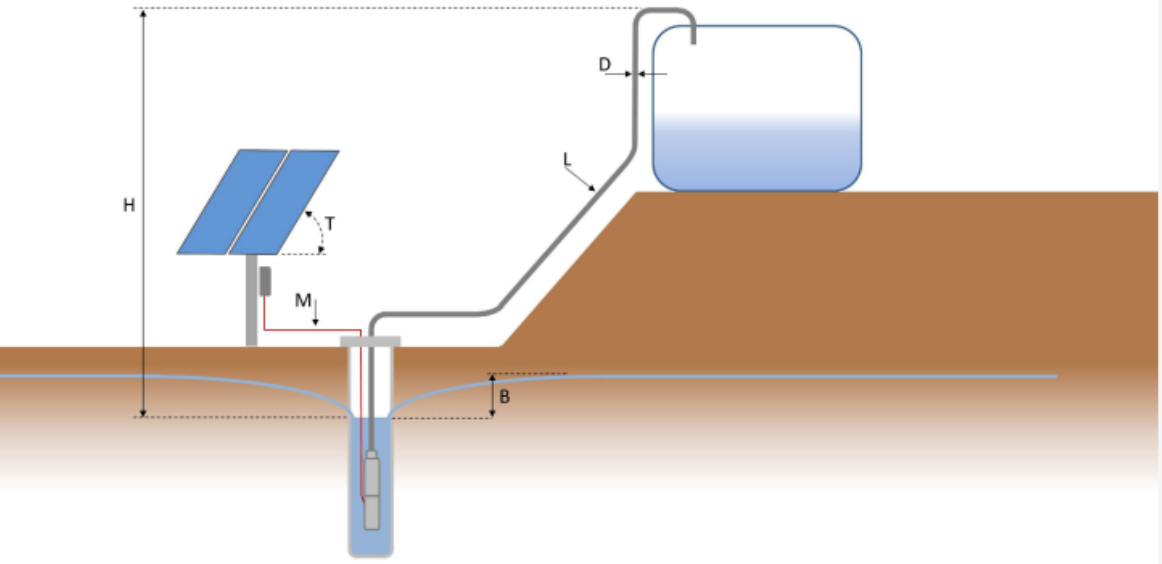
TECHNICAL ASSESMENT REPORT

FOR

SOLARIZATION OF DEEP WELLS IN TIGRAY, AFAR and SOMALI REGION OF ETHIOPIA



H (Static head):
Vertical height from the dynamic water level to the highest point of delivery.

B (Drawdown):
Lowering of water level depending on flow rate and recovery rate of the well.

D (Pipeline inner diameter)

L (Pipe length):
Entire pipeline from the pump outlet to the point of delivery. Ellbows and armatures must be added as an equivalent length of pipeline.

M (Motor cable):
The cable between controller and pump unit.

T (Tilt angle):
Angle of the PV generator surface from the horizontal plane.

Total dynamic head:
Static head plus pressure losses in the pipeline as height of a water column with the equivalent pressure.

GOAL ETHIOPIA

WASH DEPARTMENT

October 2025

Design document for the solarization of Boreholes in Tigray, Afar and Somali Region

1. Introduction

Access to reliable, affordable water is essential for sustainable development and community well-being. Many water supply systems in Ethiopia—particularly in Tigray, Afar and Somali regions—are struggling to provide consistent service. Systems in Tigray and Afar have been severely affected by the Northern conflict and continue to depend on aging, poorly maintained generators and unreliable grid connections that suffer frequent mechanical failures. These technical vulnerabilities, together with rising fuel costs, leave communities with inadequate service levels and increased exposure to water-borne disease.

Solar power presents a practical, long-term solution. Converting water supply schemes to solar-driven systems removes the recurring fuel costs and operational uncertainty associated with generators, while delivering a clean, renewable and widely available energy source. Solarization can therefore improve service reliability and align the systems with broader sustainability objectives.

The borehole data summarized in Table 2 and the 10-year demand calculations in Table 1 were reviewed with key design factors in mind—public utility needs, system losses, climatic conditions and socioeconomic realities. Using a planning standard of 20 liters per capita per day (l/c/d), the assessment shows that current systems are performing below both the installed pump capacity and the borehole safe yield.

GOAL with the Cost Modification Funding from USG-DOS Foreign Assistance Office plans to Solarizing the four selected Deppe Well water supply systems in the targeted woredas of the three regions is a strategic investment. It will reduce operating costs, stabilize water delivery and significantly enhance the quality of life for the affected communities.

2. Objective

Overall objective:

- To assess the technical viability of the selected deep wells and existing infrastructure for conversion to solar-powered water supply systems, and to evaluate the capacity and gaps in local WASH service management.

Specific objectives:

- Determine whether the selected deep wells and associated structures can reliably produce sufficient water to support a solarized pumping system (including comparison of installed pump capacity and borehole safe yield).
- Assess the current capacity of WASH committees and identify governance, operation & maintenance, financial and institutional gaps that require improvement.
- Collect and analyze primary and secondary data on water demand, borehole characteristics/performance, and water quality to inform design and implementation.

3. Designing the PV system for an AC pump with Inverter

For each of the sites the following points have been considered in the calculation of Water Demand:

- The total population benefiting from each system and average daily consumption of the individuals which is 20 l/person/day.
- Water loss and public consumption were considered 40%.
- We assumed the average life span of the equipment being used in this project is around 15 years. But we took 10 years as the systems are old and lacks qualified professionals who take care of the system.

WSP POPULATION PROJECTION & DEMAND ANALSIS FOR THE DESIGN PERIOD

No.	Village / PA NameVillage / PA Name	Woreda	Human popn 2025	Human popn 2030	Human popn 2035	Livestock popn 2025	Dem. Total 2025 (max day), in l/s	Dem. Total 2030 (max day), in l/s	Dem. Total 2035 (max day), in l/s	Dem. Total 2025 (m3/day)	Dem. Total 2030 (m3/day)	Dem. Total 2035 (m3/day)	Required Discharge (l/s)
1	Farda	Kebribeyah	4000	4751	5642	-	1.40	1.40	1.40	112.00	133.02	157.99	5.49
2	Sidehamelef	Awura	4000	4751	5642	-	1.40	1.40	1.40	112.00	133.02	157.99	5.49
3	Negash	Eastern	2200	2613	3103	-	1.40	1.40	1.40	61.60	73.16	86.89	3.02
4	May Nebri	Gubalafto	4500	5345	6348	-	1.40	1.40	1.40	126.00	149.65	177.74	6.17

Average day Domestic per capita per day demands (lpcd)	Human		Live stock	Maximazing	Public	water loss	socioeconomic	climatic		
	in 2025	20	0		0.1	0.1	0.1	0.1		
	in 2030	20			Total factor for design of source, pump & pressure raiser					0.40
	in 2035	20		Dem. factors						0.0

Figure 1 Water demand calculation

3.1 Farda WSS

3.1.1 Basic Data

Summary of Primary Data

Region	Somali
Zone:	Fafan
Woreda:	Kebribeyah
Kebele:	Farda
Project/Water Source Location-GPS	
Latitude-N	9.045562 DD
Longitude-E	43.013836 DD
Water Demand	
Population size (base-2025)	4000
Growth Rate (%)	3.50%

Type of Existing water pumping system (Borehole or Surface Pump)	BH
Existing Borehole History	
Statis Water Level (m)	100
Drowdawn (m)	20
Dyanamic water level (m)	120
Safe Yield (m3/hr)	25
Borehole Depth (m)	240
Borehole Diameter	8"
Pump Intake level (m)	72
Distance from BH head to tank (running distance)	165 m
Static Lift above Ground (BH & Reservoir)	12 M
Tank Height and Size	3 m and 25 M^3
No. of Elbows in the pipe line	6
No.of gate valves	1
No. of non-return valaves	1

Solar Energy related data	
Distance from water scheme-BH to proposed solar modules (m)	20m
How long it takes for the pump to fill the existing reservoir (Hr.)	1 hr 25 Minutes
Generator Size (Power)	40 KVA
Generator Efficiency	0.8
Generator Running time	8hr
Water Pumping yield (from pump)	5.9 l/s
Motor power rating (Pump-Kw)	11 KW
Existing cable wire size	3*16 mm^2
pipe materials and size	GI 3"

3.1.2 Yield of the water source available to the solar powered water system

Considering the primary information the total Head is 92 meters and required discharge is 19.76 m^3/hour (5.49 l/sec) the pump required will be 9.2KW.

Hydraulic Power:

Formula: $P_h = \rho g Q H$ with $\rho = 1000\text{kg/m}^3$, $g = 9.81\text{m/s}^2$,

Stepwise:

- $\rho g = 1000 \times 9.81 = 9810$
- $\rho g \times Q = 9810 \times 0.0054888 = 53.846$(W per meter of head)
- $P_h = 53.846 \times 92 = 4{,}953.832$ W. So Hydraulic power **4.953** kW.

Pump shaft power and motor input

Use $P_{shaft} = \frac{P_h}{\eta_{pump}}$and $P_{motor-in} = \frac{P_{shaft}}{\eta_{motor}}$.

Take a conservative pump efficiency = 60% (0.60) and motor efficiency = 90% (0.90):

- $P_{shaft} = \frac{4.953\text{ kW}}{0.60} = 8.255$ kW
- $P_{motor-in} = \frac{8.255}{0.90} = 9.172$ kW.

So with those efficiencies the input power required ≈ **9.2 kW**.

3.1.3 Yield of the water source available to the solar powered water system

The woreda Water Office indicated that the safe yield of the borehole is 25m^3/hr (6.9l/sec). Considering the required demand at the end of the design period an average of 5.49 l/Sec was considered for designing the solar power requirements.

The water demand of the design period is 5.49 l/s, which is less than the safe yield of the borehole. Therefore, the discharge rate of the pump does not exceed the safe yield of the borehole.

3.1.4 Designing the PV system for an AC pump with Inverter

The PV system design will be managed and done by using Grundfos or LORENTZ web and software-based design, whichever the result with optimum sizing will be selected. The below listed specifications of solar system components are the minimum requirements for selected solarization of water supply scheme.

Assumptions:

- Pump electrical rating: 9.2 kW (continuous).
- Daily run time:7.5 hours/day.
- Peak Sun Hours (site): 6.8 kWh/m²/day.
- System performance factor (losses): 0.80.
- PV module (assumed representative for 615 W module):
    - V_{mp} = 41.5 V, V_{oc} = 49.5 V, I_{mp} = 14.82 A, I_{sc} = 15.56 A.
- Inverter: 11 kW, 3-phase (400 V) (you specified).
- Power factor for AC current calc: 0.9 (typical).
- All currents/power rounded sensibly.

