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TESI DI LAUREA DI PRIMO LIVELLO

Construction of a water pumping system, with renewable sources, in a UNHCR refugee camp in Central Africa

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"Engineering is the activities

that make the resources of nature available

in a form beneficial to humans

and provide systems that will perform

optimally and economically"

Llewellen Boelter, 1957

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INTRODUCTION

According to a report drawn up with the participation of 24 UN agencies, with a world population now stood at over 6 billion, some countries have already reached the limits of their water resources The Report states that, because of climate change, by 2030, nearly half the world's population will live in areas of high water stress, including Africa that will count between 75 and 250 million people subjected to such pressure. In addition, water scarcity in some arid and semi-arid will cause the displacement of a number of people of between 24 and 700 million.

The report emphasizes the close link between poverty and water resources: the number of people living on less than $ 1.25 a day, in fact, coincides approximately with the number of those who have no access to water.

The dramatic increase in the production of biofuels, including ethanol, tripled between 2000 and 2007, and the need for an amount ranging between 1,000 and 4,000 liters of water to produce one liter of biofuel, have added further pressure to existing ones. "The global energy need increase by 60% by 2030 - according to a forecast by the International Energy Agency - and the demand for energy will come from developing countries", noted Cosgrove, Coordinator of the UN "World Water Development Report", while consumption hydropower is also intended to increase by 60%.

Water and energy, are closely related to each other.

The purpose of this thesis is to illustrate how, from a set of innovative ideas, it has come create a system of extraction of water, by means of energies that require the minimal waste, in order to help in situations of major crisis.

This project wasn’t meant to be installed by specialists, but by those who are in contact with this dramatic reality, as aid workers.

CHAPTER 1

The present and the future of water

1. The growing demand for water and energy

1.1.The challenge today: Extending services to the un served

Freshwater and energy are crucial for human well-being and sustainable socio-economic development. Their essential roles in achieving progress under every category of development goal are now widely recognized. Major regional and global crises, of climate, poverty, hunger, health and finance, that threaten the livelihood of many, especially the three billion people living on less than US$2.50 per day, are interconnected through water and energy.

Worldwide, an estimated 768 million people remain without access to an improved source of water, although by some estimates, the number of people whose right to water is not satisfied could be as high as 3.5 billion. More than 1.3 billion people still lack access to electricity, and roughly 2.6 billion use solid fuels (mainly biomass) for cooking.

1.2.The challenge to come: Meeting growing demands

Demands for freshwater and energy will continue to increase significantly over the coming decades to meet the needs of growing populations and economies, changing lifestyles and evolving consumption patterns, greatly amplifying existing pressures on limited natural resources and on ecosystems. The resulting challenges will be most acute in countries undergoing accelerated transformation and rapid economic growth, or those in which a large segment of the population lacks access to modern services.

Global water demand (in terms of water withdrawals) is projected to increase by some 55% by 2050, mainly because of growing demands from manufacturing (400%), thermal electricity generation (140%) and domestic use (130%). As a result, freshwater availability will be increasingly strained over this time period, and more than 40% of the global population is projected to be living in areas of severe water stress through 2050. There is clear evidence that groundwater supplies are diminishing, with an estimated 20% of the world’s aquifers being over-exploited. Deterioration of wetlands worldwide is reducing the capacity of ecosystems to purify water.

Global energy demand is expected to grow by more than one-third over the period to 2035, with China, India and the Middle Eastern countries accounting for about 60% of the increase. Electricity demand is expected to grow by approximately 70% by 2035.

1.3.The water–energy nexus

Freshwater and energy are critical to human well-being and sustainable socio-economic development.

Globally, demand for freshwater and energy will continue to increase significantly over the coming decades to meet the needs of increasing populations, growing economies, changing lifestyles and evolving consumption patterns. This will greatly amplify pressures on limited natural resources and ecosystems.

The challenge will be most acute in countries undergoing accelerated transformation and rapid economic growth, especially where water resources are scarce or where water-related infrastructure and services are inadequate, and where modern energy services remain largely underdeveloped.

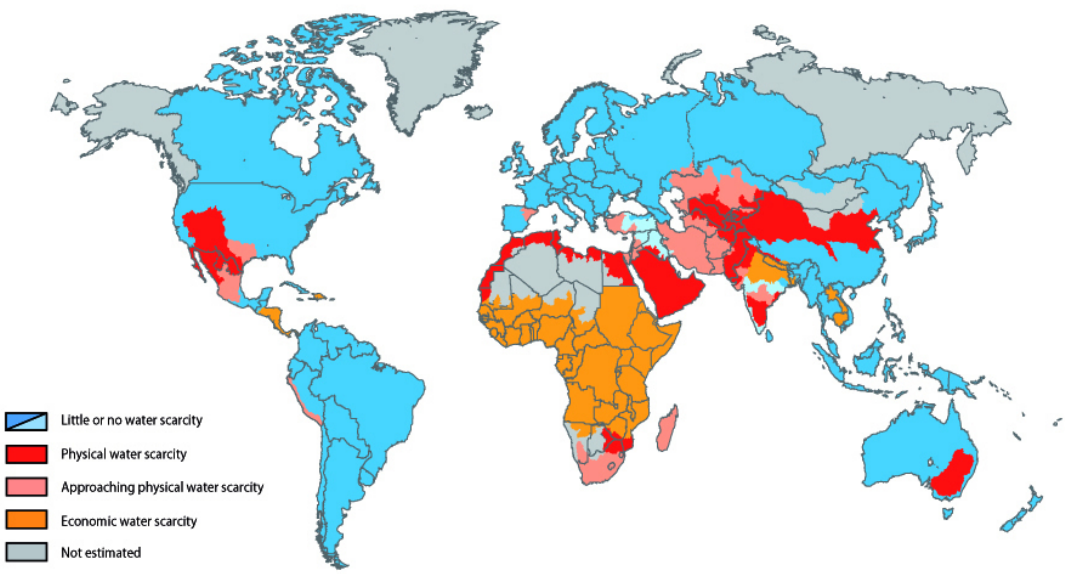


Fig.1 Areas of physical and economic water scarcity

Water and energy are strongly interlinked: water is required to produce, transport and use all forms of energy to some degree; and energy is required for the extraction, treatment and distribution of water, as well as its collection and treatment after use. Water and energy are also highly interdependent, with choices made in one domain having direct and indirect consequences on the other. The quantities of water required to produce energy are determined by the forms of energy production pursued; the allocation, use and management of freshwater resources can determine how much (or little) water is available for energy production. The choices made for water and energy can also impact other sectors, and vice versa. These interlink ages and interdependencies, along with their negative and positive externalities, lie at the heart of what has become known as the ‘water–energy nexus’.

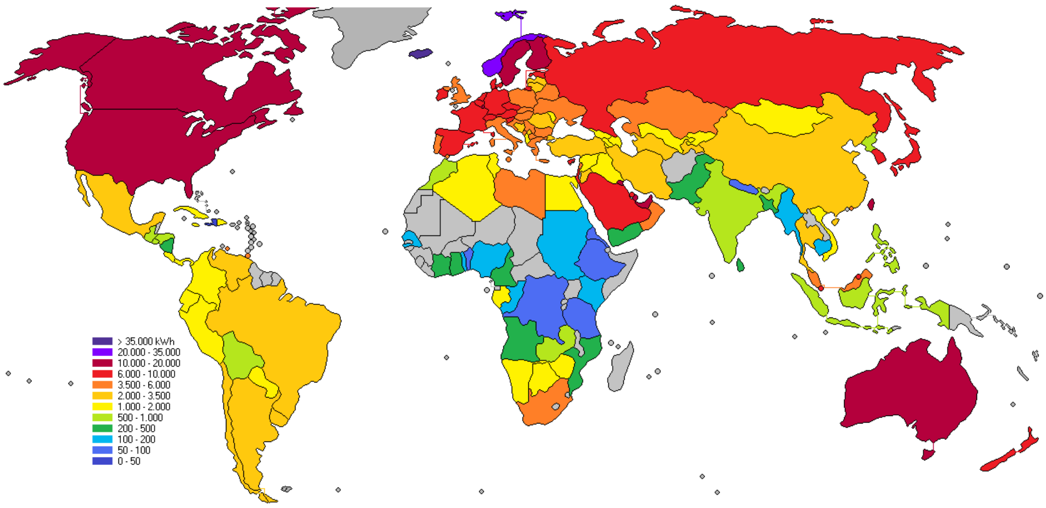


Fig.2 Worldwide Electricity Consumption

Major regional and global crises – climate, food, energy, financial – threatening the livelihood of many, including the three billion people living on less than US$2.50 per day, are interlinked through the water–energy nexus.

The same people who lack access to improved water and sanitation are also likely to lack access to electricity and rely on solid fuel for cooking.

Many people in the world still lack access to basic water and energy services. A 2013 report by WHO and UNICEF concluded that 768 million remain without access to an improved source of water and 2.5 billion people remain without access to improved sanitation, respectively. The High-level Panel on the Post-2015 Development Agenda has indicated that 2 billion people do not have access to safe water.

More than 1.3 billion people worldwide still lack access to electricity, with more than

95% of them located in sub-Saharan Africa and developing Asia, and roughly 2.6 billion people rely on the traditional use of biomass for cooking. Another estimated 400 million people rely on coal for cooking and heating purposes, which, like wood, charcoal, peat or other biomass, causes air pollution and has serious potential health implications when used in traditional stoves. It is no coincidence that the figures concerning access to water services and energy align so well; it is often the same people who are missing out on both.

Decisions made for water use and management and the production of energy can have significant, multifaceted and broad-reaching impacts on each other – often with a mix of both positive and negative repercussions. For example, drought exacerbates energy crises; energy price volatility contributes to food crises; the expansion of irrigation networks increases water and energy demand; and access to unreasonably inexpensive supplies of energy can lead to the depletion of water resources, further intensifying the impacts of droughts. Although integrated water resources management (IWRM) and the water–energy nexus have led to a growing recognition of such interdependencies, the complex direct and indirect interactions of this relationship are rarely fully appreciated, let alone incorporated into decision-making processes.

The challenge for twenty- first century governance is to take account of the multiple aspects and roles of water, and of the benefits derived from it, and to place water at the heart of decision-making.

1.4.External pressures that drive the demand for water

Alongside natural forces affecting the world's water systems, human activities interact and unite to create pressures on water resources, for which there are no substitutes. These pressures are in turn affected by a range of factors such as technological development, political, institutional and financial conditions, and climate change.

