 316
Impeller: Stainless steel
EN 1.4401
AISI 316
Bearing: SIC
Support bearing: Graflon

Installation:
Maximum ambient temperature: 333 K
Maximum operating pressure: 1600 kPa
Max pressure at stated temperature: 1600 kPa / 393 K
1600 kPa / 233 K
Type of connection: DIN
Size of inlet connection: DN 100
Size of outlet connection: DN 100
Pressure rating for pipe connection: PN 16
Flange size for motor: FF300

Electrical data:

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Company name:
Created by:
Phone:

Date: 10/31/2019

Count	Description	
	Motor standard:	IEC
	Motor type:	160MD
	IE Efficiency class:	IE3
	Rated power - P2:	15 kW
	Power (P2) required by pump:	15 kW
	Main frequency:	50 Hz
	Rated voltage:	3 x 220-240D/380-415Y V
	Rated current:	48,5-45,0/28,0-26,0 A
	Starting current:	660-780 %
	Cos phi - power factor:	0.89-0.87
	Rated speed:	2930-2950 rpm
	IE efficiency:	IE3 91,9%
	Motor efficiency at full load:	91.9-91.9 %
	Motor efficiency at 3/4 load:	92.4 %
	Motor efficiency at 1/2 load:	92.4 %
	Number of poles:	2
	Enclosure class (IEC 34-5):	55 Dust/Jetting
	Insulation class (IEC 85):	F
	Motor Number:	85U07526
	Others:	
	Minimum efficiency index, MEI ≥:	0.70
	Net weight:	178 kg
	Gross weight:	211 kg
	Shipping volume:	0.495 m³

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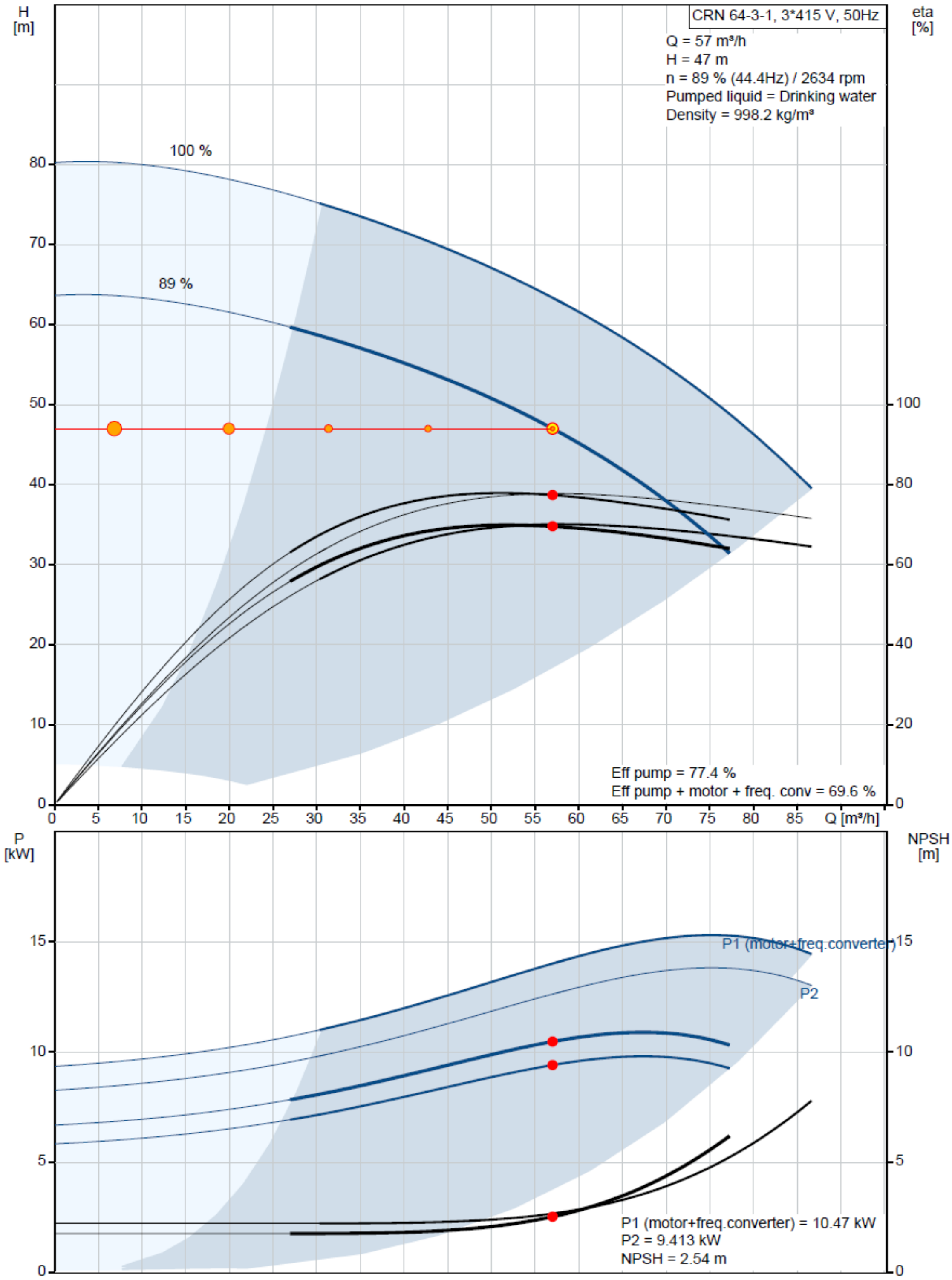
Company name:
Created by:
Phone:

Date: 10/31/2019

96123736 CRN 64-3-1 A-F-A-E-HQQE 50 Hz

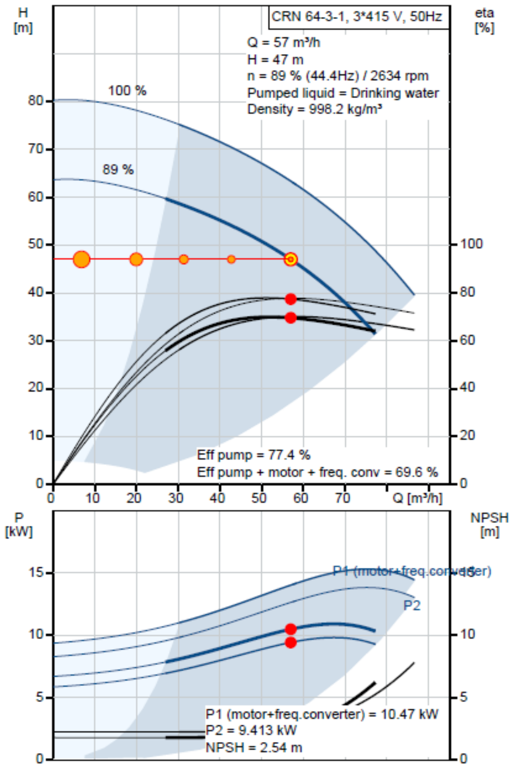


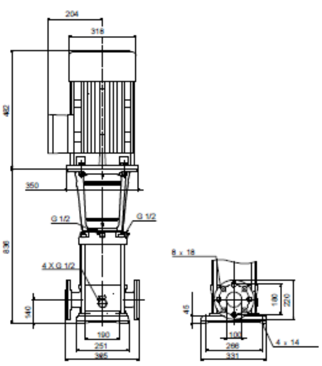
Printed from Grundfos Product Center [2019.07.001] 3/11

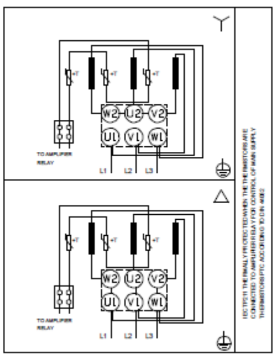
Company name:
Created by:
Phone:

Date: 10/31/2019

Description	Value
General information:	
Product name:	CRN 64-3-1 A-F-A-E-HQQE
Product No.:	96123736
EAN:	5700396699875
	5700396699875
Technical:	
Rated pump speed:	2923 rpm
Actual calculated flow:	57 m³/h
Resulting head of the pump:	47 m
Head max:	79.8 m
Stages:	3
Impellers:	3
Number of reduced-diameter impellers:	1
Low NPSH:	No
Pump orientation:	Vertical
Shaft seal arrangement:	Single
Code for shaft seal:	HQQE
Approvals on nameplate:	CE, EAC,ACS
Curve tolerance:	ISO9906:2012 3B
Pump version:	A
Model:	B
Materials:	
Base:	Stainless steel
	EN 1.4408
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Material code:	A
Code for rubber:	E
Bearing:	SIC
Support bearing:	Graflon
Installation:	
Maximum ambient temperature:	333 K
Maximum operating pressure:	1600 kPa
Max pressure at stated temperature:	1600 kPa / 393 K
	1600 kPa / 233 K
Type of connection:	DIN
Size of inlet connection:	DN 100
Size of outlet connection:	DN 100
Pressure rating for pipe connection:	PN 16
Flange size for motor:	FF300
Connect code:	F
Liquid:	
Pumped liquid:	Drinking water
Liquid temperature range:	233 .. 393 K
Density:	998.2 kg/m³
Electrical data:	
Motor standard:	IEC
Motor type:	160MD
IE Efficiency class:	IE3
Rated power - P2:	15 kW
Power (P2) required by pump:	15 kW
Main frequency:	50 Hz
Rated voltage:	3 x 220-240D/380-415Y V
Rated current:	48,5-45,0/28,0-26,0 A
Starting current:	660-780 %