Energy & PV array sizing

- Daily energy required = 9.2 kW × 7.5 h = 69 kWh/day.
- Energy produced per kWp = PSH × system_eff = 6.8 × 0.80 = 5.44 kWh/day per kWp.
- Required PV kWp = 69 ÷ 5.44 = 12.684 kWp (≈ 12.7 kWp).
- Panels required = 12.7 ÷ 0.615 = ≈ 20.7 → round up → 21 panels.
- Installed array (chosen) = 21 × 615 W = 12,915 W ≈ 12.92 kWp.

So, we need **21 × 615 W panels** (≈12.92 kWp) to meet the 9.2 kW pump for 7.5 h/day at 6.8 PSH (with 0.80 system efficiency)

Inverter Sizing Note:

- Pump = 9.2 kW.
- We assumed 11 kW inverter: that gives a margin of ~1.20× motor rating (11 / 9.2 ≈ 1.196), which is acceptable for many installations (it helps with overloads/starts).

String Layout

The input voltage of the selected inverter is 400V. So, the string configuration should consider this. The proposed layout is 7 Panels in Series X 3 Strings (7S X 3P = 21 Panels) equals to the exact panel calculated.

- V_{mp} per string = 41.5 V × 7 = 290.5 V.
- V_{oc} per string (STC) = 49.5 V × 7 = 346.5 V.
- I_{mp} per string = 14.82 A.
- Total DC current = 3 × 14.82 = 44.46 A.
- Array DC power V_{mp} 290.5 V × 44.46 A ≈ 12,915 W (matches 21×615 W).

The V_{OC} Per string is within the input voltage of the selected inverter (400 V).

AC current & breaker sizing (for the 11-kW inverter / 400 V, PF 0.9

- AC current at inverter rated power (11 kW):

  $I_{ac,inv}$ = 11000/ (√3*400*0.9)
  = 17.65 A

  AC breaker sizing (1.25× inverter rated current): 1.25 × 17.65 ≈ 22.06 A → choose a 25 A AC breaker for the inverter output circuit.

DC protection & combiner sizing

- Per-string I_{sc} ≈ **15.56 A** → choose **20 A** DC string fuse
- Total DC MPP current = 14.82*3 = 44.46 A → combiner sizing = 1.25 × 44.46 ≈ 55.6 A → use a 60–63 A DC combiner/isolator
- I_{sc_total} ≈ 3 × 15.56 ≈ 46.68 A

Configuration

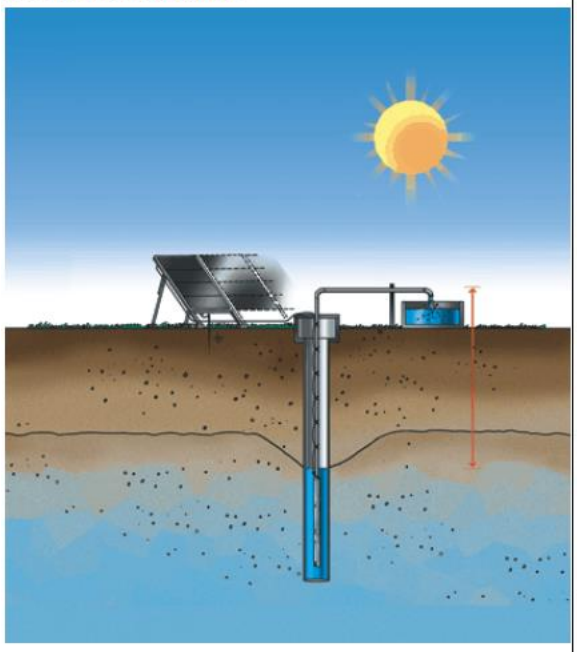
- Minimum No of Strings: 3, No of Pannels Per String: 7; Tilt Angle: 11°; Azimuth: South

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Farda WSS, Somali Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Installation and Input



Sizing Results

Water production, Peak flow and Price
Total water production per year: 61100 m³
Avg. water production per day: 167.5 m³/day
Average water production per watt per day: 13 l/Wp/day

Solar module configuration:
Number of solar modules in series: 7, in parallel: 3
Solar array rated power: 12.92 kW
Solar array rated volts: 311 V
Sun tracking: No (fixed)
Tilt angle: 9 deg.

Typical performance at solar radiation 800 W/m²
Flow: 20.6 m³/h
Total head: 91.9 m

Cables and pipes:
Pump cable length: 82 m
Pump cable size: 25 mm²
Total cable loss: 1.4 %

Material, riser pipe: Galvanized steel
Pipe size (inner diameter), riser pipe: DN 80 (81 mm)
Material, discharge pipe: Galvanized steel
Pipe size (inner diameter), discharge pipe: DN 80 (81 mm)
Pipe length of riser pipe: 72 m
Pipe length of discharge pipe: 165 m
Friction loss, discharge pipe: 5.108 m
Total friction losses: 7.875 m

Location: Somali, Ethiopia
Latitude: 9.045562 DD, Longitude: 43.013836 DD

GRUNDFOS

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Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Farda WSS, Somali Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

92953229 SP 18-16 N

Input - summary

Flow: 158m³/day ()
Month for sizing: July
Static lift above ground: 12 m
Dynamic water level: 72 m
Sun tracking: No (fixed)
Location: Somali, Ethiopia
Latitude: 9.045562 DD, Longitude: 43.013836 DD

Products

Pump: SP 18-16 N, 1 x 92953229
Solar module: 21 x NN 615W
Switch box / control unit: RSI 3x208-240V IP66 11kW 48A, 1 x 99090638
Switch box / control unit: OTDCP16, Circuit Breaker, 16Amp, 3 x 98341686
Switch box / control unit: OVR PV 40-1000 P, Surge Protection, 1 x 98341687

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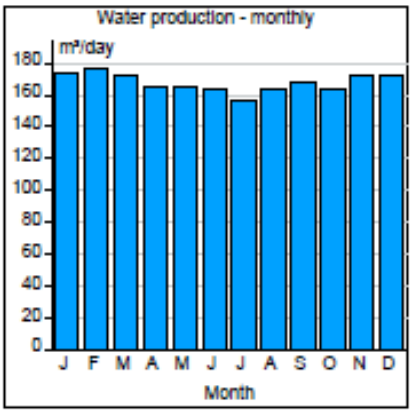
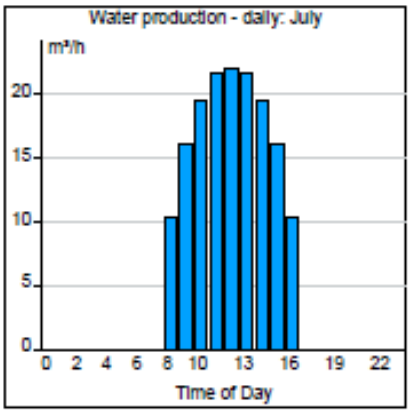
Pipe length of riser pipe: 72 m
Pipe length of discharge pipe: 165 m
Friction loss, discharge pipe: 5.108 m
Total friction losses: 7.875 m

System performance - monthly average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water production [m³/day]	173.1	176.7	172.8	164.6	164.9	163.3	157	163.3	168.5	163.4	171.7	172
Energy production Solar [kWh/day]	92.4	97.8	90.8	81.8	82.0	80.4	75.5	80.5	85.6	80.9	90.1	90.7
Radiation horizontal [kWh/m² day]	7.3	8.1	7.8	7.3	7.5	7.4	6.8	7.2	7.5	6.8	7.2	7.1
Radiation tilt [kWh/m² day]	8.0	8.5	7.9	7.1	7.1	6.9	6.5	6.9	7.4	7.0	7.8	7.8
Avg. Temp. [°C]	17.5	19.0	20.1	20.2	20.4	18.9	17.2	17.7	19.7	19.2	18.0	17.2

Data location: Latitude: 9 DD, Longitude: 43 DD





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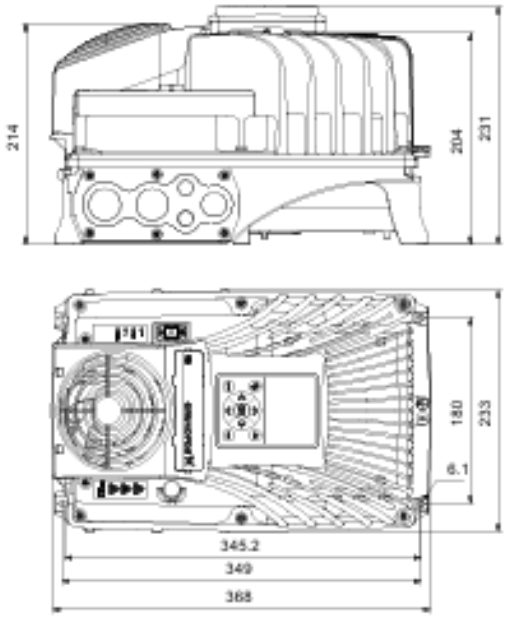
Reference Number:	Farda WSS, Somali Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
General information:	
Product name:	RSI 3x208-240V IP66 11kW 48A
Product No:	99090638
EAN number:	5712606580460
Technical:	
Approvals and markings:	CE
Installation:	
Range of ambient temperature:	-10 .. 60 °C
Relative humidity:	100 %
Liquid:	
Pumped liquid:	Water
Electrical data:	
Rated power - P2:	11 kW
Mains frequency:	50 / 60 Hz
Rated voltage:	3 x 208-240 V
Enclosure class (IEC 34-5):	IP66
Rated voltage output AC:	220 V
Voltage input DC:	400 V
Rated current output AC:	48 A
Udc:	230 V
Others:	
Net weight:	14.9 kg
Gross weight:	16.3 kg



Description	Value
General information:	
Product name:	OTDCP16, Circuit Breaker, 16Amp
Product No:	96341686
EAN number:	5711493289296

Description	Value
General information:	
Product name:	OVR PV 40-1000 P, Surge Protection
Product No:	96341687
EAN number:	5711493289302

2.2 Sidehamelef WSS

2.2.1 Basic Data

Region	Afar
Zone:	Zone 4
Woreda:	Awura
Kebele:	Sidehamelef
Project/Water Source Location-GPS	
Latitude-N	12.160008 DD
Longitude-E	40.556962 DD
Water Demand	
Population size (base-2025)	4000
Growth Rate (%)	3.5%

Summary of Primary Data

Type of Existing water pumping system (Borehole or Surface Pump)	BH
Existing Borehole History	0
Statis Water Level (m)	278
Drowdawn (m)	6
Dyanamic water level (m)	284
Safe Yield (m3/hr)	35
Borehole Depth (m)	348
Borehole Diameter	8"
Pump Intake level (m)	285
Distance from BH head to tank (running distance)	394 m
Static Lift above Ground (BH & Reservoir)	25 M
Tank Height and Size	3 m height 100
No. of Elbows in the pipe line	6
No.of gate valves	1
No. of non-return valaves	1

Solar Energy related data	
Distance from water scheme-BH to proposed solar modules (m)	20 m
How long it takes for the pump to fill the existing reservoir (Hr.)	4 hrs
Generator Size (Power)	80 KVA
Generator Efficiency	0.8
Generator Running time	4 hr
Water Pumping yield (from pump)	6 l/s
Motor power rating (Pump-Kw)	26 KW
Existing cable wire size	3*25 mm2
pipe materials and size	GI 3"

2.2.2 Yield of the water source available to the solar powered water system

Considering the primary information the total Head is 321 meters and required discharge is 19.76 m^3/Hour (5.49 l/sec) the pump required will be 30KW.