Global population is projected to reach 9.3 billion in 2050. Population growth leads to increased water demand, reflecting growing needs for drinking water, health and sanitation, as well as for energy, food and other goods and services that require water for their production and delivery. Urban areas of the world, particularly those in developing countries, are expected to absorb all this population growth, at the same time drawing in some of the rural population. This intense urbanization will increase demand for water supply, sanitation services and electricity for domestic purposes.

In the absence of sustainable resource management practices for limiting the impact of wasteful consumption and unsustainable resource use, economic development can negatively impact water supplies in terms of quality and quantity. Consumer demand

and increasing standards of living are driving increased demand for water, most notably by middle income households in developing and emerging economies through their greater demand for food, energy and other goods, the production of which can require significant quantities of water.

Water of acceptable quality and in adequate quantity is needed to meet food production demands. At the same time, food production and supply have a negative impact on the sustainability and quality of water resources.

Agriculture is the biggest water user, with irrigation accounting for 70% of global water withdrawals. With increasing demand for food, competition for water is rising. Specialized crops and livestock products often require more water (and in most cases more energy) to produce and lead to higher levels of water pollution. In the pursuit of food security, technological advancements in the agricultural sector could have significant impacts, both positive and negative, on water demand, supply and quality.

Paradoxically, technical progress aimed at improving resource use efficiency may not always serve the intended goal of decreasing resource consumption. In terms of water (as for energy), the implementation of resource- saving technologies may indeed decrease per unit consumption, but the savings are often immediately 'reinvested' to increase production and thus do not lead to an overall decrease in demand.

Technology can also create rapid, dramatic and unexpected changes (both in terms of pressures and solutions), making it the most unpredictable driver (WWAP, 2009). This is particularly true in the context of water and energy, where technologies to improve the efficiency or productivity in one domain can have an opposing effect on the other. For example, the rapid dispersion of energy technologies, such as the combination of horizontal drilling and hydraulic fracturing in areas with scarce or variable water supplies, can lead to significant localized water stress.

Climate change impacts the hydrological cycle and consequently impacts water resources. It is an additional stressor through its effects on other external pressures and thus acts as an amplifier of the already intense competition for water resources. For example, higher temperatures and an increase in the rate of evaporation may affect water supplies directly and potentially increase the water demand for agriculture and energy. Significant levels of uncertainty exist with respect to climate change projections, and these uncertainties increase greatly when focusing on local scales. Water resources management is in a difficult transition phase, trying to accommodate large uncertainties associated with climate change while struggling to implement a difficult set of principles and institutional changes associated with integrated water resources management (Stakhiv, 2011).

Government policies concerning water and water-related sectors, including agriculture and energy, as well as environmental protection, can obviously exacerbate or alleviate pressures on water resources. The challenge facing government lies in better coordinated planning and assessing trade- offs at the national level.
Investment by both the public and the private sectors will be a determining factor for the levels to which the provision of water and water-related services will increase.

1.5.Water availability

While data on precipitation – which can be measured with relative ease – are generally available for most countries, river runoff and groundwater levels are generally much more difficult and costly to monitor. As a result, trends regarding changes in the overall availability of freshwater supplies are difficult to determine in all but a few places in the world. However, it is clear that several countries face varying degrees of water scarcity, stress or vulnerability.

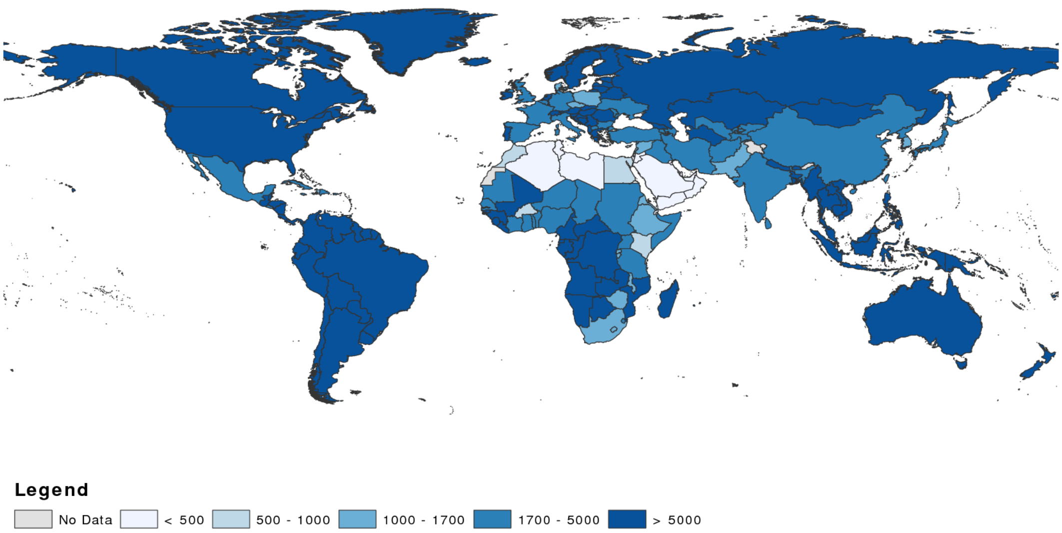


Fig.3 Total renewable water resources

In the absence of flow regulation by artificial storage infrastructure, the availability of surface water varies from place to place across days, seasons, years and decades as a function of climate variability. Climate change means past hydrological trends are no longer indicative of future water availability. According to the most recent climate projections from the Intergovernmental Panel on Climate Change (IPCC) (2008), dry regions are to a large extent expected to get drier and wet regions are expected to get wetter, and overall variability will increase. There is mounting evidence that this is

indeed happening as a result of an intensification of the water cycle and it is affecting local regional water supplies, including those available for energy production.
There is clear evidence that groundwater supplies are diminishing, with an estimated 20% of the world's aquifers being over-exploited, some massively so. Globally, the rate of groundwater abstraction is increasing by 1% to 2% per year (WWAP, 2012), adding to water stress in several areas and compromising the availability of groundwater to serve as a buffer against local supply shortages.

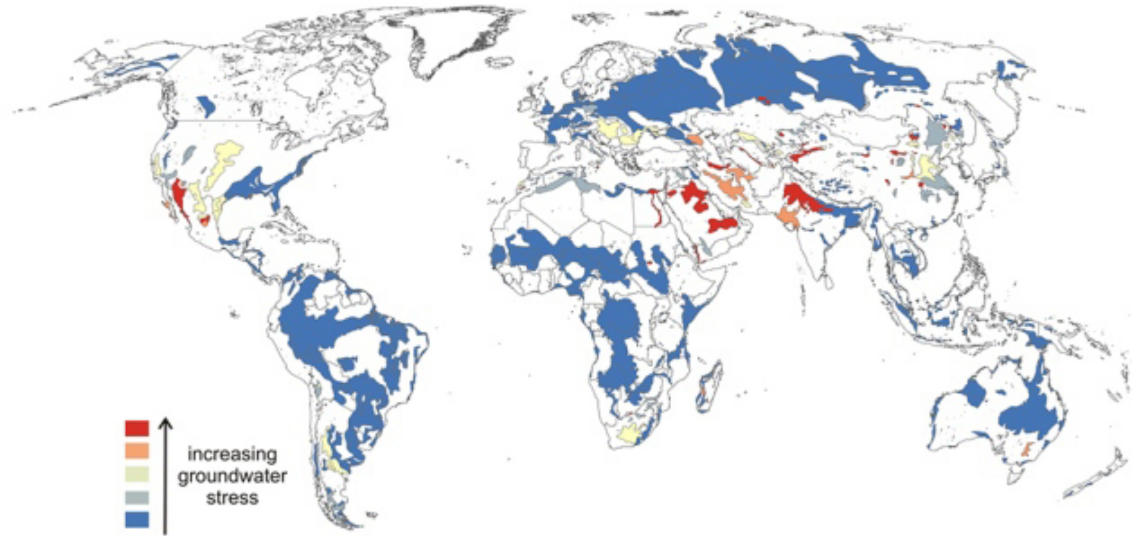


Fig.4 Water stress of aquifers important for

1.6.Electrical power generation

Approximately 90% of global power generation is water intensive. Water is used directly for hydropower generation as well as for all forms of thermal power generation schemes. Water also indirectly enables power generation through the cooling it provides for the vast majority of thermal power plants.
Increasing ambient water temperatures and changes in overall water availability create risks for the power sector. Power plants have had to shut down because of lack of water for cooling purposes or because of high water temperatures; droughts are threatening the hydropower capacity of many countries; and several reports conclude that water availability could be a constraint for the expansion of the power sector in many emerging economies.
Almost 1.3 billion people did not have access to electricity in 2010. Although access differs significantly across regions, the majority of the unserved population resides in LDCs and sub-Saharan Africa in particular.
Globally, electricity demand is expected to grow by roughly 70% by 2035.

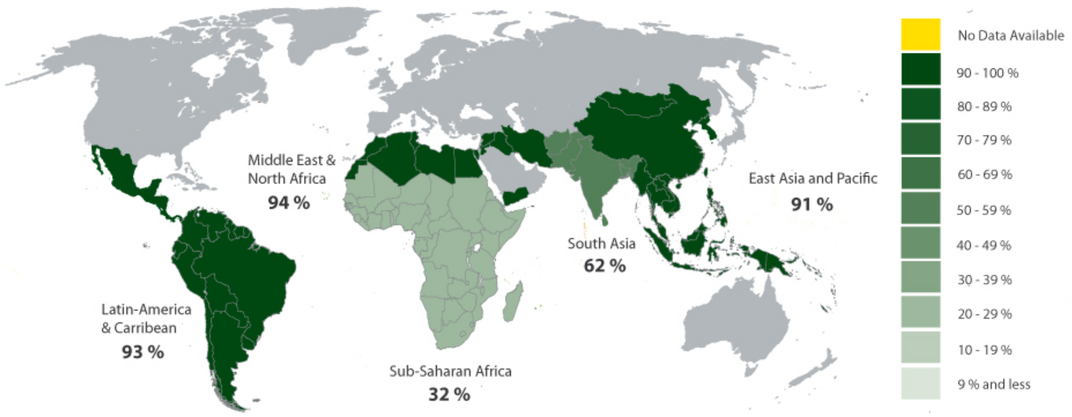


Fig.5 Access to electricity in developing countries as a percentage of the

1.7.Solar and wind power

Broadly, there are two primary categories of solar technologies. One, solar photovoltaic (PV), converts solar energy directly into electricity. Like wind, solar PV generally consumes minimal water, mainly in the production stage and during cleaning and maintenance. The other, concentrated solar power (CSP), commonly known as 'solar thermal', concentrates solar rays to produce steam to power turbines.