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Company name:
Created by:
Phone:

Date: 10/31/2019

Description	Value
Cos phi - power factor:	0.89-0.87
Rated speed:	2930-2950 rpm
IE efficiency:	IE3 91,9%
Motor efficiency at full load:	91.9-91.9 %
Motor efficiency at 3/4 load:	92.4 %
Motor efficiency at 1/2 load:	92.4 %
Number of poles:	2
Enclosure class (IEC 34-5):	55 Dust/Jetting
Insulation class (IEC 85):	F
Motor protection:	PTC
Motor Number:	85U07526
Controls:	
Frequency converter:	NONE
Others:	
Minimum efficiency index, MEI ≥:	0.70
Net weight:	178 kg
Gross weight:	211 kg
Shipping volume:	0.495 m³

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Borehole pump 2

Company name:
Created by:
Phone:

Date: 09/02/2020

Qty.	Description
1	**SP 46-4**

Note! Product picture may differ from actual product

Product No.: 15A01904

Submersible borehole pump, suitable for pumping clean water. Can be installed vertically or horizontally. All steel components are made in stainless steel, EN 1.4301 (AISI 304), that ensures high corrosive resistance. This pump carries drinking water approval.

The pump is fitted with a 7.5 kW MS6000 motor with sand shield, mechanical shaft seal, water-lubricated journal bearings and a volume compensating diaphragm. The motor is a canned type submersible motor offering good mechanical stability and high efficiency. Suitable for temperatures up to 40 °C.

The motor is fitted with the Grundfos Tempcon sensor that, by use of powerline communication together with a MP204 control panel, enables temperature monitoring.

The motor is for direct-on-line starting (DOL).

Liquid:

Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³

Technical:

Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	48.2 m³/h
Resulting head of the pump:	32.58 m
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Motor version:	T40

Materials:

Pump:	Stainless steel EN 1.4301 AISI 304
Impeller:	Stainless steel EN 1.4301 AISI 304
Motor:	Stainless steel DIN W.-Nr. 1.4301 AISI 304

Installation:

Pump outlet:	RP4

GRUNDFOS

Company name:
Created by:
Phone:

Date: 09/02/2020

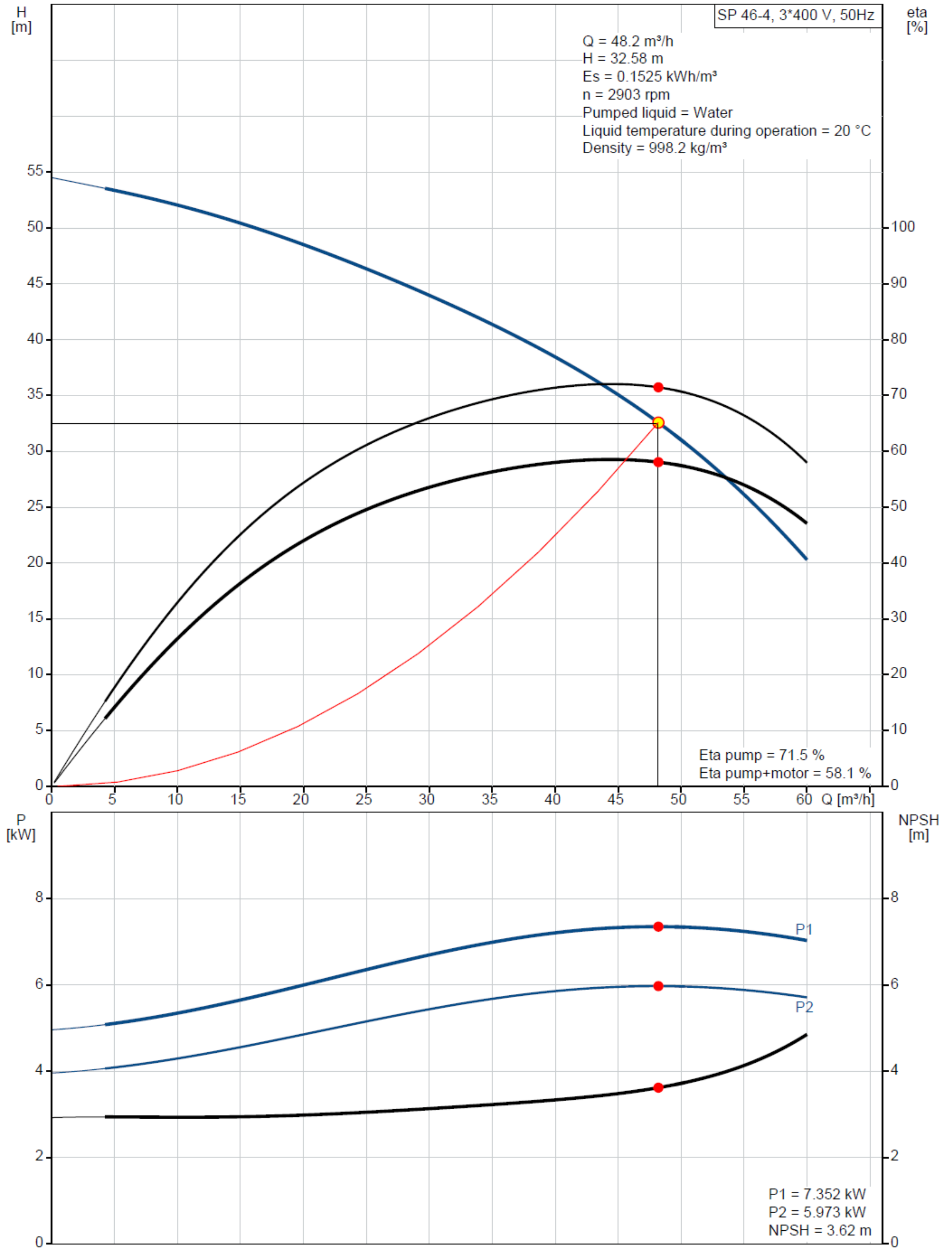
Qty.	Description	
	Motor diameter:	6 inch
	Electrical data:	
	Motor type:	MS6000
	Rated power - P2:	7.5 kW
	Power (P2) required by pump:	7.5 kW
	Mains frequency:	50 Hz
	Rated voltage:	3 x 380-400-415 V
	Rated current:	17.8-17.2-17.2 A
	Starting current:	460-510-530 %
	Cos phi - power factor:	0.84-0.82-0.79
	Rated speed:	2850-2870-2880 rpm
	Start. method:	direct-on-line
	Enclosure class (IEC 34-5):	IP68
	Insulation class (IEC 85):	F
	Built-in temp. transmitter:	yes
	Motor No:	78195512
	Others:	
	Minimum efficiency index, MEI â‰¥:	0.40
	ErP status:	EuP Standalone/Prod.
	Net weight:	54.2 kg
	Gross weight:	78.5 kg
	Shipping volume:	0.179 m³
	Danish VVS No.:	388340040
	Finnish LVI No.:	4762749

Company name:
Created by:
Phone:

GRUNDFOS

Date: 09/02/2020

15A01904 SP 46-4 50 Hz

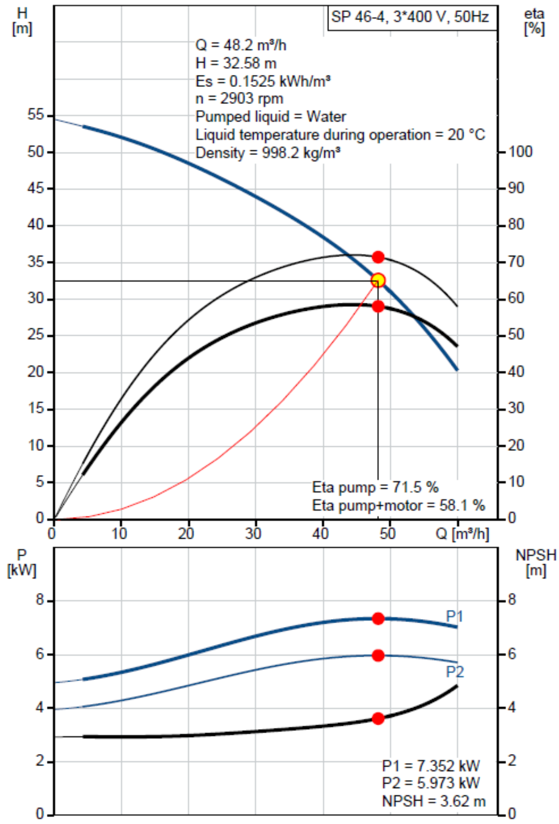


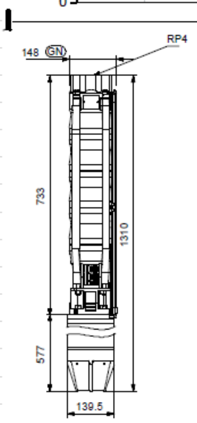
GRUNDFOS

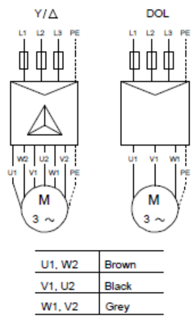
Company name:
Created by:
Phone:

Date: 09/02/2020

Description	Value
General information:	
Product name:	SP 46-4
Product No:	15A01904
EAN number:	5708601060632
	5708601060632
Technical:	
Pump speed on which pump data are based:	2900 rpm
Actual calculated flow:	48.2 m³/h
Resulting head of the pump:	32.58 m
Stages:	4
Impeller reduc.:	NONE
Shaft seal for motor:	CER/CARNBR
Approvals on nameplate:	CE,GOST2
Curve tolerance:	ISO9906:2012 3B
Model:	B
Valve:	YES
Motor version:	T40
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	DIN W.-Nr. 1.4301
	AISI 304
Installation:	
Pump outlet:	RP4
Motor diameter:	6 inch
Liquid:	
Pumped liquid:	Water
Maximum liquid temperature:	40 °C
Max liquid t at 0.15 m/sec:	40 °C
Selected liquid temperature:	20 °C
Density:	998.2 kg/m³
Electrical data:	
Motor type:	MS6000
Applic. motor:	GRUNDFOS
Rated power - P2:	7.5 kW
Power (P2) required by pump:	7.5 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 380-400-415 V
Rated current:	17.8-17.2-17.2 A
Starting current:	460-510-530 %
Cos phi - power factor:	0.84-0.82-0.79
Rated speed:	2850-2870-2880 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Motor protec:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Motor No:	78195512
Others:	
Minimum efficiency index, MEI â‰¥:	0.40
ErP status:	EuP Standalone/Prod.







Appendix B – Main incomer sample power log

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
		Hz	V	V	V	A	A	A	kW	
06/09/2019	11:00:14 AM	50.003	424.5	425.4	424.8	14.4	13.8	13.2	7.32	0.72
06/09/2019	11:01:14 AM	50.001	424.6	425.7	425.0	14.4	13.9	13.2	7.35	0.72
06/09/2019	11:02:14 AM	50.000	424.6	426.2	425.1	14.4	13.9	13.3	7.35	0.72
06/09/2019	11:03:14 AM	49.995	422.8	424.3	423.2	48.3	48.6	47.7	24.72	0.8
06/09/2019	11:04:14 AM	50.002	421.0	422.2	421.4	66.4	66.9	65.8	41.25	0.85
06/09/2019	11:05:14 AM	50.005	421.3	422.5	421.8	66.4	66.8	65.8	41.28	0.85
06/09/2019	11:06:14 AM	49.997	421.2	422.4	421.6	66.3	66.8	65.8	41.25	0.85
06/09/2019	11:07:14 AM	49.995	421.0	422.3	421.2	66.3	67.0	65.6	41.25	0.85
06/09/2019	11:08:14 AM	50.005	420.8	421.9	420.9	66.4	67.0	65.6	41.22	0.85
06/09/2019	11:09:14 AM	49.999	420.6	421.7	420.8	66.3	66.9	65.6	41.22	0.85
06/09/2019	11:10:14 AM	50.000	420.7	421.6	420.6	66.5	67.0	65.5	41.22	0.85
06/09/2019	11:11:14 AM	50.005	421.0	421.9	420.9	66.5	66.9	65.4	41.22	0.85
06/09/2019	11:12:14 AM	49.998	421.2	422.1	421.2	66.4	66.8	65.5	41.22	0.85
06/09/2019	11:13:14 AM	50.000	421.2	422.2	421.2	66.4	66.8	65.4	41.19	0.85
06/09/2019	11:14:14 AM	49.999	422.2	423.1	422.4	56.4	56.5	55.6	31.29	0.81
06/09/2019	11:15:14 AM	49.999	424.5	425.6	424.5	14.4	13.9	13.2	7.35	0.72
06/09/2019	11:16:14 AM	50.001	424.6	425.4	424.4	14.4	13.9	13.2	7.35	0.72
06/09/2019	11:17:14 AM	50.000	424.6	425.3	424.5	14.4	13.9	13.2	7.35	0.72
06/09/2019	11:18:14 AM	50.001	424.3	425.2	424.5	14.4	13.9	13.2	7.35	0.72
06/09/2019	11:19:14 AM	50.000	424.5	425.2	424.4	14.4	13.9	13.2	7.35	0.72
06/09/2019	11:20:14 AM	49.999	424.7	425.4	424.6	14.5	13.9	13.2	7.35	0.72
06/09/2019	11:21:14 AM	50.004	424.6	425.2	424.5	14.5	13.9	13.1	7.35	0.72