Hydraulic Power:

Formula: $P_h = \rho g Q H$ with $\rho = 1000 \text{kg/m}^3$, $g = 9.81 \text{m/s}^2$, Q = 0.005488 m^3/s

Stepwise:

- $\rho g = 1000 \times 9.81 = 9810$
- $\rho g \times Q = 9810 \times 0.005488 = 53.846$(W per meter of head)
- $P_h = 53.846 \times 321 = 17{,}284.566$ W. So **Hydraulic power = 17.28 kW**.

Pump shaft power and motor input

Use $P_{shaft} = \frac{P_h}{\eta_{pump}}$ and $P_{motor-in} = \frac{P_{shaft}}{\eta_{motor}}$.

Take a conservative **pump efficiency = 60% (0.60)** and **motor efficiency = 90% (0.90)**:

- $P_{shaft} = \frac{17.28 \text{ kW}}{0.65} = 26.58 \text{ kW}$
- $P_{motor-in} = \frac{26.58}{0.90} = 29.54 \text{ kW}$

So with those efficiencies the input power required ≈ **30 kW**.

2.2.3 Yield of the water source available to the solar powered water system

The woreda Water Office indicated that the safe yield of the borehole is 35m^3/hr (9.7l/sec). Considering the required demand at the end of the design period an average of 5.49 l/Sec was considered for designing the solar power requirements.

The water demand of the design period is 5.49 l/s, which is less than the safe yield of the borehole. Therefore, the discharge rate of the pump does not exceed the safe yield of the borehole.

2.2.4 Designing the PV system for an AC pump with Inverter

The PV system design will be managed and done by using Grundfos or LORENTZ web and software-based design, whichever the result with optimum sizing will be selected. The below listed specifications of solar system components are the minimum requirements for selected solarization of water supply scheme.

Assumptions:

- Pump electrical rating: 30 kW (continuous).
- Daily run time: 8 hours/day.
- Peak Sun Hours (site): 7 kWh/m²/day.
- System performance factor (losses): 0.80.
- PV module (assumed representative for 615 W module):
  - V_{mp} = 41.5 V, V_{oc} = 49.5 V, I_{mp} = 14.82 A, I_{sc} = 15.56 A.
- Inverter: 45 kW, 3-phase (800 V).
- Power factor for AC current calc: 0.9 (typical).
- All currents/power rounded sensibly.

Energy & PV array sizing

- Daily energy required = 30 kW × 8 h = 240 kWh/day.
- Energy produced per kWp = PSH × system_eff = 7 × 0.80 = 5.6 kWh/day per kWp.
- Required PV kWp = 240 ÷ 5.6 = 42.8571 kWp (≈ 42.86 kWp).
- Panels required = 42.86 ÷ 0.615 = ≈ 69.69 → round up → 70 panels.
- Installed array (chosen) = 70 × 615 W = 43,050 W ≈ 43.05 kWp.

So, we need **70 × 615 W panels** (≈43.05 kWp) to meet the 30-kW pump for 8 h/day at 7 PSH (with 0.80 system efficiency)

Inverter Sizing Note:

- Pump = 30 kW.
- We assumed 45 kW inverter: that gives a margin of 1.5× motor rating (45 / 30 ≈ 1.5), which is acceptable for many installations (it helps with overloads/starts).

String Layout

The input voltage of the selected inverter is 800V. So, the string configuration should consider this. The proposed layout is 14 Panels in Series X 5 Strings (14S X 5P = 70 Panels) similar to panels calculated.

- V_{mp} per string = 41.5 V × 14 = 581 V.
- V_{oc} per string (STC) = 49.5 V × 14 = 693 V.
- I_{mp} per string = 14.82 A.
- Total DC current = 5 × 14.82 = 74.1 A.
- Array DC power V_{mp} 581 V × 74.1 A ≈ 43,052 W (matches 70×615 W).

The V_{OC} Per string is within the input voltage of the selected inverter (800 V).

AC current & breaker sizing (for the 30-kW inverter / 800 V, PF 0.9

- AC current at inverter rated power (30 kW):
  $I_{ac,inv}$ = 30000/(√3*800*0.9) = 24.06 A
  AC breaker sizing (1.25× inverter rated current): 1.25 × 24.06 ≈ 30.07 A → choose a 30 A AC breaker for the inverter output circuit.

DC protection & combiner sizing

- Per-string I_{sc} ≈ **15.56 A** → choose **20 A** DC string fuse
- Total DC MPP current = 14.82*5 = 74.1 A → combiner sizing = 1.25 × 74.1 ≈ 92.6 A → use a 100 A DC combiner/isolator
- I_{sc_total} ≈ 5 × 15.56 ≈ 77.8 A

Configuration

- Minimum No of Strings: 5
- No of Pannels Per String: 14
- Tilt Angle: 12°
- Azimuth: South

GRUNDFOS

Company name:	GOAL Ethiopia
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Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Sidehamelef WSS, Afar Region	**Client Number:**	0912101888
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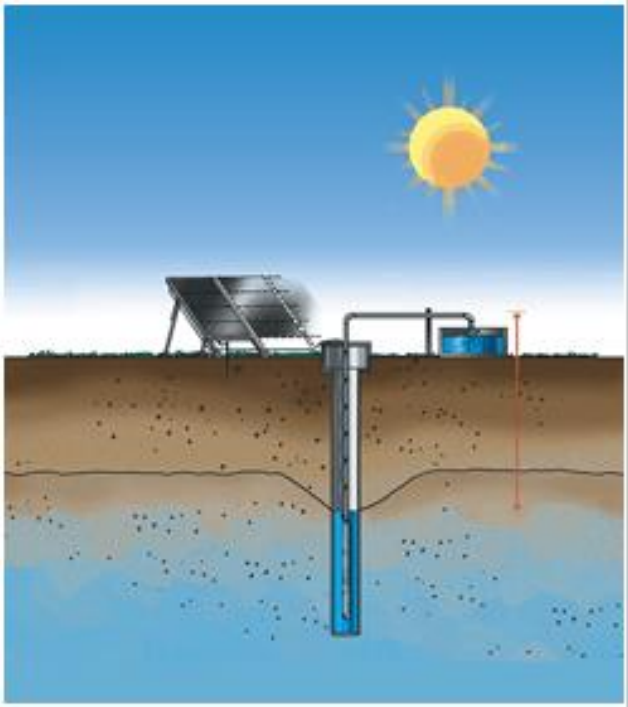
Installation and Input



Sizing Results

Water production, Peak flow and Price
Total water production per year: 56300 m³
Avg. water production per day: 154.3 m³/day
Average water production per watt per day: 3.9 l/Wp/day

Solar module configuration:
Number of solar modules in series: 13, in parallel: 5
Solar array rated power: 39.98 kW
Solar array rated volts: 578 V
Sun tracking: No (fixed)
Tilt angle: 11 deg.

Typical performance at solar radiation 800 W/m²
Flow: 20.3 m³/h
Total head: 331.7 m

Cables and pipes:
Pump cable length: 82 m
Pump cable size: 16 mm²
Total cable loss: 1.9 %

Material, riser pipe: Galvanized steel
Pipe size (inner diameter), riser pipe: DN 80 (81 mm)
Material, discharge pipe: Galvanized steel
Pipe size (inner diameter), discharge pipe: DN 80 (81 mm)
Pipe length of riser pipe: 285 m
Pipe length of discharge pipe: 394 m
Friction loss, discharge pipe: 12.2 m
Total friction losses: 21.74 m

Location: Sekoyta Shet, Afar, Ethiopia
Latitude: 12.160008 DD, Longitude: 40.556962 DD

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Sidehamelef WSS, Afar Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

92941001 SPE 18-48

Input - summary

Flow: 158m³/day ()
Month for sizing: July
Static lift above ground: 25 m
Dynamic water level: 285 m
Sun tracking: No (fixed)
Location: Sekoyta Shet, Afar, Ethiopia
Latitude: 12.160008 DD, Longitude: 40.556962 DD

Products

Pump: SPE 18-48, 1 x 92941001
Solar module: 65 x NN 615W
Switch box / control unit: RSI 3x380-440V IP54 45kW 87A, 1 x 99648886
Switch box / control unit: OTDCP16, Circuit Breaker, 16Amp, 5 x 98341686
Switch box / control unit: OVR PV 40-1000 P, Surge Protection, 1 x 98341687
Others: Sine-wave filter, 1 x 97774436

Sizing results - summary

Water production, Peak flow and Price
Total water production per year: 56300 m³
Avg. water production per day: 154.3 m³/day
Average water production per watt per day: 3.9 l/Wp/day

Solar module configuration:
Number of solar modules in series: 13, in parallel: 5
Solar array rated power: 39.98 kW
Solar array rated volts: 578 V
Sun tracking: No (fixed)
Tilt angle: 11 deg.

Typical performance at solar radiation 800 W/m²
Flow: 20.3 m³/h
Total head: 331.7 m

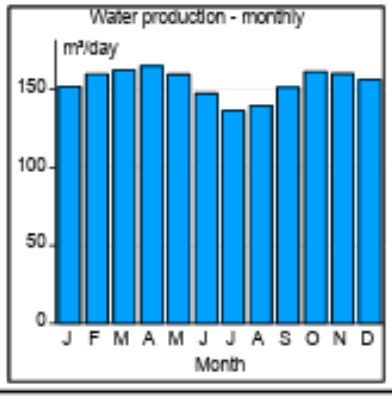
Cables and pipes:
Pump cable length: 82 m
Pump cable size: 16 mm²
Total cable loss: 1.9 %

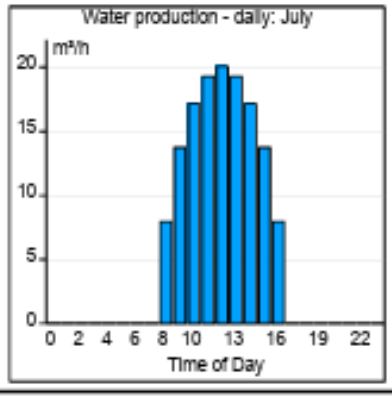
Material, riser pipe: Galvanized steel
Pipe size (inner diameter), riser pipe: DN 80 (81 mm)
Material, discharge pipe: Galvanized steel
Pipe size (inner diameter), discharge pipe: DN 80 (81 mm)
Pipe length of riser pipe: 285 m
Pipe length of discharge pipe: 394 m
Friction loss, discharge pipe: 12.2 m
Total friction losses: 21.74 m