Using the same type of cooling system (and assuming today's generation of technology and cleaning frequency), CSP consumes approximately five times more water per unit energy than a gas-fired power plant, two times more than a coal-fired plant and 1.5 times more than a nuclear plant. There are efforts to reduce this need for water in many aspects of solar thermal systems, ranging from mirrors to fluids and thermal storage. Dry cooling is already being implemented in some CSP power plants around the world, including the Ain Beni Mathar CSP-CC power plant in Morocco.

During the period 2000–2010, electricity generation from wind grew by 27% and from solar PV by 42% per year on average. While hydropower and geothermal electricity produced at optimal sites are still among the cheapest ways of generating electricity, the levelized cost of electricity is declining for wind, solar PV, CSP and some biomass technologies. Wind and solar power are expected to continue expand rapidly over the next 20 years.

In a study comparing various sources of renewable energy in terms of environmental and social impacts, wind power turned out to be the most sustainable, mainly because of its low GHG emissions and water consumption. Wind and solar PV consume negligible amounts of water, yet they provide an intermittent service that needs to be compensated for by other sources of power (which *do* require water) to maintain load balances on larger grids. Climate information is critical for the safety and basic operations of these renewable energy sources (as well as hydropower) to ensure consistency and cost-effectiveness of power generation.

CHAPTER 2

General information on the pumps

1.The pumps

1.1.Resources

The amount of water in the world is constant. It is changing position, quality, phase, etc., but it is constant. Seawater accounts for approx. 97.5% of all water. Fresh water accounts for the remaining 2.5%. Two- thirds of the fresh water is bound as glaciers, polar ice, and snow cover. The remaining, less than 1% of all water in the world, is somehow available in different sources for mankind to use.

These sources are:

- Groundwater, shallow or deep underground aquifers of water.
- Surface water, from rivers or lakes.

In case fresh water isn't available, seawater or contaminated water is treated and used as fresh water.

1.2.Well yield and operational efficiency

Each well has specific capacity, consisting of m^3/h for each meter of drawdown of the pumping water level.

The smaller the voltage drop in power cables, the better the operational efficiency.

- Overpumping will result in deep drawdown. This gives room for oxidation, resulting in the formation of ochre which may clog well screen and pump. This means increased service costs for well regeneration and possibly reduced well life.
- Overpumping means lowering of the water level of the aquifer which can result in chemical changes and precipitation of heavy metals. Infiltration of nitrate and pesticides in the water may occur, resulting in increased expenses for water treatment.

The most common effect of overpumping of a well or aquifer is increased water consumption. This is covered by increased pump capacity or longer duty time of the groundwater pumps without increasing the catchment area or the number of wells.

1.2.1.Aquifer load

When pumping at constant capacity for several hours, the dynamic water level in the level is lowered considerably, this means that the amount of pumped water exceeds the influx. If the level drops from year to year, the quantity of pumped water should be reduced and water from other aquifers should be utilized.

1.2.2.Well load

During test pumping, the amount of pumped water is increased at fixed intervals which will result in a lowering of the dynamic water level. If the drawdown is plotted against increased pumping, a rough parabola will result.

1.2.3.Linear drawdown at moderate flows

At moderate flows, this means that typically an increased amount of water of 1 m^3/h will result in an almost linear increase in the drawdown of 10 cm/m^3.

An increase from 10 to 20 m^3/h will consequently result in a lowering of the water level of approx. 1 m an increase from 10 to 30 m^3/h will give a lowering of the water level approx. 2m.

At moderate flows, the drawdown curve will be close to linear as the increased drawdown is due to flow resistance in screen setting.

1.2.4.Parabolic drawdown at large flows

At increasingly large flows, a progressively increasing frictional resistance in screen setting and aquifer will give a parabolic drawdown curve of the second degree. This means a progressively falling water level in the well with increased pumping.

An increase from 80 to 90 m^3/h will give an additional drawdown of approx. 5m from 80 to 100 m^3/h approx. 11 m, i.e. much more than at moderate flows. The most economic well load occurs at a flow where the drawdown curve goes from linear to progressive.

If the well yield is not sufficient to meet the water requirement, even by prolonged operation, the following should be done:

- Have a specialist look at the problem.
- Have a supplementary well drilled.

Please note that rules and regulations may vary from country to country.

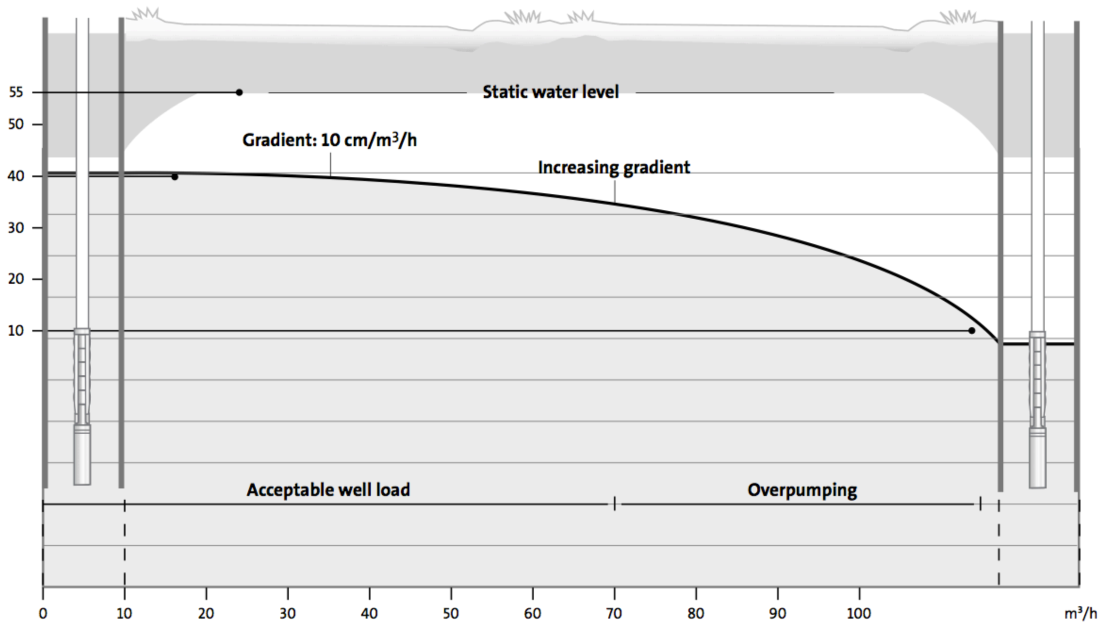


Fig.7 Dynamic water-level variations by test pumping

1.3.Freshwater supply

The supply of fresh water for drinking water, irrigation and various industrial applications is the most common application for submersible pumps. Pumps of many different designs, and made from many different materials can be used with a reasonably good result here.

However, in some livestock watering and irrigation applications, the water quality is so poor that pumps made of standard stainless steel material do not survive very long. In these cases a pump in EN 1.4401/ AISI 316 or EN 1.4539/AISI 904L stainless steel can be used.

Estimates for a timeframe for carrying out several activities include:

- The recommended service periods caused by wear and tear.
- The expected service repair cost.
- The loss of efficiency in the service periods.

Submersible pumps are subject to wear just like all other pumps. Unfortunately, their placement underground makes viewing this wear difficult.

The diagram here enables you to calculate the following:

- When should I service my submersible pump?
- How much efficiency has been lost since the last service?
- How much will a renovation cost (approximately)?

A number of things must be determined beforehand. They include:

- Water velocity at the component you wish to test
- The conditions related to pump material and the pumping environment
- The presence or absence of solids and aggressive carbon dioxide.

The chart below is useful as a guideline to determine the service intervals for submersible pumps. Follow the steps below:

1 Note point 1 on Curve A. Pump material and media conditions are as indicated in the legend.

2 Draw a parallel line to the right. Impeller material loss is approx. 0.18mm per 1,000 hours of operation (point 2).

3 Follow the parallel line until you reach the differentiation line that corresponds to aggressive CO_2 and component material. Note the conditions in the example (point 3).

4 Drop directly down (90°). The aggressive CO_2 con- tent has increased the material loss to 0.25mm. Note the salinity level of the water (point 4). Draw a horizontal line through this point; follow it to the left and read the results.

5 Recommended service intervals for your pump: After every 6,000 hours of operation (point 5).

6 Loss of efficiency: Approx. 18% (point 6).

7 Estimated cost of renovating the pump: 75% of the price of a new pump (point7).

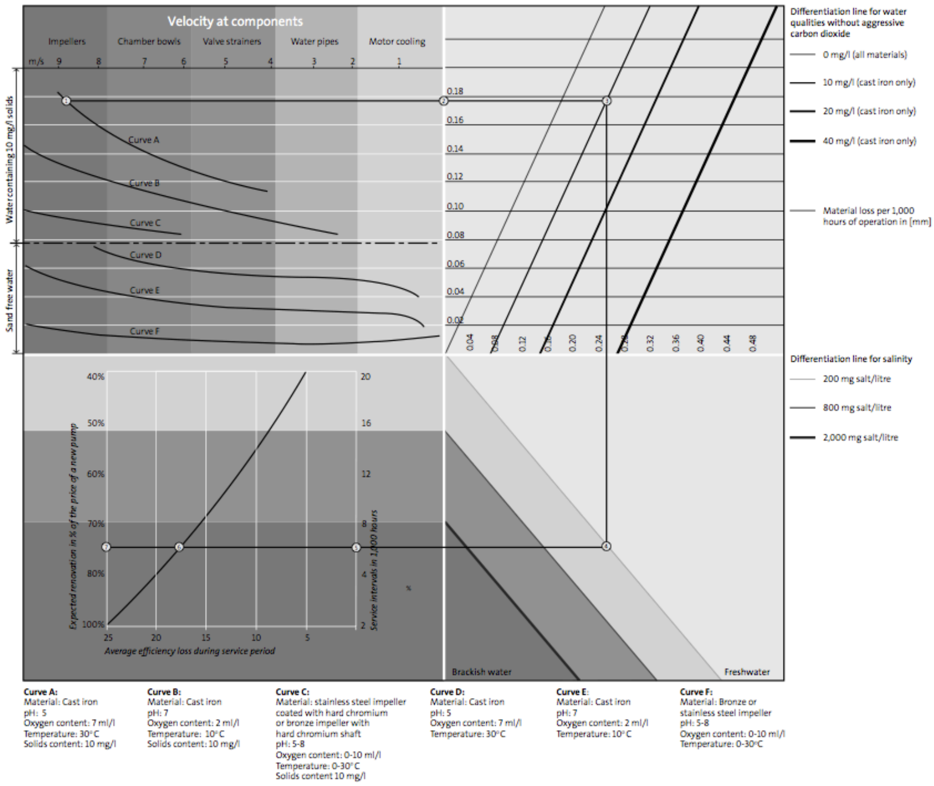


Fig.8 Recommended service intervals for submersible pumps

1.4.Dewatering

Dewatering in connection with mining applications or construction sites is often done with submersible pumps. The water quality determines whether the pump can be a standard EN 1.4301 (AISI 304) pump, or if it has to be stainless steel of a higher grade. When reducing groundwater levels, the aquifer is exposed to oxygen, creating rust and other adhesive solids. They are washed out and penetrates the well screen, then passing on to the pump inlet.