Date	Time	Frequency	U1 RMS	U2 RMS	U3 RMS	A1 RMS	A2 RMS	A3 RMS	Power	PF
06/09/2019	11:22:14 AM	50.001	424.8	425.4	424.6	14.5	13.9	13.1	7.35	0.72
06/09/2019	11:23:14 AM	50.001	424.6	425.3	424.7	14.5	13.9	13.2	7.35	0.72
06/09/2019	11:24:14 AM	50.000	424.9	425.8	425.1	21.7	21.3	20.7	8.67	0.72
06/09/2019	11:25:14 AM	50.001	422.1	423.4	422.4	58.9	59.4	58.3	34.74	0.84
06/09/2019	11:26:14 AM	49.994	421.3	422.4	421.4	66.4	67.0	65.6	41.22	0.85
06/09/2019	11:27:14 AM	50.001	421.3	422.2	421.3	66.5	66.9	65.6	41.25	0.85
06/09/2019	11:28:14 AM	49.994	421.3	422.1	421.4	66.6	66.7	65.6	41.22	0.85
06/09/2019	11:29:14 AM	50.004	421.3	422.2	421.3	66.5	66.8	65.6	41.25	0.85
06/09/2019	11:30:14 AM	49.999	421.3	422.5	421.3	66.3	67.0	65.5	41.22	0.85
06/09/2019	11:31:14 AM	50.003	421.4	422.6	421.4	66.3	67.1	65.5	41.25	0.85
06/09/2019	11:32:14 AM	50.005	421.4	422.6	421.4	66.3	67.2	65.5	41.25	0.85
06/09/2019	11:33:14 AM	50.001	421.5	422.7	421.8	66.3	66.9	65.7	41.25	0.85
06/09/2019	11:34:14 AM	50.005	421.7	422.9	422.2	66.3	66.8	65.9	41.28	0.85
06/09/2019	11:35:14 AM	49.997	421.7	422.9	421.9	66.2	66.9	65.6	41.25	0.85
06/09/2019	11:36:14 AM	50.005	423.5	424.8	423.8	45.2	45.5	44.5	22.23	0.78
06/09/2019	11:37:14 AM	49.996	425.0	426.4	425.3	14.4	14.0	13.3	7.35	0.72
06/09/2019	11:38:14 AM	50.001	425.3	426.5	425.4	14.4	14.0	13.2	7.38	0.72
06/09/2019	11:39:14 AM	50.003	425.1	426.6	425.6	14.4	14.0	13.3	7.38	0.72
06/09/2019	11:40:14 AM	49.998	425.6	426.7	425.9	14.5	14.0	13.3	7.38	0.72
06/09/2019	11:41:14 AM	49.998	425.7	426.8	426.1	14.5	14.0	13.3	7.38	0.72
06/09/2019	11:42:14 AM	50.003	425.2	426.5	425.6	14.4	14.0	13.3	7.38	0.72
06/09/2019	11:43:14 AM	50.001	425.3	426.6	425.7	14.4	14.0	13.3	7.38	0.72
06/09/2019	11:44:14 AM	50.000	425.7	426.7	426.0	14.5	14.0	13.3	7.38	0.72
06/09/2019	11:45:14 AM	50.001	426.0	426.9	425.9	14.5	14.0	13.2	7.38	0.72

Appendix C – PVSYST simulation results

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude -9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt: 10°		Azimuth 0°

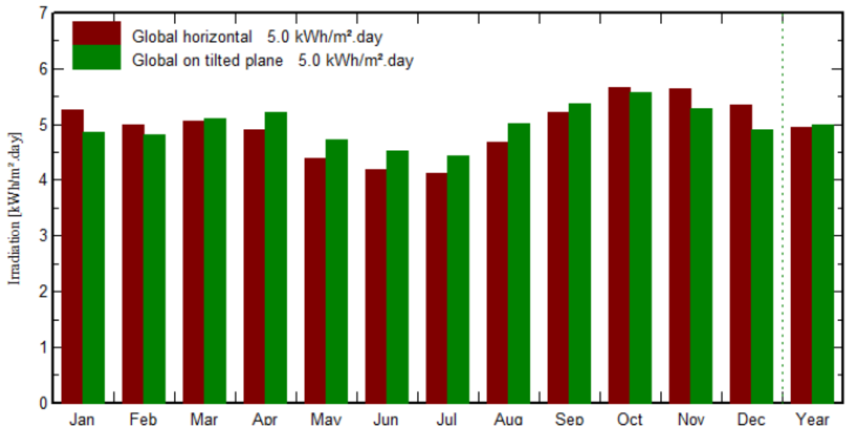
PV Installation main features

Module Type	Standard
Technology	Thin film
Mounting method	Flat roof
Back ventilation properties	Free Standing