System performance - monthly average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water production [m³/day]	152.1	160	162.4	165.1	159.8	147.6	136.4	139.9	151.2	161.6	160.2	156.2
Energy production Solar [kWh/day]	222.1	241.3	246.3	253.4	238.7	212.0	194.9	199.0	217.0	245.2	242.7	232.6
Radiation horizontal [kWh/m² day]	5.9	6.6	7.1	7.7	7.4	6.6	6.0	6.0	6.5	6.9	6.5	6.1
Radiation tilt [kWh/m² day]	6.4	7.0	7.2	7.5	7.1	6.3	5.8	5.9	6.4	7.2	7.1	6.7
Avg. Temp. [°C]	26.3	27.8	30.6	33.1	35.1	36.2	34.8	34.4	35.1	31.8	28.9	26.9

Data location: Latitude: 13 DD, Longitude: 41 DD



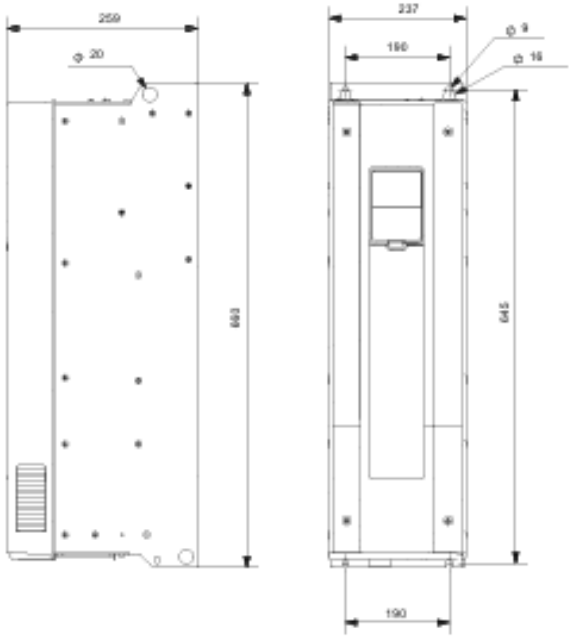


GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Sidehamelef WSS, Afar Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

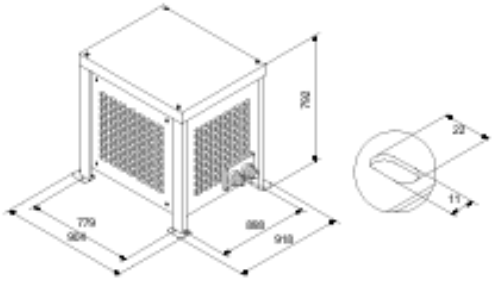
Description	Value
General information:	
Product name:	RSI 3x380-440V IP54 45kW 87A
Product No:	99648886
EAN number:	5713832409495
Technical:	
Approvals and markings:	CE
Installation:	
Range of ambient temperature:	-10 .. 50 °C
Relative humidity:	95 %
Liquid:	
Pumped liquid:	Water
Electrical data:	
Rated power - P2:	45 kW
Mains frequency:	50 / 60 Hz
Rated voltage:	3 x 380-440 V
Enclosure class (IEC 34-5):	IP54
Rated voltage output AC:	380 V
Voltage input DC:	800 V
Rated current output AC:	87 A
Udc:	400 V
Others:	
Net weight:	37.5 kg
Gross weight:	40.5 kg



Description	Value
General information:	
Product name:	OTDCP16, Circuit Breaker, 16Amp
Product No:	98341686
EAN number:	5711493289296

Description	Value
General information:	
Product name:	OVR PV 40-1000 P, Surge Protection
Product No:	98341687
EAN number:	5711493289302

Description	Value
General information:	
Product name:	Sine-wave filter
Product No:	97774436
EAN number:	5710624160251
Installation:	
Mounted on:	FLOOR
Electrical data:	
Mains frequency:	50 Hz
Rated voltage:	x 200-500 V
Rated current:	115 A
Rated current at 100 Hz:	86 A
Enclosure class (IEC 34-5):	IP23
Inductor loss:	470 W
Others:	
Net weight:	205 kg
Danish VVS No.:	382997115



2.3 Negash WSS

2.3.1 Basic Data

Summary of Primary Data

Region	Tigray
Zone:	Eastern
Woreda:	Kileteawelalo
Kebele:	Negash
Project/Water Source Location-GPS	
Latitude-N	13.887276 DD
Longitude-E	39.591376 DD
Water Demand	
Population size (base-2025)	2200
Growth Rate (%)	3.5%

Type of Existing water pumping system (Borehole or Surface Pump)	BH
Existing Borehole History	0
Statis Water Level (m)	12
Drowdawn (m)	28
Dyanamic water level (m)	40
Safe Yield (m3/hr)	18
Borehole Depth (m)	58
Borehole Diameter	6"
Pump Intake level (m)	48
Eistance from BH head to tank (running distance)	1210 m
Static Lift above Ground (BH & Reservoir)	66 M
Tank Height and Size	3m height 50 m3
No. of Elbows in the pipe line	6
No.of gate valves	1
No. of non-return valaves	1

Solar Energy related data	
Distance from water scheme-BH to proposed solar modules (m)	20 m
How long it takes for the pump to fill the existing reservoir (Hr.)	4 hrs and 30 minutes
Generator Size (Power)	32 KVA
Generator Efficiency	0.8
Generator Running time	8 hr
Water Pumping yield (from pump)	3 l/s
Motor power rating (Pump-Kw)	7.5kw
Existing cable wire size	3*6 mm2
Pipe materials and size	HDPE 63 mm

2.3.2 Yield of the water source available to the solar powered water system

Considering the primary information the total Head is 175 meters and required discharge is 10.5 m^3/hour (3 l/sec) the pump required will be 7.5 KW.

Hydraulic Power:

Formula: $P_h = \rho g Q H$ with $\rho = 1000 \text{kg/m}^3$, $g = 9.81 \text{m/s}^2$, Q = 0.002917 m^3/s

Stepwise:

- $\rho g = 1000 \times 9.81 = 9810$
- $\rho g \times Q = 9810 \times 0.002917 = 28.615$(W per meter of head)
- $P_h = 28.615 \times 175 = 5{,}007$ W. So **Hydraulic power = 5 kW**.

Pump shaft power and motor input

Use $P_{shaft} = \frac{P_h}{\eta_{pump}}$and $P_{motor-in} = \frac{P_{shaft}}{\eta_{motor}}$.

Take a conservative **pump efficiency = 60% (0.60)** and **motor efficiency = 90% (0.90)**:

- $P_{shaft} = \frac{5\text{kW}}{0.7} = 7.1$ kW
- $P_{motor-in} = \frac{7.1kW}{0.90} = 7.8$ kW

So with those efficiencies the input power required ≈ **7.5 kW**.

2.2.3 Yield of the water source available to the solar powered water system

The woreda Water Office indicated that the safe yield of the borehole is 18m^3/hr (5 l/sec). Considering the required demand at the end of the design period an average of 3.02 l/Sec was considered for designing the solar power requirements.

The water demand of the design period is 3.02 l/s, which is less than the safe yield of the borehole. Therefore, the discharge rate of the pump does not exceed the safe yield of the borehole.

2.2.4 Designing the PV system for an AC pump with Inverter

The PV system design will be managed and done by using Grundfos or LORENTZ web and software-based design, whichever the result with optimum sizing will be selected. The below listed specifications of solar system components are the minimum requirements for selected solarization of water supply scheme.

Assumptions:

- Pump electrical rating: 7.5 kW (continuous).
- Daily run time: 8 hours/day.
- Peak Sun Hours (site): 6.2 kWh/m²/day.
- System performance factor (losses): 0.80.
- PV module (assumed representative for 615 W module):
  - V_{mp} = 41.5 V, V_{oc} = 49.5 V, I_{mp} = 14.82 A, I_{sc} = 15.56 A.
- Inverter: 11 kW, 3-phase (800 V).
- Power factor for AC current calc: 0.9 (typical).
- All currents/power rounded sensibly.

Energy & PV array sizing

- Daily energy required = 7.5 kW × 8 h = 60 kWh/day.
- Energy produced per kWp = PSH × system_eff = 6.2 × 0.80 = 4.96 kWh/day per kWp.
- Required PV kWp = 60 ÷ 4.96 = 12.09 kWp (≈ 12.1 kWp).
- Panels required = 12.1 ÷ 0.615 = ≈ 19.67 → round up → 20 panels.
- Installed array (chosen) = 20 × 615 W = 12,300 W ≈ 12.3 kWp.

So, we need **20 × 615 W panels** (≈12.3 kWp) to meet the 7.5-kW pump for 8 h/day at 7 PSH (with 0.80 system efficiency)

Inverter Sizing Note:

- Pump = 7.5 kW.
- We assumed 11 kW inverter: that gives a margin of 1.47× motor rating (11 / 7.5 ≈ 1.47), which is acceptable for many installations (it helps with overloads/starts).

String Layout

The input voltage of the selected inverter is 800V. So, the string configuration should consider this. The proposed layout is 10 Panels in Series X 2 Strings (10S X 2P = 20 Panels) similar to panels calculated.

- V_{mp} per string = 41.5 V × 10 = 415 V.
- V_{oc} per string (STC) = 49.5 V × 10 = 495 V.
- I_{mp} per string = 14.82 A.
- Total DC current = 2 × 14.82 = 29.64 A.
- Array DC power V_{mp} 415 V × 29.64 A ≈ 12,300 W (matches 20×615 W).

The V_{OC} Per string is within the input voltage of the selected inverter (800 V).

AC current & breaker sizing (for the 11-kW inverter / 800 V, PF 0.9

- AC current at inverter rated power (30 kW):
  $I_{ac,inv}$ = 11000/(√3*800*0.9) = 8.82 A
  AC breaker sizing (1.25× inverter rated current): 1.25 × 8.82 ≈ 11.03 A → choose a 16 A AC breaker for the inverter output circuit.