To maintain pump performance, the duty point is to be selected to the right of the best efficiency point.

The higher the velocity inside the pump, the longer intervals between service can be. A high velocity prevents the pump from clogging up and losing performance. In very adhesive mixtures, it can be beneficial to remove the non-return valve from the pump to enhance back- wash of the pump and pipes after pump stoppage.

1.5.Mining

The water quality is very often aggressive in relation to the submersible pump, and high-grade stainless steel is recommendable.

One way of doing this is described in the following:

1 Find the chloride corrosion potential (chloride equivalent = ppm chloride – (0.5 x ppm acid)).

2 With this chloride equivalent, use fig. 10 to find the minimum pH value acceptable for EN 1.4539 (AISI 904L) stainless steel. If the illustration indicates that there is a high corrosion risk, epoxy coating of the motor is required.

3 Most power cable materials and junction kits are unstable in acidic waters.

4 Install the pump centering device on your pump or motor to ensure perfect cooling of the entire surface.

If corrosion occurs, install ion-exchange units to bring down the chloride content, or install zinc an odes as cathodic protection.

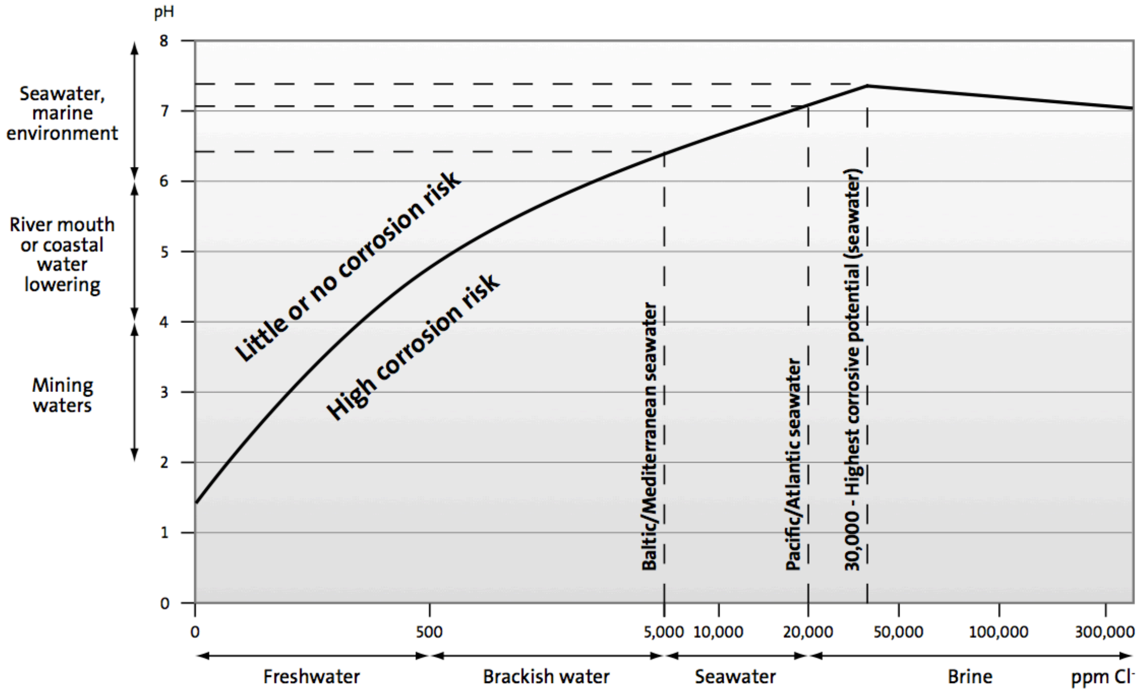


Fig.9 Corrosion due to chlorides

1.6.Corrosive water (seawater)

Submersible pumps are used for many seawater applications like fish farming, offshore industrial applications and water supply for reverse osmosis-treated water.

SP pumps are available in different materials and corrosion classes depending on the application of the pumps. The combination of salinity and temperature is not favorable to stainless steel, and must always be taken into consideration.

A good way to compare the corrosion resistance of stainless steel, is to compare its resistance against pitting.

$$PRE = (\% Cr) + (3.3 \times \%Mo)$$

For comparison to other stainless steel types, which contain Nitrogen (N) the formula looks like below:

$$PREN=(\%Cr)+(3.3x\%Mo)+(16x\%N)$$

In addition to temperature and salinity, the corrosion temperature is affected by the presence of other metals, acids and biological activity.

The elastomer components in the pump may also be damaged by poor water quality, for example if the water has a high content of hydrocarbons and many chemicals. In such cases the standard elastomer can be replaced by FKM rubber.

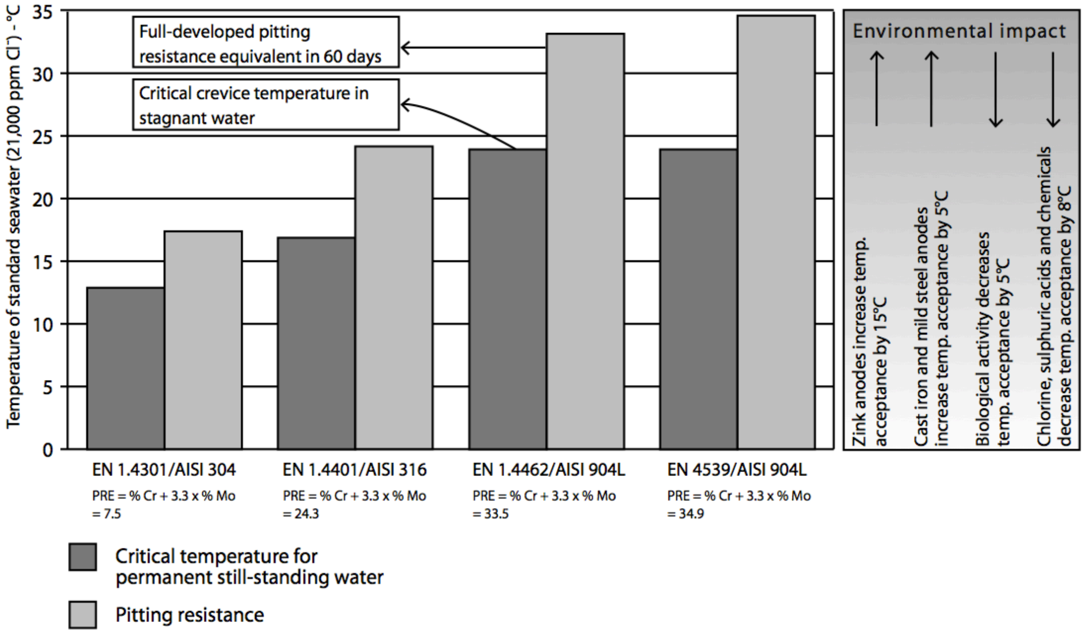


Fig.10 Corrosion resistance of seawater-submerged pumps

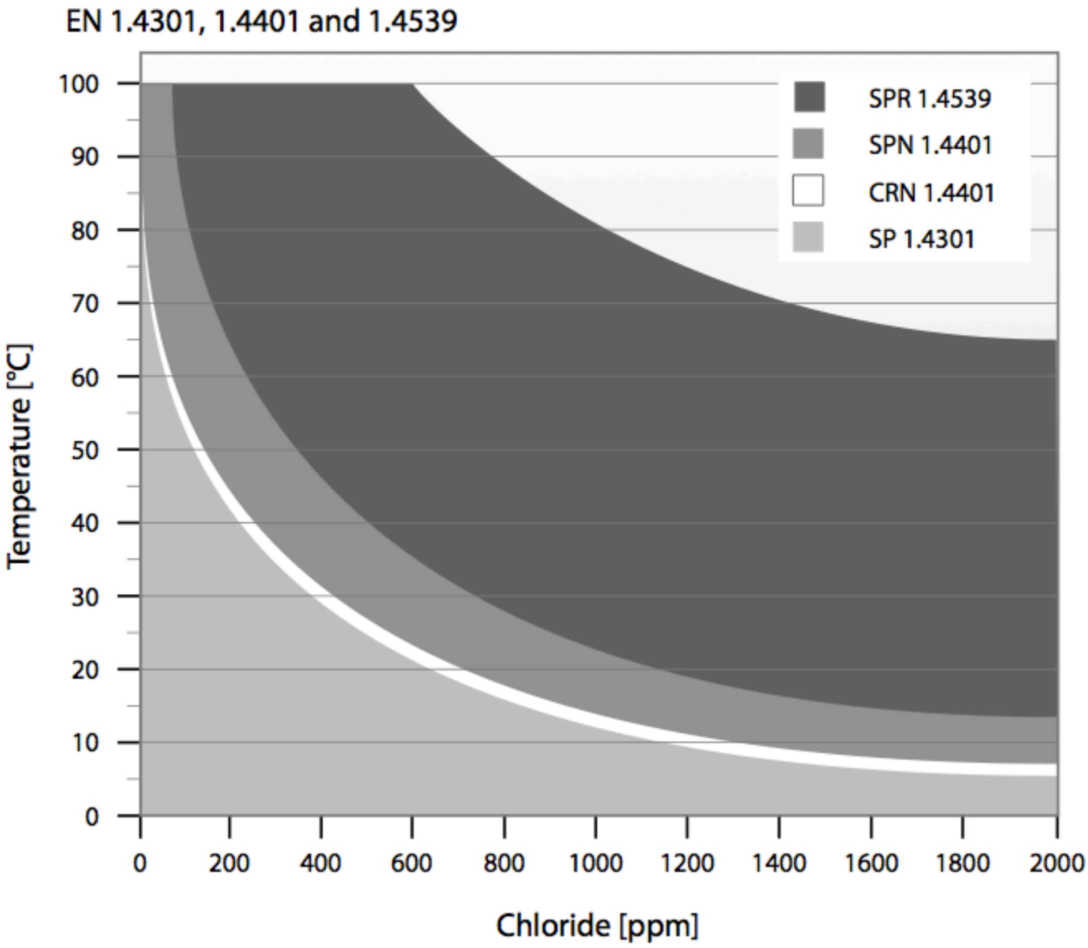


Fig.11 Corrosion diagram

1.7.Hot water and geothermal water

Groundwater close to the surface will be close to the average annual air temperature in the region. Going deeper, the temperature will increase 2 to 3 °C for each 100m of well depth, in the absence of geothermal influence.