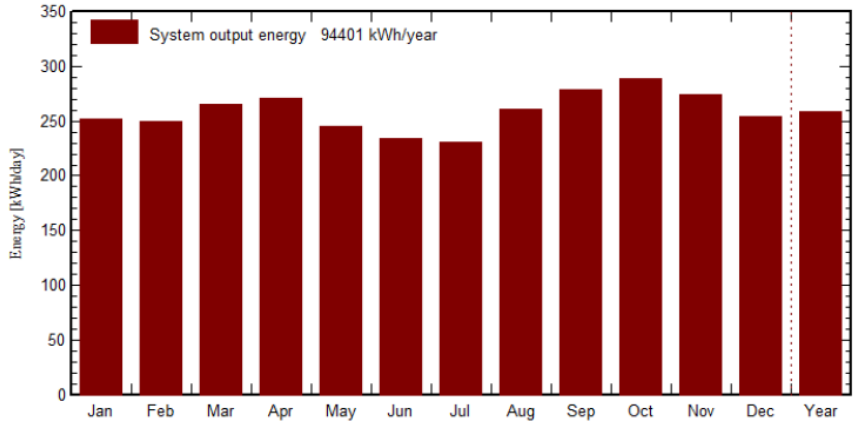
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	61.1 kWp		
Collector Area	Acoll	611 m²		
Annual energy yield	Eyear	94.4 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	252.3	7821
Feb	4.99	249.7	6992
Mar	5.05	264.8	8208
Apr	4.91	270.4	8112
May	4.39	245.0	7595
June	4.19	234.3	7030
Jul	4.12	230.1	7133
Aug	4.67	260.7	8083
Sept	5.21	279.0	8369
Oct	5.67	288.8	8954
Nov	5.64	274.1	8224
Dec	5.35	254.2	7882
Year	4.95	258.6	94401

Grid System Pre-sizing

Geographical Site	**Honiara**	Country	**Solomon Islands**
Situation	Latitude -9.45° S		Latitude 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10m
Collector Plane Orientation	Tilt:10°		Azimuth: 0°

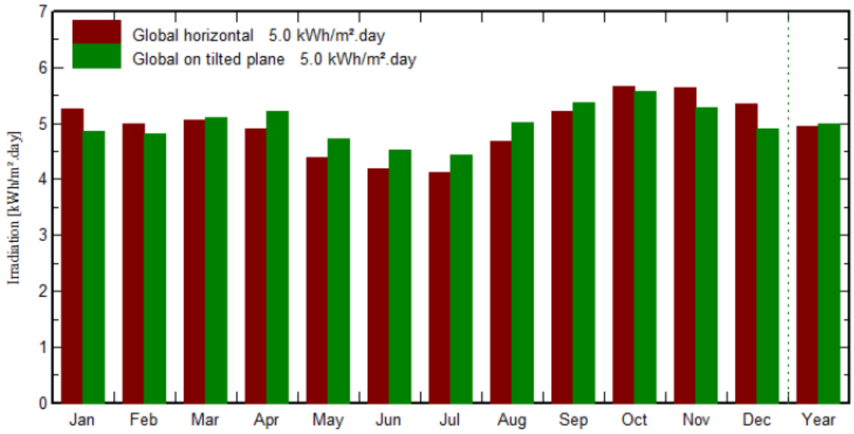
PV Installation main features

Module Type	Standard
Technology	Monocrystalline cell
Mounting method	Flat roof
Back ventilation properties	Free Standing

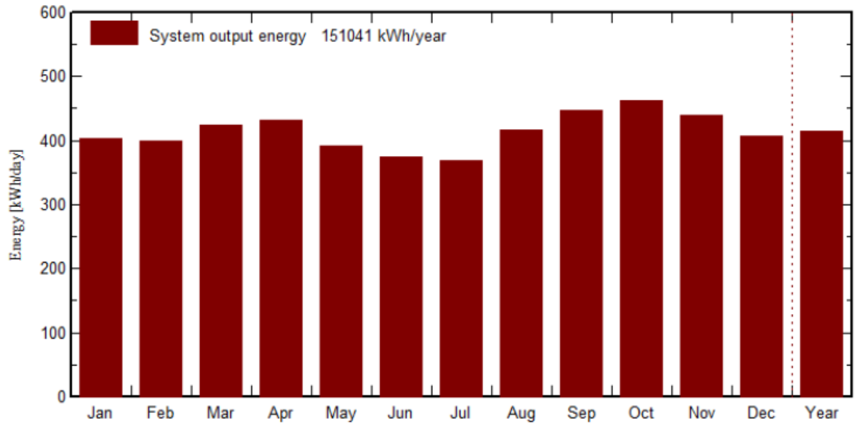
System characteristics and pre-sizing evaluation