DC protection & combiner sizing

- Per-string I_{sc} ≈ **15.56 A** → choose **20 A** DC string fuse
- Total DC MPP current = 14.82*2 = 29.64 A → combiner sizing = 1.25 × 29.64 ≈ 37.05 A → use a 40 A DC combiner/isolator
- I_{sc_total} ≈ 2 × 15.56 ≈ 31.12 A

Configuration

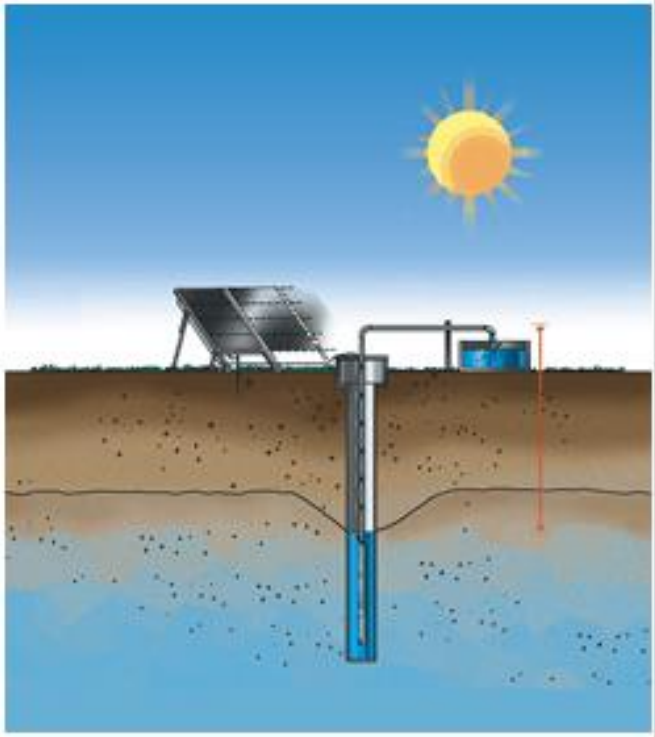
- Minimum No of Strings: 2
- No of Pannels Per String: 10
- Tilt Angle: 14°
- Azimuth: South

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Negash WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Installation and Input



Sizing Results

Water production, Peak flow and Price
Total water production per year: 33100 m³
Avg. water production per day: 90.6 m³/day
Average water production per watt per day: 5.7 l/Wp/day

Solar module configuration:
Number of solar modules in series: 13, in parallel: 2
Solar array rated power: 15.99 kW
Solar array rated volts: 578 V
Sun tracking: No (fixed)
Tilt angle: 13 deg.

Typical performance at solar radiation 800 W/m²
Flow: 9.8 m³/h
Total head: 182.7 m

Cables and pipes:
Pump cable length: 82 m
Pump cable size: 6 mm²
Total cable loss: 2.2 %

Material, riser pipe: Galvanized steel
Pipe size (inner diameter), riser pipe: DN 65 (69 mm)
Material, discharge pipe: PE100 PN16 SDR11
Pipe size (inner diameter), discharge pipe: Ø 63 (51.4 mm)
Pipe length of riser pipe: 48 m
Pipe length of discharge pipe: 1210 m
Friction loss, discharge pipe: 83.74 m
Total friction losses: 68.75 m

Location: Tigray, Ethiopia
Latitude: 13.887276 DD, Longitude: 39.591376 DD

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Negash WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

98699071 SP 9-40

Input - summary

Flow: 87m³/day ()
Month for sizing: July
Static lift above ground: 66 m
Dynamic water level: 48 m
Sun tracking: No (fixed)
Location: Tigray, Ethiopia
Latitude: 13.887276 DD, Longitude: 39.591376 DD

Products

Pump: SP 9-40, 1 x 98699071
Solar module: 26 x NN 615W
Switch box / control unit: RSI 3x380-440V IP66 11kW 23A, 1 x 99044363
Switch box / control unit: OTDCP16, Circuit Breaker, 16Amp, 2 x 98341686
Switch box / control unit: OVR PV 40-1000 P, Surge Protection, 1 x 98341687
Others: Sine-wave filter, 1 x 96754977

Sizing results - summary

Water production, Peak flow and Price
Total water production per year: 33100 m³
Avg. water production per day: 90.6 m³/day
Average water production per watt per day: 5.7 l/Wp/day

Solar module configuration:
Number of solar modules in series: 13, in parallel: 2
Solar array rated power: 15.99 kW
Solar array rated volts: 578 V
Sun tracking: No (fixed)
Tilt angle: 13 deg.

Typical performance at solar radiation 800 W/m²
Flow: 9.8 m³/h
Total head: 182.7 m

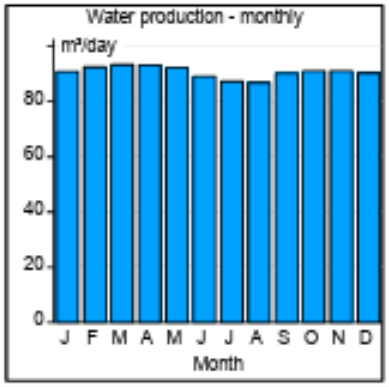
Cables and pipes:
Pump cable length: 82 m
Pump cable size: 6 mm²
Total cable loss: 2.2 %

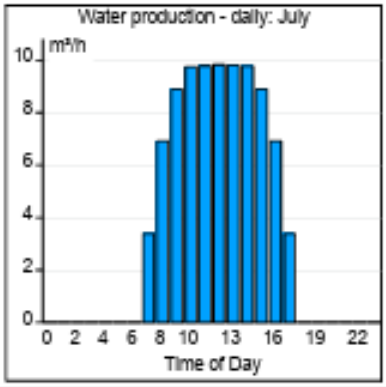
Material, riser pipe: Galvanized steel
Pipe size (inner diameter), riser pipe: DN 65 (69 mm)
Material, discharge pipe: PE100 PN16 SDR11
Pipe size (inner diameter), discharge pipe: Ø 63 (51.4 mm)
Pipe length of riser pipe: 48 m
Pipe length of discharge pipe: 1210 m
Friction loss, discharge pipe: 83.74 m
Total friction losses: 68.75 m

System performance - monthly average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water production [m³/day]	90.8	92.5	93.3	93.2	92.1	89.1	87.3	86.8	90.2	91	91	90.3
Energy production Solar [kWh/day]	114.5	118.5	117.3	110.8	101.0	90.3	85.6	86.4	100.2	109.7	113.9	113.0
Radiation horizontal [kWh/m² day]	7.1	7.8	8.2	8.1	7.7	6.8	6.3	6.2	7.0	7.3	7.2	6.9
Radiation tilt [kWh/m² day]	8.0	8.4	8.3	7.9	7.2	6.4	6.0	6.0	7.0	7.7	8.0	7.9
Avg. Temp. [°C]	18.7	20.6	22.4	23.4	23.8	21.5	17.9	17.4	19.4	20.3	19.1	18.2

Data location: Latitude: 13 DD, Longitude: 39 DD



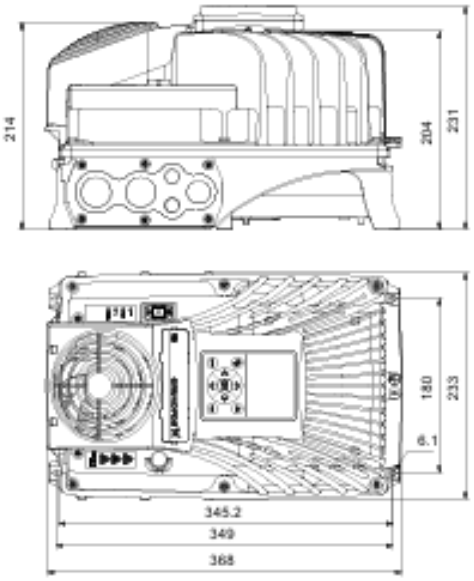


GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Negash WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

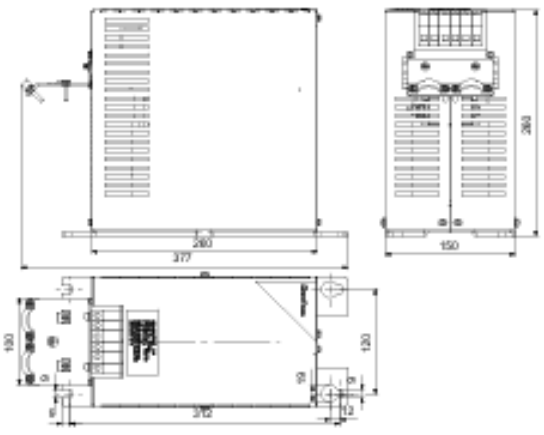
Description	Value
General information:	
Product name:	RSI 3x380-440V IP66 11kW 23A
Product No:	99044363
EAN number:	5712605678687
Technical:	
Approvals and markings:	CE
Installation:	
Range of ambient temperature:	-10 .. 60 °C
Relative humidity:	100 %
Liquid:	
Pumped liquid:	Water
Electrical data:	
Rated power - P2:	11 kW
Mains frequency:	50 / 60 Hz
Rated voltage:	3 x 380-440 V
Enclosure class (IEC 34-5):	IP66
Rated voltage output AC:	380 V
Voltage input DC:	800 V
Rated current output AC:	23 A
Udc:	400 V
Others:	
Net weight:	14.9 kg
Gross weight:	16.3 kg



Description	Value
General information:	
Product name:	OTDCP16, Circuit Breaker, 16Amp
Product No:	98341686
EAN number:	5711493289296

Description	Value
General information:	
Product name:	OVR PV 40-1000 P, Surge Protection
Product No:	98341687
EAN number:	5711493289302

Description	Value
General information:	
Product name:	Sine-wave filter
Product No:	96754977
EAN number:	5700838641097
Installation:	
Mounted on:	WALL
Electrical data:	
Mains frequency:	60 Hz
Rated voltage:	x 200-500 V
Rated current:	23 A
Rated current at 120 Hz:	15.3 A
Enclosure class (IEC 34-5):	IP20
Cable size:	16 mm2
Inductor loss:	150 W
Others:	
Net weight:	16.9 kg
Danish VVS No.:	382997024



2.4 May Nebri WSS

2.4.1 Basic Data

Summary of Primary Data

Region	Tigray
Zone:	North wello
Woreda:	Hintalo
Kebele:	May Nebri
Project/Water Source Location-GPS	0
Latitude-N	13.135747 DD
Longitude-E	39.499266 DD
Water Demand	
Population size (base-2025)	4500
Growth Rate (%)	0.17

Type of Existing water pumping system (Borehole or Surface Pump)	BH
Existing Borehole History	0
Statis Water Level (m)	30
Drowdawn (m)	15
Dyanamic water level (m)	45
Safe Yield (m3/hr)	43.2
Borehole Depth (m)	110m
Borehole Diameter	8"
Pump Intake level (m)	105
Eistance from BH head to tank (running distance)	1450 m
Static Lift above Ground (BH & Reservoir)	103 M
Tank Height and Size	3m height 50 m3
No. of Elbows in the pipe line	6
No.of gate valves	1
No. of non-return valaves	1

Solar Energy related data	
Distance from water scheme-BH to proposed solar modules (m)	20 m
How long it takes for the pump to fill the existing reservoir (Hr.)	2 hrs and 30 minutes
Generator Size (Power)	60 KVA
Generator Efficiency	0.8
Generator Running time	8 hrs
Water Pumping yield (from pump)	10 l/s
Motor power rating (Pump-Kw)	18.5kw
Existing cable wire size	3*25 mm2
Pipe materials and size	GI 3"

2.4.2 Yield of the water source available to the solar powered water system

Considering the primary information the total Head is 200 meters and required discharge is 22 m^3/hour (6.1 l/sec) the pump required will be 18.5 KW.

Hydraulic Power:

Formula: $P_h = \rho g Q H$ with $\rho = 1000 \text{kg/m}^3$, $g = 9.81 \text{m/s}^2$, Q = 0.006111 m^3/s

Stepwise:

- $\rho g = 1000 \times 9.81 = 9810$
- $\rho g \times Q = 9810 \times 0.006111 = 59.95$(W per meter of head)
- $P_h = 59.95 \times 200 = 11{,}990$ W. So **Hydraulic power = 11.9 kW**.