In geothermal areas, this increase might be as high as 5 to 15 °C for each 100m of well depth. Going deep for water requires temperature-resistant elastomers, electrical cables, connections and motors.

Hot groundwater is used for general heating applications, and for leisure in many areas, especially those with volcanic activity.

The motor liquid of your submersible motor has a higher boiling point temperature than the well water prevents the motor bearing lubrication from being reduced due to the lower viscosity of the liquid. The motor must be submerged deeper to raise the boiling temperature as the table below.

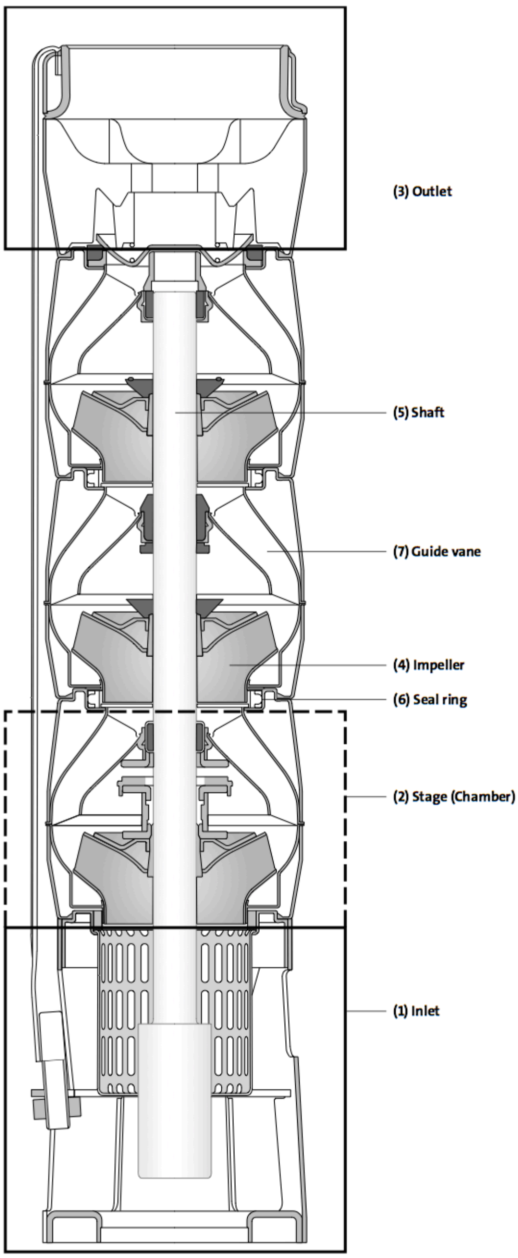
Gas in the water is to be expected where there is geothermal activity. To avoid reduced pump capacity in a geothermal water installation where air is mixed in, it’s recommends to install the pump a minimum of 50m below the dynamic water level.

2.Pump principle

The SP pump is a centrifugal pump, where the principle is to transform mechanical energy from the motor to velocity energy in the pumped medium, and thereby creating a pressure difference between the pump inlet and outlet.

The pump consists in principle of an inlet (1), a number of pump stages (2) and a pump outlet (3). Each pump stage creates a pressure difference, and the more pressure needed, the more stages need to be included.

A pump stage includes an impeller (4) where the impeller blades transfer energy to the water in terms of a velocity and pressure increase. Each impeller is fixed to the pump shaft (5) by means of a spline connection or split-cone connection.



For submersible pumps, there are two general design types: • radial • semi-axial.

The radial design is characterized by a large difference between the impeller inlet and the outlet diameter of the impeller. It is suitable where a high head is required.

The semi-axial design is more suitable for larger flow pumps.

A seal ring (6) between the impeller inlet and the chamber ensures that any back flow is limited. The chamber includes a guide vane (7), which leads the water to the next stage. It also converts the dynamic pressure into static pressure.

In addition to guiding the water into the first impellers, the pump inlet is also the interconnector for the motor. For larger pumps and motors there are various standards depending on the supplier. The pump inlet must be designed in order to deliver the water to the first impeller in the best possible way and thereby minimize the losses as much as possible. For some radial designed impellers, the inlet also includes a priming screw (fastened on the pump shaft) in order to secure the water intake and avoid dry running of the pump.

The pump outlet normally includes a non-return valve, which prevents back flow in the riser pipe, when the pump is stopped. Several benefits are obtained such as:

- Energy loss due to back flush is avoided.
- A counter pressure is always ensured, when start ing up the pump again. This is essential in order to make certain that pump performance remains on the pump curve.
- Damage in the pump due to water hammering is limited.
- Contamination of the groundwater due to back flush is limited.

2.1.Motor types, general description

A submersible motor consists of a motor body and a motor cable. The cable is detachable in a plug system. The cable is dimensioned for submerged use in order to minimize the spatial requirement along the pump. The motor cable is connected to the drop cable above the pump by use of a cable termination kit. The drop cable used to raise and lower the pump.

2.1.1.Canned

In a canned motor, the windings are enamel wire (like in standard surface motors) hermetically sealed from the surroundings and filled with embedding material in order to withhold the windings and at the same time increase heat transfer. These motors have a journal bearing system, consisting of upper and lower radial bearings as well as up thrust and down thrust bearings. Thrust and journal bearings run hydro dynamically in the water-based motor liquid.

2.1.2.Wet wound (rewind able)

Wet wound motors have a special water resistance wire, and a watertight joint between the windings and the motor cable. The joint is always inside the motor, and no plug system is available. The motor liquid mainly consists of clean water.

The liquid circulates around the entire motor, transferring heat away from windings and rotor and lubricating the bearing systems.

2.1.3. Oil-filled

An oil-filled motor is equipped with an impregnated standard surface motor winding. Transformer oil is filled into the motor and used as lubricant and cooling. The oil can be mineral or vegetable oil with high insulation resistance. The motor cable splice is typically made inside the motor as in a wet wound motors, few have plug systems. Oil-filled motors incorporate a ball-bearing system.

2.1.4. Single-phase motors

There are several versions of single-phase motors. They all have their distinctive advantages and disadvantages. Most types need a capacitor and some other accessories, which is built into a starter box. The starter box is dedicated for starting a given motor at specific voltage and frequency.

2.1.5. Permanent-split capacitor (PSC) motors

Simple and reliable, PSC motors have a run-type capacitor included in the circuit. The capacitor size is a compromise between adding starting torque and ensuring a high efficiency during operation.

2.1.6. Capacitor-start/induction-run (CSIR) motor

The start-up capacitor boosts the torque during start up. Then it is disconnected by a switch. The CSIR motor type is typically used for smaller kW ratings.

Pros: Locked-rotor torque.

Cons: Noisy operation (true single-phase), relay needed to cut out the start-up capacitor.

2.1.7. Capacitor-start/capacitor-run (CSCR) motors

This motor type has both a starting capacitor to boost starting torque, and a run capacitor (PSC). This ensures a smooth operation and a good efficiency. The motor type combines the advantages of both of the above types.

Pros: Good starting torque, high efficiency.

Cons: Price of control box.

2.1.8. Resistance-start/induction-run (RSIR) motor

This motor has a relay built directly into the motor winding. The relay disconnects the starting phase when the motor is running.

Pros: No need for capacitors (no control box), ease of installation.

Cons: Limited starting torque, limited kW ratings (only through 1.1 kW).

2.1.9.Terminology; 2-wire and 3-wire motors

The terminology is related to the number of wires needed in the installation excluding earth cable. 2- wire motors must be supplied by three leads: phase, neutral end earth. 3-wire motors must be supplied by four leads: phase, neutral, point between start- and run winding in motor + earth cable.

2-wire motors:

- PSC motors a capacitor is built into the motor.
- RSIR.

3-wire motors:

- PSC motors if there is a capacitor in the starter box on the ground.
- CSIR motors
- CSCR motors

2.1.10.Motor derating

Motor derating is where there are special requirements to the motor, such as high water temperature, voltage tolerances outside of acceptable interval, or voltage unbalance. All of these situations stress the motor winding more than what it has been designed for.

The simplest solution is to use an oversized motor, typically not more two output sizes above the required output. The result is an extended lifetime, but the efficiency is not optimal, since the motor never operates at its optimal duty point. The power factor is normally be low due to the partial load on the construction.

A better solution is to have a motor specially wound in a larger stack length. Due to the increased surface, the electrical data and cooling capability are improved. These motors are designed for higher temperatures, wider voltage tolerances, etc. Also, the efficiency of a standard motor is maintained or even increased.

2.2.Frequency converters

Frequency converters are the ideal device to control the performance of the pump, by adjusting the speed of the motor. It is therefore also an ideal starter type, both for reduction of the locked-rotor current and for reduction of pressure surges.

Note: a low frequency produces slow impeller rotation, reducing pump performance.