PV-field nominal power (STC)	Pnom	97.8 kWp		
Collector Area	Acoll	611 m²		
Annual energy yield	Eyear	151 MWh	Specific yield	1545 kWh/kWp

Meteo and incident energy



System Output



	GL horiz. kWh/ m² day	System output kWh/day	System Output kWh
Jan	5.25	403.7	12514
Feb	4.99	399.5	11187
Mar	5.05	423.6	13133
Apr	4.91	432.6	12978
May	4.39	392.0	12152
June	4.19	374.9	11248
Jul	4.12	368.2	11413
Aug	4.67	417.2	12932
Sept	5.21	446.3	13390
Oct	5.67	462.1	14326
Nov	5.64	438.6	13159
Dec	5.35	406.8	12610
Year	4.95	413.8	151041

Definition of Geographical Site

Geographical Site	**Honiara**	Country	**Solomon Islands**

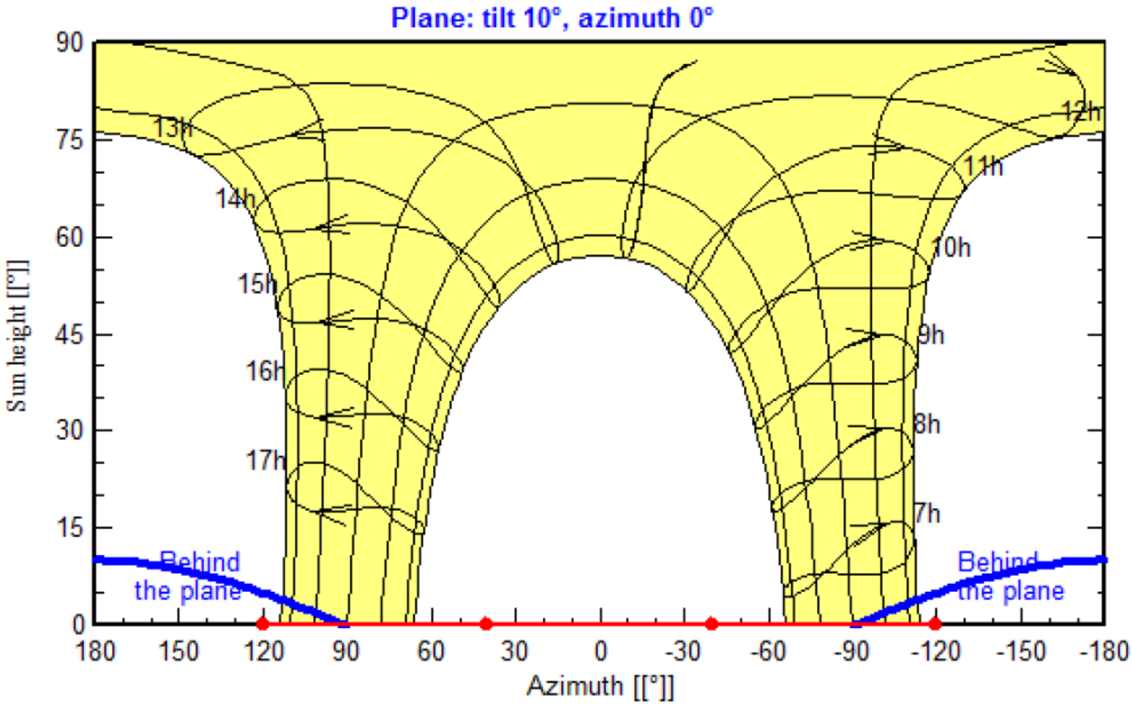
File New.SIT of 01/10/19 12h40

Situation	Latitude: -9.45° S		Longitude: 159.96° E
Time defined as	Legal Time	Time zone UT+11	Altitude: 10 m

Monthly Meteo values

	Jan	Feb	Mar	April	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Year
Hor. Global (kWh/ m² day)	5.25	4.99	5.05	4.91	4.39	4.19	4.12	4.67	5.21	5.67	5.64	5.35	4.95
Extraterrestrial (kWh/ m² day)	10.90	10.86	10.49	9.66	8.75	8.23	8.40	9.16	10.06	10.65	10.85	10.85	9.90
Clearness index	0.481	0.459	0.482	0.508	0.502	0.509	0.491	0.510	0.518	0.532	0.520	0.493	0.50
Amb Temp (°C)	27.1	26.9	26.8	27.0	26.8	26.3	26.0	26.0	26.2	26.5	26.7	27.0	26.2
Wind velocity (m/s)	3.7	4.1	3.9	3.6	4.2	5.0	5.9	6.1	5.5	4.7	3.8	3.5	4.5

Solar paths at Honiara, (Lat. -9.45° S, long. 159.96° E, alt. 10 m) - Legal Time



Appendix D – Photographs taken during the study