Pump shaft power and motor input

Use $P_{shaft} = \frac{P_h}{\eta_{pump}}$and $P_{motor-in} = \frac{P_{shaft}}{\eta_{motor}}$.

Take a conservative **pump efficiency = 60% (0.60)** and **motor efficiency = 90% (0.90)**:

- $P_{shaft} = \frac{11.9\text{kW}}{0.7} = 17$ kW
- $P_{motor-in} = \frac{17kW}{0.90} = 18.8$ kW

So with those efficiencies the input power required ≈ **18.5 kW**.

2.4.3 Yield of the water source available to the solar powered water system

The woreda Water Office indicated that the safe yield of the borehole is 43.2m^3/hr (12 l/sec). Considering the required demand at the end of the design period an average of 6.17 l/Sec was considered for designing the solar power requirements.

The water demand of the design period is 6.17 l/s, which is less than the safe yield of the borehole. Therefore, the discharge rate of the pump does not exceed the safe yield of the borehole.

2.4.4 Designing the PV system for an AC pump with Inverter

The PV system design will be managed and done by using Grundfos or LORENTZ web and software-based design, whichever the result with optimum sizing will be selected. The below listed specifications of solar system components are the minimum requirements for selected solarization of water supply scheme.

Assumptions:

- Pump electrical rating: 18.5 kW (continuous).
- Daily run time: 8 hours/day.
- Peak Sun Hours (site): 6.06 kWh/m²/day.
- System performance factor (losses): 0.80.
- PV module (assumed representative for 615 W module):
  - V_{mp} = 41.5 V, V_{oc} = 49.5 V, I_{mp} = 14.82 A, I_{sc} = 15.56 A.
- Inverter: 22 kW, 3-phase (800 V).
- Power factor for AC current calc: 0.9 (typical).
- All currents/power rounded sensibly.

Energy & PV array sizing

- Daily energy required = 18.5 kW × 8 h = 148 kWh/day.
- Energy produced per kWp = PSH × system_eff = 6.06 × 0.80 = 4.84 kWh/day per kWp.
- Required PV kWp = 148 ÷ 4.84 = 30.58 kWp (≈ 31 kWp).
- Panels required = 31 ÷ 0.615 = ≈ 50.4 → round up → 52 panels.
- Installed array (chosen) = 52 × 615 W = 31,980 W ≈ 31.98 kWp.

So, we need **52 × 615 W panels** (≈31.98 kWp) to meet the 18.5-kW pump for 8 h/day at 6.06 PSH (with 0.80 system efficiency)

Inverter Sizing Note:

- Pump = 18.5 kW.
- We assumed 22 kW inverter: that gives a margin of 1.2× motor rating (22 / 18.5 ≈ 1.19), which is acceptable for many installations (it helps with overloads/starts).

String Layout

The input voltage of the selected inverter is 800V. So, the string configuration should consider this. The proposed layout is 13 Panels in Series X 4 Strings (13S X 4P = 52 Panels) similar to panels calculated.

- V_{mp} per string = 41.5 V × 13 = 539.5 V.
- V_{oc} per string (STC) = 49.5 V × 13 = 643.5 V.
- I_{mp} per string = 14.82 A.
- Total DC current = 4 × 14.82 = 59.28 A.
- Array DC power V_{mp} 539.5 V × 59.28 A ≈ 31,981 W (matches 52×615 W).

The V_{OC} Per string is within the input voltage of the selected inverter (800 V).

AC current & breaker sizing (for the 22-kW inverter / 800 V, PF 0.9

- AC current at inverter rated power (30 kW):
  $I_{ac,inv}$ = 22000/(√3*800*0.9) = 17.6 A
  AC breaker sizing (1.25× inverter rated current): 1.25 × 17.6 ≈ 22.05 A → choose a 25 A AC breaker for the inverter output circuit.

DC protection & combiner sizing

- Per-string I_{sc} ≈ **15.56 A** → choose **20 A** DC string fuse
- Total DC MPP current = 14.82*4 = 59.28 A → combiner sizing = 1.25 × 59.28 ≈ 74.1 A → use a 75 A DC combiner/isolator
- I_{sc_total} ≈ 4 × 15.56 ≈ 62.24 A

Configuration

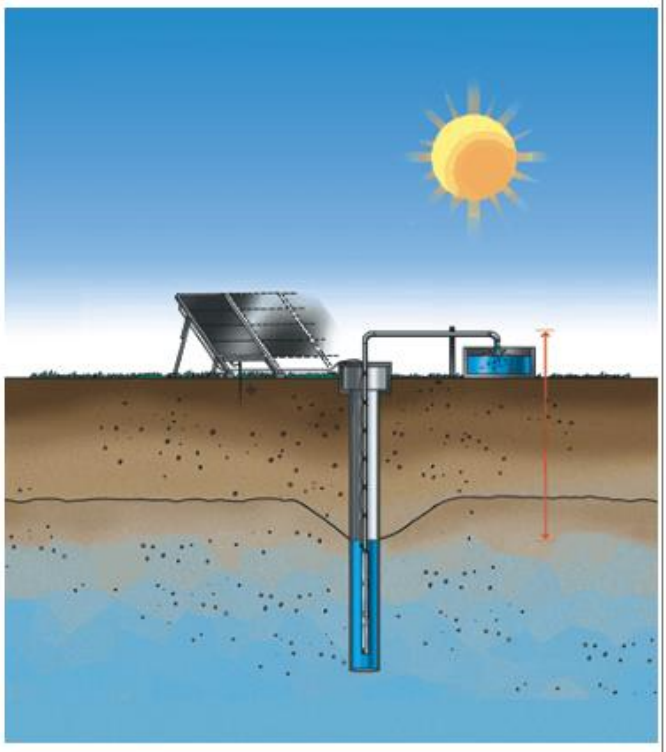
- Minimum No of Strings: 4
- No of Pannels Per String: 13
- Tilt Angle: 14°
- Azimuth: South

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	May Nebri WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Installation and Input



Sizing Results

Water production, Peak flow and Price
Total water production per year: 69100 m³
Avg. water production per day: 189.2 m³/day
Average water production per watt per day: 5.9 l/Wp/day

Solar module configuration:
Number of solar modules in series: 13, in parallel: 4
Solar array rated power: 31.98 kW
Solar array rated volts: 578 V
Sun tracking: No (fixed)
Tilt angle: 13 deg.

Typical performance at solar radiation 800 W/m²
Flow: 21.2 m³/h
Total head: 203.1 m

Cables and pipes:
Pump cable length: 82 m
Pump cable size: 16 mm²
Total cable loss: 1.6 %

Material, riser pipe: Galvanized steel
Pipe size (inner diameter), riser pipe: DN 80 (81 mm)
Material, discharge pipe: Galvanized steel
Pipe size (inner diameter), discharge pipe: DN 80 (81 mm)
Pipe length of riser pipe: 105 m
Pipe length of discharge pipe: 1450 m
Friction loss, discharge pipe: 56.88 m
Total friction losses: 55.15 m

Location: Zamra Shet, May Nebri, Tigray, Ethiopia
Latitude: 13.135747 DD, Longitude: 39.499266 DD

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Created by:	WASH Team
Phone:	0912101888
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Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	May Nebri WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

92952124 SP 18-33

Input - summary

Flow: 178m³/day ()
Month for sizing: July
Static lift above ground: 103 m
Dynamic water level: 45 m
Sun tracking: No (fixed)
Location: Zamra Shet, May Nebri, Tigray, Ethiopia
Latitude: 13.135747 DD, Longitude: 39.499266 DD

Products

Pump: SP 18-33, 1 x 92952124
Solar module: 52 x NN 615W
Switch box / control unit: RSI 3x380-440V IP66 22kW 46A, 1 x 99044366
Switch box / control unit: OTDCP16, Circuit Breaker, 16Amp, 4 x 98341686
Switch box / control unit: OVR PV 40-1000 P, Surge Protection, 1 x 98341687
Others: Sine-wave filter, 1 x 96755019

Sizing results - summary

Water production, Peak flow and Price
Total water production per year: 69100 m³
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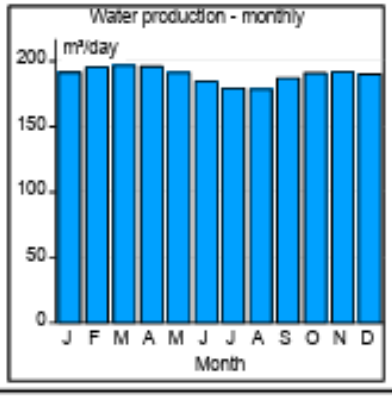
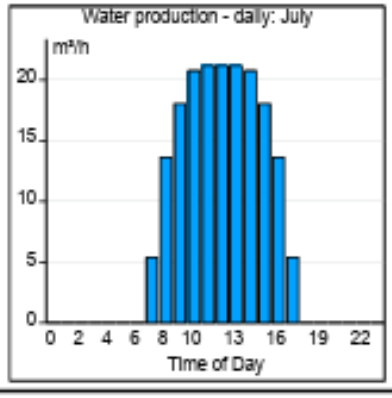
Pipe size (inner diameter), discharge pipe: DN 80 (81 mm)
Pipe length of riser pipe: 105 m
Pipe length of discharge pipe: 1450 m
Friction loss, discharge pipe: 56.88 m
Total friction losses: 55.15 m

System performance - monthly average

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Water production [m³/day]	191.3	195.1	196.7	195.9	191.1	184.3	179.2	178.3	187.1	190.9	191.5	190
Energy production Solar [kWh/day]	229.3	237.8	235.5	222.3	202.4	181.0	171.6	173.2	201.0	220.0	228.3	226.3
Radiation horizontal [kWh/m² day]	7.1	7.8	8.2	8.1	7.7	6.8	6.3	6.2	7.0	7.3	7.2	6.9
Radiation tilt [kWh/m² day]	8.0	8.4	8.3	7.9	7.2	6.4	6.0	6.0	7.0	7.7	8.0	7.9
Avg. Temp. [°C]	18.7	20.6	22.4	23.4	23.8	21.5	17.9	17.4	19.4	20.3	19.1	18.2

Data location: Latitude: 13 DD, Longitude: 39 DD





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Company name:	GOAL Ethiopia
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Phone:	0912101888
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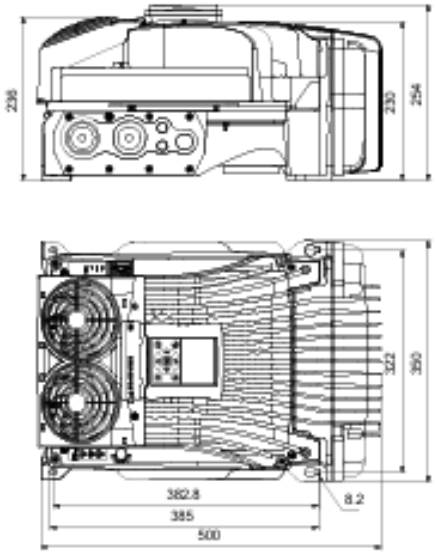
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	May Nebri WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