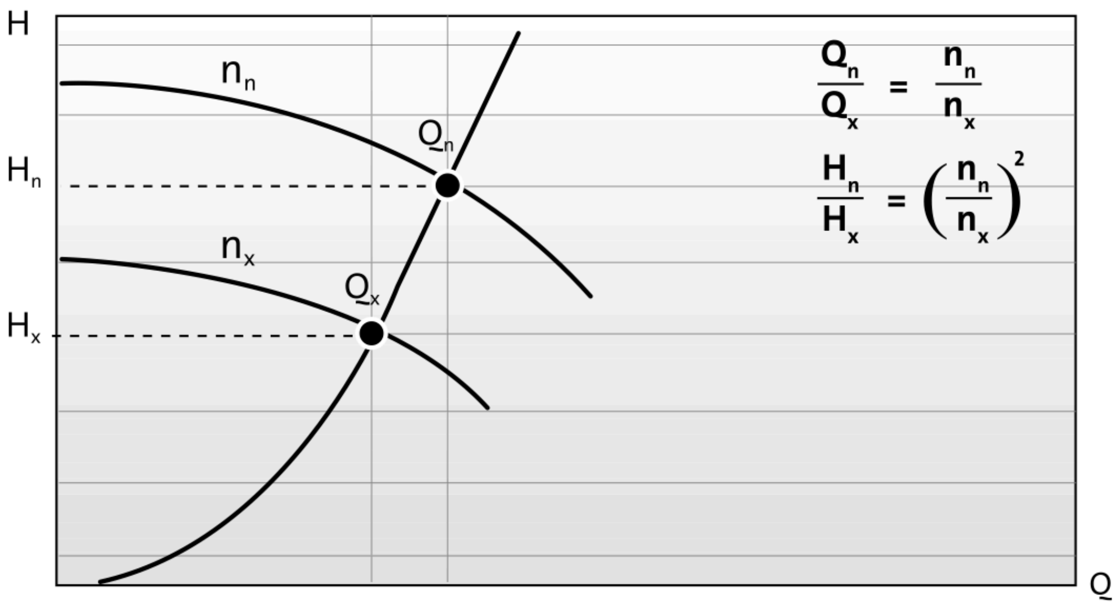


Fig.12 Pump performance with different frequencies

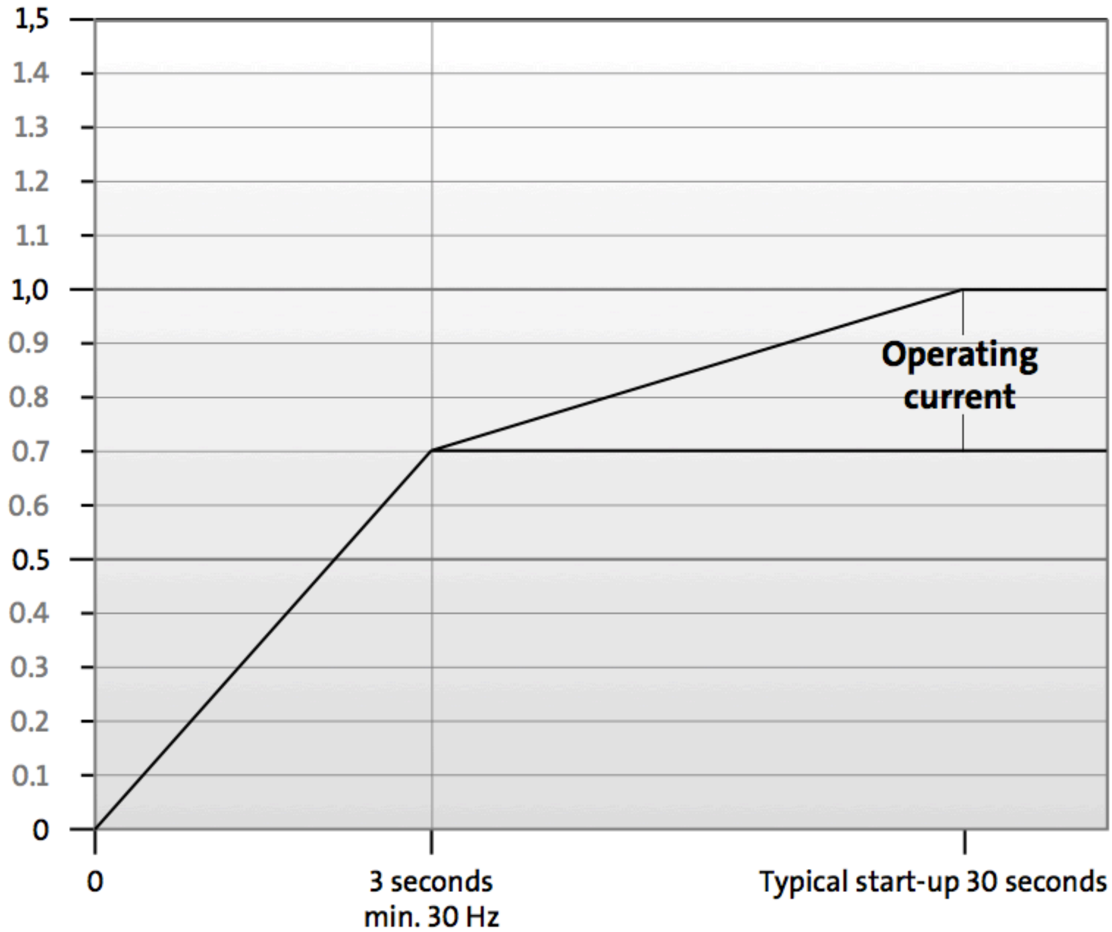


Fig. 13 Current flow by frequency converter starting

Frequency converters are used in connection with operation at variable performance. There are several types of frequency converters on the market, each having its own characteristics. A brief overview is presented here:

- The simplest frequency converter is based on a voltage frequency curve. This converter is some- times called an U/f or V/f converter. They calculate the actual output voltage from the frequency, without taking the actual load into consideration. Different U/f or V/f curves can be chosen to optimize for the actual application. Pumps will typically use the Variable Torque curve. These frequency converters are the cheapest on the market, and are often employed.

The next step is the Vector-Controlled frequency converter. This frequency converter uses a model of the motor, and calculates the output voltage based on several parameters including the actual load. This gives higher performance in controlling the shaft of the motor, such as a higher accuracy of min-1, torque, etc. These drives are more expensive than the U/f based drives, and are typically used for industrial applications. However, they are also used in systems where instabilities often occur. The more precise way of controlling the shaft normally eliminates the problems caused by an instable pump, The vector control led drives usually have a higher efficiency, or an automatic energy optimizer function.

The output section of a frequency converter can be made in two different ways: either with six or with 12 transistors.

This can also be referred to as 6-pulse and 12-pulse inverters. Six transistors are the most commonly found solution, as it is the cheapest and the simplest way of creating an output stage. To reduce the stress on motor insulation and increase the control performance, the 12-transistor output stage was introduced. 12-transistor operation is typically combined with advanced controls that are based on flux models of the motor. The advantage of a 12-transistor solution usually includes improved control at low speeds and less stress on the motor. A 12-pulse frequency converter lies in the expensive range of frequency converters.

The main selection factor for combining frequency converter and pump is the full load amps including the overload factor. The frequency converter should be chosen so it can deliver the required current all the time. For example, if the motor requires 9.7 A, chose a frequency converter with and output cur- rent at 9.7 A or higher.

2.3.Wells and well conditions

A well is a hole, stretching from the surface of the earth to the underground aquifer, where the ground- water is found. The depth of the well may vary from a few meters to several hundred meters.

Wells are typically drilled with special drilling equipment, which is able to penetrate the various layers of the ground, such as sand, clay, bedrock, etc. Inside the drilled hole a casing (pipe) is typically installed, which prevents the well from collapsing around the pump.

Below the casing, and in line with the aquifer, is another ‘casing’ with fine slots. This is the well screen, where the slots allows the water to enter the well. It holds back sand and larger particles trying to enter the well.

To improve the filtering function, the borehole typically features a diameter that is 2-3” larger than the casing. A fine sand gravel pack filter is placed be- tween the casing and the aquifer. Some casings come with a pre-made gravel pack filter. Made correctly, this filtering method prevents sand and silt from entering the well.

Recommendations on sand content varies from one country to another.

The National Ground Water Association (NGWA) in USA recommends the following sand limits in well water:

- 1.10 mg/l in water used for food and beverage processing.
- 2.50 mg/l in water for private homes, institutions and industries.
- 3.10mg/l in water for sprinkler irrigation, industrial evaporative cooling and other applications where a moderate content of solids is not particularly harmful.
- 4.15mg/l in water for flood irrigation.

If the concentration of sand exceeds 15 mg/l, so much material will be removed from the well that the aquifer and the strata above it may collapse and thus shorten the life of the well.

If the well water has a sand content higher than 50 mg/l, a special pump and motor is available on request.

Before the well can be put into operation, it must be developed. A new well will always produce some sand and silt in the beginning, and well development is the process of pumping a new well free from sand and silt. It is done by pumping with a very high flow, which draws the fine particles in the aquifer into the filter of the well. This slowly makes the filter more effective. After approximately one day of pumping, the well is normally pumped clean, and is ready for normal operation.

The pump used for well development wears out relatively quickly because of the high sand content, and it should therefore always be replaced with a new pump as soon as the well does not produce any more sand.

The pump must always be installed above the screen area of the casing. In this way, you ensure that the water is forced past the motor, providing adequate motor cooling. If the pump cannot be installed above the screen filter, a cooling sleeve is always recommended to create the necessary flow along the motor for proper cooling.

2.3.1.Well diameter

In general, the larger the diameter of the pump, the higher the efficiency.

However, the pump must be able to fit into the well, and a certain minimum clearance between motor surface and internal well diameter is therefore al- ways required.

In a correctly designed well, with the well screen be- low the pump and motor, the water has to pass the clearance between the casing and the motor. This will cause a friction loss.

If at the same time the motor is eccentric positioned in the well with one side against the casing, the single sided inlet of water into the pump will create turbulences and affect the performance of the pump.

In wells with well screen area positioned above the pump, the water has to pass the clearance be- tween the pump and the casing, which will cause a friction loss.

If at the same time the pump is positioned eccentric against the casing, it will restrict the inflow at half of the suction interconnected. This single sided U-turn of inlet water will create inlet turbulence affecting the function of the pump.

2.3.2.Well yield

Many pumps are able to over pump the well, which means it will run dry in a short period of time. The pump must be selected with due respect to the capacity of the well, so over pumping is avoided. We therefore recommend monitoring the water table.

Several problems may arise from over pumping:

- Dry running and pump damage.
- Infiltration of non-potable water, i.e. seawater
- Chemical reactions in the well when oxygen contacts the dry aquifer.

Excessive drawdown also triggers increased power consumption, since it must be compensated with additional pump lift.

2.3.3.Water temperature

The limiting factor is the submersible motor and cooling of the motor. Cooling is the key to a long life- time of the motor.

Submersible motors installed at maximum acceptable water temperature must be cooled at a flow rate of at least 0.15 m/s, which ensures tubular flow. This velocity is ensured by not letting the pump flow drop below a certain minimum value.

In large diameter wells or tanks it may be necessary to use a flow sleeve to increase the flow along the motor to minimum 0.15 m/s.

3.Multipower Pumps

3.1.4HS pumps

4HS MultiPower pumps (4HS MP), powered by renewable energy sources, are a new range coming from the 4HS pumps with built-in inverter.

4HS MultiPower pumps may be powered by AC or DC with a wide range of operating voltage (90 - 265 VAC / 90 - 340 VDC).

This means that 4HS MP pumps can be connected to solar panels, batteries, wind turbine and diesel generator.

A special software algorithm allows for adjusting the hydraulic performance to each source and to the available power while maximizing the pumped water.

3.2.All the advantages of built-in electronics

The built-in electronics inside the motor avoids the use of shielded cables and output filters and it is the ideal solution for any application in remote locations without surveillance and climatically adverse.

In fact, in the traditional solutions, the solar inverter is placed above ground and, being exposed to the weather, could suffer of:

- Overheating
- Water infiltration
- Thermal shock
- Damaging by animals or people

4HS MultiPower pumps do not need of any external electronic component; it is just enough to connect the pump cable to the power source and start to extract water.

The built-in electronic is directly cooled by the water flow; the operating temperature of the electronic components is so low as to ensure considerably longer a life than a on-surface inverter affected by high temperature, humidity, dust and solar radiation.

3.3.4HS technology

4HS pumps are entirely made of stainless steel AISI 304 to grant a long life of the components.

Pump, motor and hydraulic components can be easily disassembled to have simple maintenance and replacement operations.

3.3.1.Motor

- Resined and incapsulated stator made of stainless steel AISI 304.
- Water cooled rotor.
- Kingsbury thrust bearing.

Built-in inverter module (MINT)

- Completely filled of resin.
- Removable power cable.

3.3.2.Centrifugal pump

Impellers and diffusers in stainless steel. Built-in no return valve. The helical rotor pump The 4HS "H" pumps are equipped with a helical rotor that moves within a double helix rubber stator. The rotor is made of AISI 316 stainless steel and coated with a hard chrome surface. During operation, the rotor moves on the rubber surface and it' s lubricated by the pumped water. The flow rate is directly proportional to pump speed while the pressure supplied is kept al- most constant. In this way, unlike a centrifugal pump, the helical rotor pump provides high head even at low rpm, ensuring water on surface even with very low available power or low irradiation. In addition, the helical rotor pumps feature higher hydraulic efficiency than centrifugal pumps of same flow. This saves in the number of PV panels necessary for the application.

3.3.3.Permanent magnets motor

The 4HS "H" pumps are equipped with AC permanent magnets motor.

The rotor uses Neodymium magnets coated with thin layers of Copper and Nickel, to ensure, in addition to superior magnetic performance, greater reliability and durability.

High motor efficiency and high starting torque make pump moving even in low light conditions.

The integrated inverter module realizes the conversion from DC energy into useful electrical energy to drive the engine efficiently and, at the same time, adjusts the pump speed in relation to available irradiation, maximizing the power extracted (MPPT).

Over-current, over-temperature, lack of water protections are integrated on-board.

In the application with solar panel, the function MPPT (Maximum Power Point Tracking) maximizes the input power for various conditions of radiation and temperature.

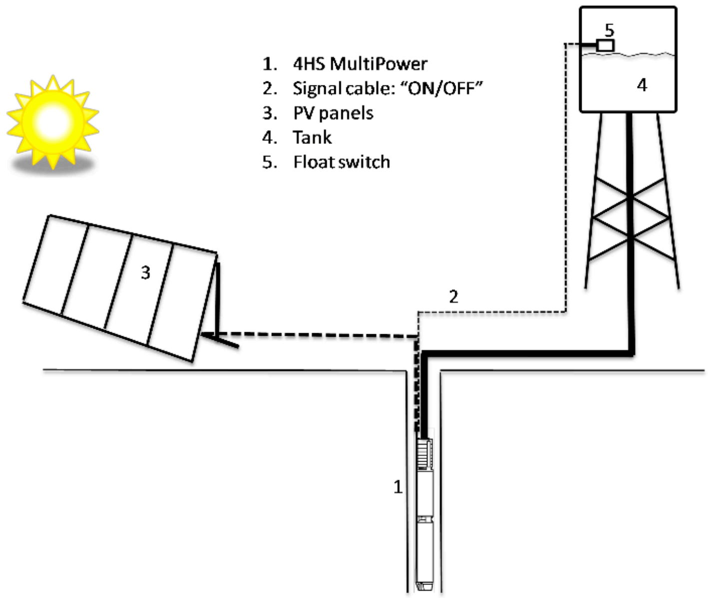
When radiation grows, pump increases the rotation speed as well as the water flow.

When radiation decreases (presence of clouds or different hours of the day), pumps reduces the speed and thus the water flow but still provide water until the radiation falls below the minimum value to ensure the operation.

3.4.Installation

4HS MultiPower pump can be installed with CM Multi-Power control module or without it, so becoming a “plug and pump” system.

If the CM MultiPower control module is not used, signal cables can be used to control pump ON/OFF the connecting, for example, a float switch.



All the protections against overload, overvoltage and dry running are integrated into the on board inverter.

If the signal cables are connected to the CM MultiPower control module, it is possible to:

- Control the electric parameters (current, power, voltage).
- Record and store all the alarms related to the working hours.
- Connect a pressure or a flow sensor to control the pump performances.
- Connect a pressure or float switch.
- Provide an alarm digital output for remote control.

Integrated on board protection

Protections against overvoltage, overload and dry running are integrated into the pump electronic circuit.

Electronic protection against dry running avoids the use of the probes.

For the correct selection of a 4HS MultiPower pump to be used in a photovoltaic (PV) system, it is necessary to know:

- Desired daily water quantity.
- Total head (static + dynamic).
- Installation location.
- Working period (seasonal or year).

  Based on location it is possible to get from maps and tables (available in the web) the following values.
- Average daily radiation per year, minimum and maximum.
- Optimal tilt angle of the photovoltaic panels.

Starting from daily radiation could be considered the number of hours with $1kW/m^2$, standard value to which PV panels performances are referred.

Dividing the required water quantity by the hours, nominal pump is calculated and, in addition to the required head, the right pump could be selected.

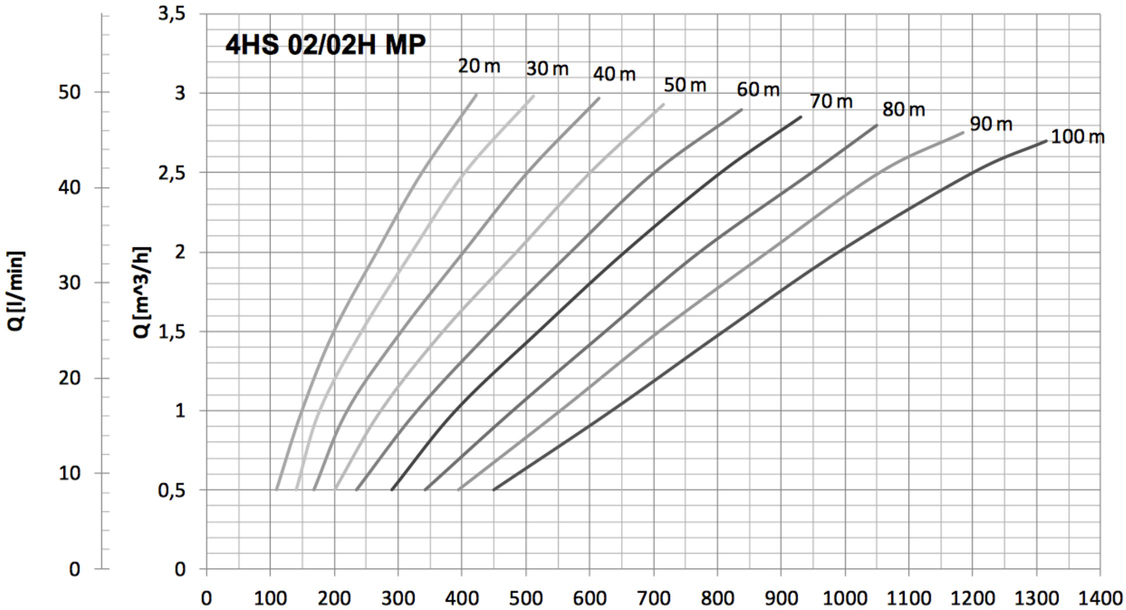
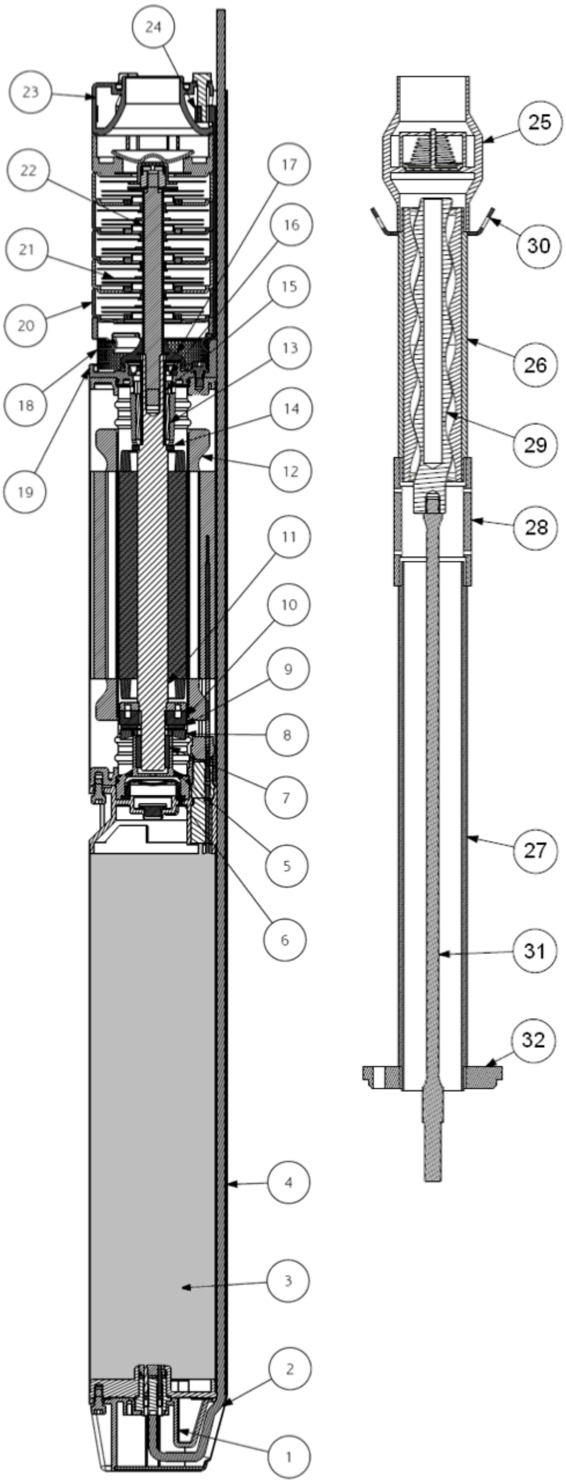


Fig. 14 Performance



REF	DESCRIPTION	MATERIAL
1	Power supply bracket	AISI 304
2	Cable for drinking water applications	ACS-KTM-WRAS compliant
3	MINT: Electronic Integrated Module	
4	Cable guard	AISI 304
5	Lower thrust bearing	AISI 304
6	Rubber diaphragm	EPDM
7	Lower carbon bush	CTI25
8	Tilting disc	AISI 304
9	Pads	AISI420j
10	Carbon disc	CTI25
11	Shaft with rotor	AISI 431
12	Canned type stator	AISI 304
13	Upper carbon bush	CTI25
14	Upper thrust bearing	Teflon
15	Ceramized sleeve	AISI 304 + Ceramic
16	Lip seal	FKM
17	Rotating sandguard	NBR
18	Pump filter	AISI 304
19	Pump bracket	AISI 304
	Centrifugal pump	
20	Diffusers	AISI 304
21	Impellers	AISI 304
22	Pump shaft	AISI 304
23	Discharge	AISI 304
24	Straps	AISI 304
	Helicoidal rotor pump	
25	No-return valve	AISI 304
26	Helicoidal stator	EPDM + AISI 304
27	Supporting pipe	AISI 304
28	Junction	AISI 304
29	Helicoidal rotor	AISI 316 cromed
30	Safety hook	AISI 304
31	Flexible shaft	AISI 316
32	Pump adaptor	AISI 304

Fig.15 Pumps

CHAPTER 4

4.Freight transport

4.1.Ship transport

Sea transport has been the largest carrier of freight throughout recorded history. Transport by water is cheaper than transport by air.