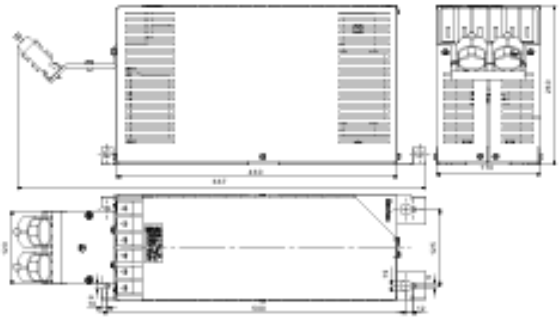
Description	Value
General information:	
Product name:	RSI 3x380-440V IP66 22kW 46A
Product No:	99044366
EAN number:	5712605678717
Technical:	
Approvals and markings:	CE
Installation:	
Range of ambient temperature:	-10 .. 60 °C
Relative humidity:	100 %
Liquid:	
Pumped liquid:	Water
Electrical data:	
Rated power - P2:	22 kW
Mains frequency:	50 / 60 Hz
Rated voltage:	3 x 380-440 V
Enclosure class (IEC 34-5):	IP66
Rated voltage output AC:	380 V
Voltage input DC:	800 V
Rated current output AC:	46 A
Udc:	400 V
Others:	
Net weight:	31.5 kg
Gross weight:	33.6 kg



Description	Value
General information:	
Product name:	OTDCP16, Circuit Breaker, 16Amp
Product No:	98341686
EAN number:	5711493289296

Description	Value
General information:	
Product name:	OVR PV 40-1000 P, Surge Protection
Product No:	98341687
EAN number:	5711493289302

Description	Value
General information:	
Product name:	Sine-wave filter
Product No:	96755019
EAN number:	5700838642001
Installation:	
Mounted on:	WALL
Electrical data:	
Mains frequency:	60 Hz
Rated voltage:	x 200-500 V
Rated current:	45.5 A
Rated current at 120 Hz:	30.6 A
Enclosure class (IEC 34-5):	IP20
Cable size:	50 mm2
Inductor loss:	270 W
Others:	
Net weight:	39 kg
Danish VVS No.:	382997048



Summary of Primary Data				
Region	Somali	Afar	Tigray	Tigray
Zone:	Fafan	Zone 4	Eastern	North wello
Woreda:	Kebribeyah	Awura	Kileteawelalo	Hintalo
Kebele:	Farda	Sidehamelef	Negash	May Nebri
Project/Water Source Location-GPS				
Latitude-N	9.045562 DD	12.160008 DD	13.887276 DD	13.135747 DD
Longitude-E	43.013836 DD	40.556962 DD	39.591376 DD	39.499266 DD
Type of Existing water pumping system (Borehole or Surface Pump)	BH	BH	BH	BH
Existing Borehole History				
Statis Water Level (m)	100	278	12	30
Drowdawn (m)	20	6	28	15
Dyanamic water level (m)	120	284	40	45
Safe Yield (m3/hr)	25	35	18	43.2
Borehole Depth (m)	240	348	58	110m
Borehole Diameter	8"	8"	6"	8"
Pump Intake level (m)	72	285	48	105
Distance from BH head to tank (running distance)	165 m	394 m	1210 m	1450 m
Static Lift above Ground (BH & Reservoir)	12 M	25 M	66 M	103 M
Tank Height and Size	3 m and 25 M^3	3 m height 100 m^3	3m height 50 m^3	3m height 50 m^3
No. of Elbows in the pipe line	6	6	6	6
No.of gate valves	1	1	1	1
No. of non-return valaves	1	1	1	1
Water Demand				
Population size (base)	4000	4000	2200	4500
Growth Rate (%)	3.50%	3.50%	3.50%	17.00%
Solar Energy related data				
Distance from water scheme-BH to proposed solar modules (m)	20m	20 m	20 m	20 m
Space Available for solar modules (yes/no)	YES	Yes	yes	yes
How long it takes for the pump to fill the existing reservoir (Hr.)	1 hr 25 Minutes	4 hrs	4 hrs and 30 minutes	2 hrs and 30 minutes
Generator Size (Power)	40 KVA	80 KVA	32 KVA	60 KVA
Generator Efficiency	0.8	0.8	0.8	0.8
Generator Running time	8hr	4 hr	8 hr	8 hrs
Water Pumping yield (from pump)	5.9 l/s	6 l/s	3 l/s	10 l/s
Motor power rating (Pump-Kw)	11 KW	26 KW	7.5kw	18.5kw
Existing cable wire size	3*16 mm^2	3*25 mm^2	3*6 mm^2	3*25 mm^2
pipe materials and size	GI 3"	GI 3"	HDPE 63 mm	GI 3"

Figure 2 Basic data of the Water Supply Systems

3. Recommendations

1. **Maintenance:** Develop and implement a routine maintenance plan to ensure the long-term efficiency and reliability of the solar power systems. This includes cleaning the solar panels regularly to remove dust, dirt, and debris, which can reduce energy generation. Periodic checks on electrical connections, inverters, and other safety devices are crucial to prevent potential failures and ensure the system operates at peak efficiency. Maintenance logs should be kept to track performance and identify recurring issues.
2. **Warranties:** Ensure all components of the solar power system are covered under reliable warranties to safeguard against potential defects or failures. Solar panels should have a minimum warranty of 10 years, covering performance degradation and manufacturing defects. Inverters, which are critical to system functionality, should have at least a 5-year warranty, along with other key components such as charge controllers and mounting structures. These warranties provide financial protection and ensure that replacements or repairs can be carried out without significant additional costs during the warranty period.

4. Impact of Solarization

The motorized water supply schemes selected for solarization are currently not fully functional. Damage to electromechanical components (mainly the power units and submersible pumps) from conflict and the natural aging of the installed equipment has led to intermittent service and increased health risks for beneficiaries. In addition, the Water supply systems sites in Afar and Somali are remote, making timely fuel delivery difficult and further reducing water availability below minimum standards. Upgrading these schemes to solar powered Pumping systems will provide predictable daytime energy enabling more frequent pumping windows and sharply reducing interruptions caused by fuel shortages. As a result, system reliability and per-capita water supply will improve to meet minimum standards, while operation and maintenance costs will be significantly reduced. This will raise system reliability and per-capita water supply to acceptable levels while significantly lowering operation and maintenance costs. The solar designs target a minimum of 20 L per person per day (20 L/p/d), which would substantially improve the health outcomes of the served populations.

5. Cost Benefit Analysis

We conducted a lifecycle cost analysis for each targeted water supply system and a comparable-capacity solar-powered configuration (full details in Annexes 15–18). The analysis incorporated: initial capital costs, routine operation and maintenance, periodic replacement of major components, and fuel costs for diesel-operated systems over the expected project lifetime. Using these inputs, the cumulative-cost profiles were compared and the incremental capital outlay for solarization was divided by the annual net savings to estimate payback.

Results indicate a robust economic case for solarization, with payback periods ranging from about 1.5 to 2.5 years across the examined sites. This short payback reflects large recurring diesel and maintenance savings at remote sites and the predictable performance of solar systems. Key implications are:

- The higher initial investment in PV and controllers is rapidly recovered through eliminated or reduced fuel purchases and lower engine maintenance.
- After payback, solarized systems generate sustained operational savings that can be reallocated to spare parts, preventive maintenance, or service expansion.
- The economic outcome is sensitive to assumptions such as diesel price, annual pumping hours, and component lifetimes; these sensitivities are documented in Annexes 15–18.

6. Safety of Solarization Systems and Equipment

To protect the solar pumping installations from theft, vandalism and accidental damage, the support structures and key components will be designed and installed with security in mind, and physical perimeter security will be provided. Anti-theft measures include tamper-resistant fastenings and lockable inverter/battery cabinets, reinforced concrete mounting plinths, and secure anchor bolts for panels and pumps. Each site will be surrounded by a durable security fence with a lockable gate.

At handover, the community and the Water, Sanitation and Hygiene Committee (WASHCO) will formally recruit an on-site operator and security guard. Their roles, selection criteria, training, and remuneration will be agreed in writing and funded from the scheme's O&M account. The person will be trained in basic system operation, preventive maintenance and safe shutdown procedures, on access control, incident reporting and escalation procedures. A simple asset register, logbook and incident-reporting form will be handed over to the WASHCO so that all events, maintenance actions and security incidents are recorded and reviewed at monthly meetings. These combined technical, physical and institutional measures will significantly reduce the risk of loss or damage while strengthening local ownership and the long-term sustainability of the solarized water supply.

7. Type of Solar Pump proposed for each scheme

7.1 Negash Water Supply Scheme

GRUNDFOS

Company name:	GOAL Ethiopia
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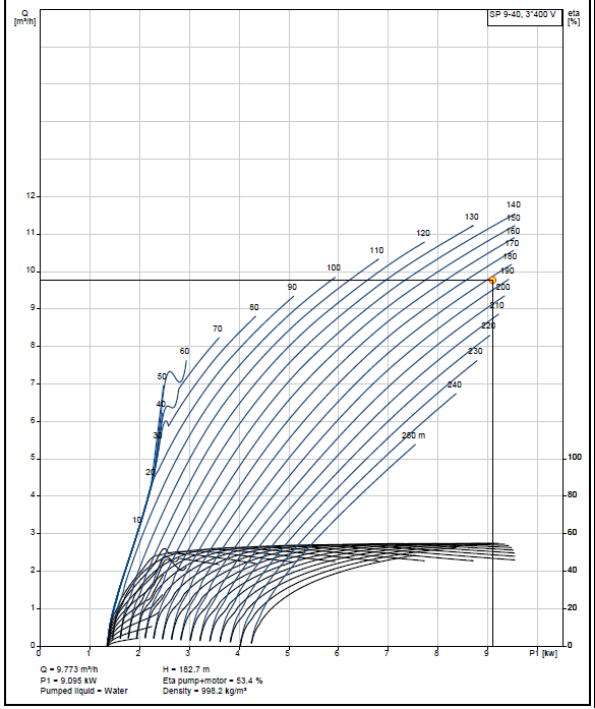
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Negash WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

98699071 SP 9-40



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Phone:	0912101888
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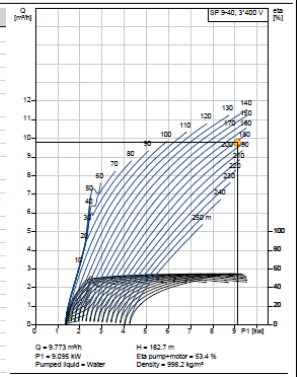
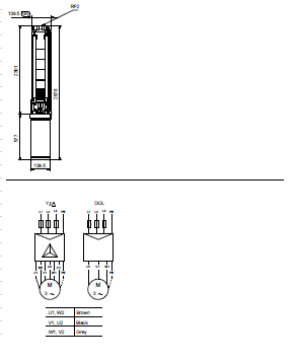
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Negash WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
General information:	
Product name:	SP 9-40
Product No:	98699071
EAN number:	5712600106253
Technical:	
Pump speed on which pump data are based:	2900 rpm
Rated flow:	9 m³/h
Rated head:	212 m
Stages:	40
Number of reduced-diameter impellers:	NONE
Shaft seal for motor:	CER/CARNBR
Approvals:	CE,EAC,UKCA,SEPRO,MOROCCO
Approvals for drinking water:	ACS,DM174
Curve tolerance:	ISO9906:2012 3B
Model:	A
Motor version:	T40
Return valve:	YES
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:	
Maximum ambient pressure:	60 bar
Maximum operating pressure:	60 bar
Maximum outlet pressure:	26.2 bar
Type of connection:	Rp
Size of connection:	2 inch
Motor diameter:	6 inch
Minimum borehole diameter:	145 mm
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-15 .. 40 °C
Max liquid t at 0.15 m/sec:	40 °C
Electrical data:	
Motor type:	MS6000
Motor flange design:	NEMA
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





GRUNDFOS

Company name:	GOAL Ethiopia
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Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Negash WSS, Tigray Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
Enclosure class (IEC 34-5):	IP68
Insulation class (IEC 85):	F
Built-in motor protection:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Length of cable:	5 m
Power cable type:	FLAT
Motor No:	78195512
Cable number:	96164209
Windings:	Enamelled
Others:	
Minimum efficiency index, MEI ≥:	0.70
Net weight:	68.1 kg
Gross weight:	106 kg
Shipping volume:	0.338 m³
Environmental approvals:	WEEE

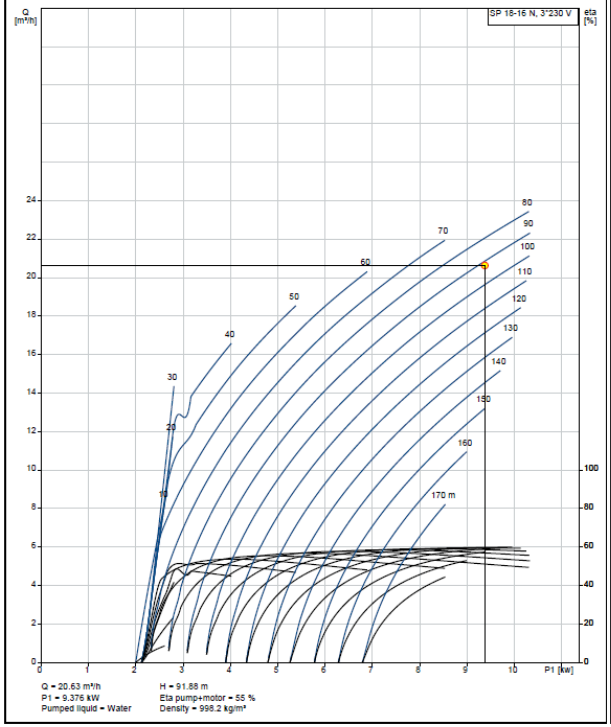
7. 2 Farda Water Supply Scheme

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Farda WSS, Somali Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

92953229 SP 18-16 N



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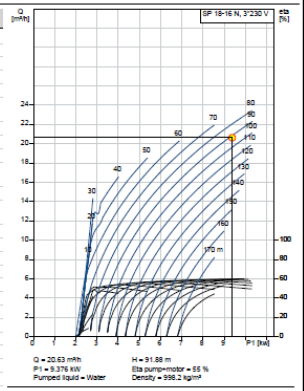
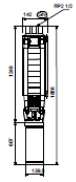
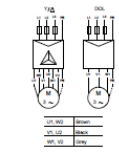
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Farda WSS, Somali Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
General information:	
Product name:	SP 18-16 N
Product No:	92953229
EAN number:	5715122089042
Technical:	
Pump speed on which pump data are based:	2900 rpm
Rated flow:	18 m³/h
Rated head:	122 m
Stages:	16
Number of reduced-diameter impellers:	NONE
Shaft seal for motor:	SIC/SIC/FKM
Approvals:	CE,EAC,UKCA,SEPRO,MOROCCO
Curve tolerance:	ISO9906:2012 3B
Model:	A
Motor version:	T40
Return valve:	YES
Materials:	
Pump:	Stainless steel
	EN 1.4401
	AISI 316
Impeller:	Stainless steel
	EN 1.4401
	AISI 316
Motor:	Stainless steel
	DIN W.-Nr. 1.4539
	AISI 904L
Installation:	
Maximum ambient pressure:	60 bar
Maximum operating pressure:	60 bar
Maximum outlet pressure:	17.7 bar
Type of connection:	Rp
Size of connection:	2 1/2 inch
Motor diameter:	6 inch
Minimum borehole diameter:	145 mm
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-15 .. 40 °C
Max liquid t at 0.15 m/sec:	40 °C
Electrical data:	
Motor type:	MS6000
Motor flange design:	Grundfos
Rated power - P2:	9.2 kW
Power (P2) required by pump:	9.2 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 220-230 V
Rated current:	38.5-39.0 A
Starting current:	530-550 %
Cos phi - power factor:	0.81-0.77
Rated speed:	2880-2890 rpm
Start. method:	direct-on-line
Enclosure class (IEC 34-5):	IP68







GRUNDFOS

Company name:	GOAL Ethiopia
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Phone:	0912101888
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Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Farda WSS, Somali Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
Insulation class (IEC 85):	F
Built-in motor protection:	NONE
Thermal protec:	external
Built-in temp. transmitter:	yes
Length of cable:	5 m
Power cable type:	FLAT
Motor No:	78105613
Cable number:	96300112
Windings:	Enamelled
Others:	
Minimum efficiency index, MEI ≥:	0.70
Net weight:	71.7 kg
Gross weight:	101 kg
Shipping volume:	0.232 m³
Environmental approvals:	WEEE

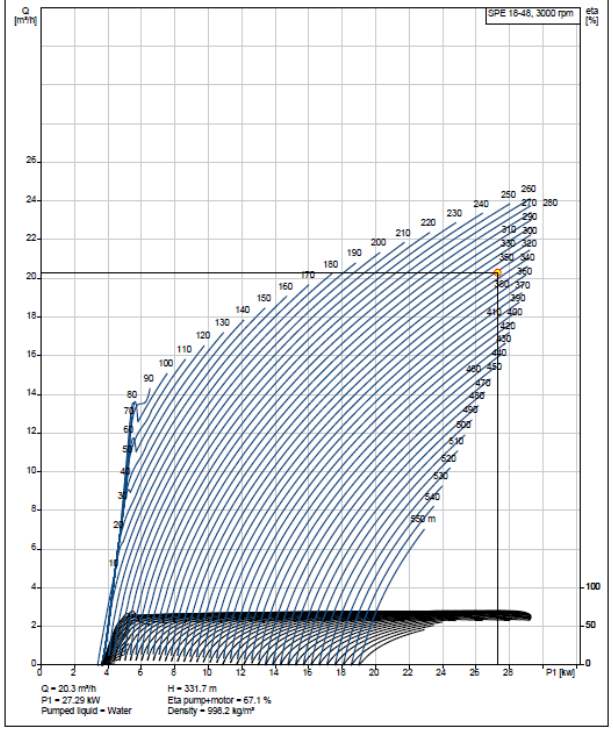
7. 3 Sidehamelef Water Supply Scheme

GRUNDFOS

Company name:	GOAL Ethiopia
Created by:	WASH Team
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Sidehamelef WSS, Afar Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

92941001 SPE 18-48



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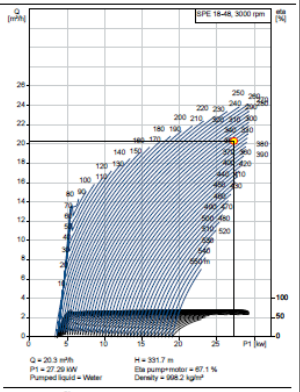
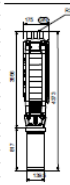
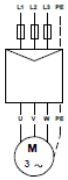
Phone:	0912101888
Email:	hkedir.yasin@gmail.com
Date:	20/10/2025

Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Sidehamelef WSS, Afar Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
General Information:	
Product name:	SPE 18-48
Product No:	92941001
EAN number:	5715121882811
Technical:	
Pump speed on which pump data are based:	3000 rpm
Rated flow:	18 m³/h
Rated head:	393 m
Stages:	48
Number of reduced-diameter impellers:	NONE
Shaft seal for motor:	SIC/SIC NBR
Approvals:	CE,EAC,UKCA,SEPRO,MOROCCO
Approvals for drinking water:	ACS,DM174
Curve tolerance:	ISO9906:2012 3B
Model:	A
Motor version:	T60
Return valve:	YES
Materials:	
Pump:	Stainless steel
	EN 1.4301
	AISI 304
Impeller:	Stainless steel
	EN 1.4301
	AISI 304
Motor:	Stainless steel
	EN 1.4301
	AISI 304
Installation:	
Maximum ambient pressure:	60 bar
Maximum outlet pressure:	55.5 bar
Type of connection:	R
Size of connection:	3 inch
Motor diameter:	6 inch
Minimum borehole diameter:	190 mm
Liquid:	
Pumped liquid:	Water
Liquid temperature range:	-15 .. 60 °C
Max liquid f at 0.15 m/sec:	60 °C
Electrical data:	
Motor type:	PM
Motor flange design:	Grundfos
Rated power - P2:	30 kW
Power (P2) required by pump:	30 kW
Mains frequency:	50 Hz
Rated voltage:	3 x 350-440 V
Motor frequency:	100 Hz
Rated current:	61.8 A
Rated speed:	1650-3000 rpm
Number of poles:	4
Method of start:	Direct-on-line (DOL)
Enclosure class (IEC 34-5):	IP68







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Project:	Water Supply System Solarization	**Client:**	GOAL
Reference Number:	Sidehamelef WSS, Afar Region	**Client Number:**	0912101888
		Contact:	Kedir Yasin

Description	Value
Insulation class (IEC 85):	F
Ex-protection standard:	NONE
Thermal protec:	external
Built-in temp. transmitter:	no
Length of cable:	5 m
Cable type:	FLAT
Number of cables:	1
Motor No:	76207720
Windings:	Enamelled
Rpm related to frequency:	3000 rpm at 100 Hz
Controls:	
Frequency converter:	VFD IPM type required
Others:	
Minimum efficiency index, MEI ≥:	0.70
Gross weight:	223 kg
Shipping volume:	0.496 m³
Recommended CUE (IP20):	99616721
Recommended Sine wave filter (IP20):	97774436
Environmental approvals:	WEEE