Ship transport can be over any distance by boat, ship, sailboat or barge, over oceans and lakes, through canals or along rivers. Shipping may be for commerce, recreation or the military purpose. Virtually any material can be moved by water; however, water transport becomes impractical when material delivery is highly time-critical.

Containerization revolutionized ship transport starting in the 1970s. "General cargo" includes goods packaged in boxes, cases, pallets, and barrels.

4.2.Cargo

The word cargo refers in particular to goods or produce being conveyed – generally for commercial gain – by ship, boat, or aircraft, although the term is now often extended to cover all types of freight, including that carried by train, van, truck, or intermodal container. The term cargo is also used in case of goods in the cold-chain, because the perishable inventory is always in transit towards a final end-use, even when it is held in cold storage or other similar climate-controlled facility.

Multi-modal container units, designed as reusable carriers to facilitate unit load handling of the goods contained, are also referred to as cargo, specially by shipping lines and logistics operators. Similarly, aircraft ULD boxes are also documented as cargo, with associated packing list of the items contained within. When empty containers are shipped each unit is documented as a cargo and when goods are stored within, the contents are termed as containerized cargo.

4.2.1.Marine

Seaport terminals handle a wide range of maritime cargo.

- Automobiles are handled at many ports and are usually carried on specialized roll-on/roll-off ships.
- Break bulk cargo is typically material stacked on pallets and lifted into and out of the hold of a vessel by cranes on the dock or aboard the ship itself. The volume of break bulk cargo has declined dramatically worldwide as containerization has grown. One way to secure break bulk and freight in intermodal containers is by using Dunnage Bags.
- Bulk cargo, such as salt, oil, tallow, and scrap metal, is usually defined as

commodities that are neither on pallets nor in containers. Bulk cargoes are not handled as individual pieces, the way heavy-lift and project cargoes are. Alumina, grain, gypsum, logs, and wood chips, for instance, are bulk cargoes.

- Neo-bulk cargo comprises individual units that are counted as they are loaded and unloaded, in contrast to bulk cargo that is not counted, but that are not containerized.
- Containers are the largest and fastest growing cargo category at most ports worldwide. Containerized cargo includes everything from auto parts, machinery and manufacturing components to shoes and toys to frozen meat and seafood.

Project cargo and the heavy lift cargo include items like manufacturing equipment, air conditioners, factory components, generators, wind turbines, military equipment, and almost any other oversized or overweight cargo which is too big or too heavy to fit into a container.

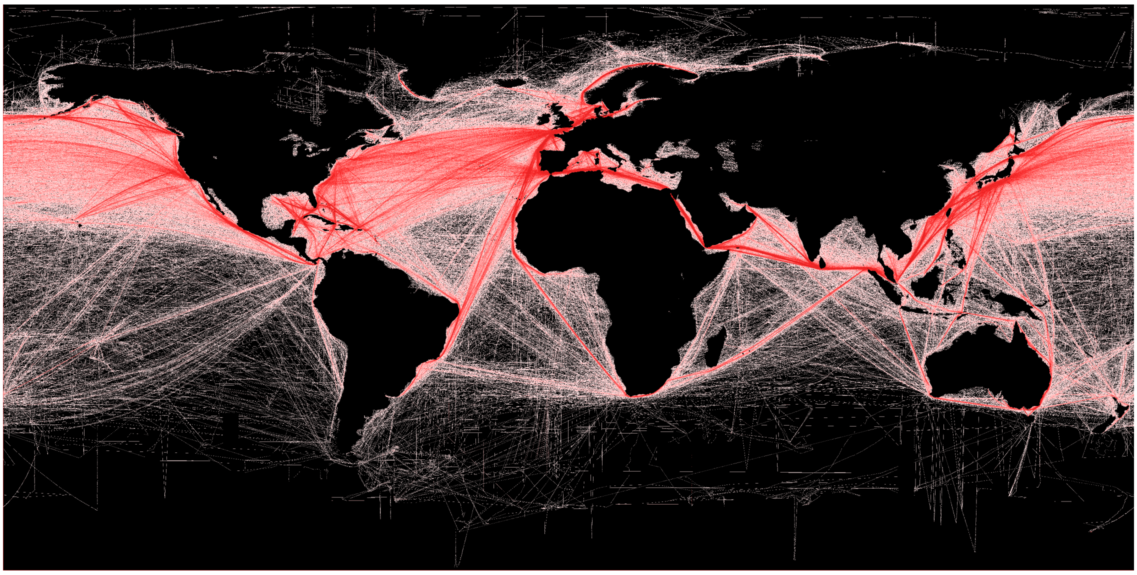


Fig.16 Sea routes

4.2.2.Air

Air cargo, commonly known as air freight, is collected by firms from shippers and delivered to customers. Eventually manufacturers started designing aircraft for other types of freight as well.

There are many commercial aircraft suitable for carrying cargo such as the Boeing 747 and the bigger An-124, which was purposely built for easy conversion into a cargo aircraft. Such large aircraft employ quick-loading containers known as unit load devices (ULDs), much like containerized cargo ships.

4.2.3.Train

Trains are capable of transporting a large number of containers that come from shipping ports. Trains are also used for the transportation of cement, grain, steel, wood and coal. They are used because they can carry a large amount and generally have a direct route to the destination. Under the right circumstances, freight transport by rail is more economic and energy efficient than by road, especially when carried in bulk or over long distances.

The main disadvantage of rail freight is its lack of flexibility. For this reason, rail has lost much of the freight business to road transport. Rail freight is often subject to transshipment costs, since it must be transferred from one mode of transportation to another. Practices such as containerization aim at minimizing these costs. When transporting point-to-point bulk loads such as cement or grain, with specialized bulk handling facilities at the rail sidings, rail mode of transport remains the most convenient and preferred option.

Many governments are currently trying to encourage shippers to use trains more often because of the environmental benefits.

4.2.4.Road

Many firms transport all types of cargo by road. Delivering everything from letters to houses to cargo containers, these firms offer fast, sometimes same-day, delivery.

Retailers and manufacturers of all kinds rely upon delivery trucks, be they full size semi trucks or smaller delivery vans. These smaller road haulage companies constantly strive for the best routes and prices to ship out their products. Indeed, the level of commercial freight transported by smaller businesses is often a good barometer of healthy economic development as it's these types of vehicles that move and transport literally anything, including couriers transporting parcel and mail. You can see the different types and weights of vehicles that are used to move cargo around.

4.3.Shipment categories

Freight is usually organized into various shipment categories before it is transported. An item's category is determined by:

- the type of item being carried.
- how large the shipment is, in terms of both item size and quantity.
- how long the item for delivery will be in transit.

Shipments are typically categorized as household goods, express, parcel, and freight shipments:

- Household goods (HHG) include furniture, art and similar items.
- Very small business or personal items like envelopes are considered overnight express or express letter shipments. These shipments are rarely over a few kilograms or pounds and almost always travel in the carrier's own packaging. Express shipments almost always travel some distance by air. An envelope may go coast to coast in the United States overnight or it may take several days, depending on the service options and prices chosen by the shipper.
- Larger items like small boxes are considered *parcels* or *ground shipments*. These shipments are rarely over 50 kg (110 lb), with no single piece of the shipment weighing more than about 70 kg (154 lb). Parcel shipments are always boxed, sometimes in the shipper's packaging and sometimes in carrier-provided packaging. Service levels are again variable but most ground shipments will move about 800 to 1,100 kilometres (497 to 684 mi) per day. Depending on the origin of the package, it can travel from coast to coast in the United States in about four days. Parcel shipments rarely travel by air and typically move via road and rail. Parcels represent the majority of business-to-consumer shipments.
- Beyond express, and parcel shipments, movements are termed freight shipments.

4.3.1.Less than truckload (LTL) cargo

It's the first category of freight shipment, which represents the majority of freight shipments and the majority of business-to-business (B2B) shipments. LTL shipments are also often referred to as motor freight and the carriers involved are referred to as motor carriers.

LTL shipments range from 50 to 7,000 kg (110 to 15,430 lb), being less than 2.5 to 8.5 m (8 ft 2.4 in to 27 ft 10.6 in) the majority of times. The average single piece of LTL freight is 600 kg (1,323 lb) and the size of a standard pallet. Long freight and/or large freight are subject to extreme length and cubic capacity surcharges.

Trailers used in LTL can range from 28 to 53 ft (8.53 to 16.15 m). The standard for city deliveries is usually 14.63 m (48 ft). In tight and residential environments the 8.53 m (28 ft) trailer is used the most.

The shipments are usually palletized, stretch and packaged for a mixed-freight environment. Unlike express or parcel, LTL shippers must provide their own packaging, as carriers do not provide any packaging supplies or assistance. However, circumstances may require crating or other substantial packaging.

4.3.2.Air freight shipments

They are very similar to LTL shipments in terms of size and packaging requirements. However, air freight or air cargo shipments typically need to move at much faster speeds than 800 km or 497 mi per hour. Air shipments may be booked directly with the carriers, through brokers or with online marketplace services. While shipments move faster than standard LTL, air shipments don't always actually move by air.

4.3.3.Shipping costs

Truckload (TL) carriers usually charge a rate per kilometer or mile. The rate varies depending on the distance, geographic location of the delivery, items being shipped, equipment type required, and service times required. TL shipments usually receive a variety of surcharges very similar to those described for LTL shipments above. In the TL market, there are thousands more small carriers than in the LTL market. Therefore, the use of transportation intermediaries or brokers is extremely common.

4.3.4.Security concerns

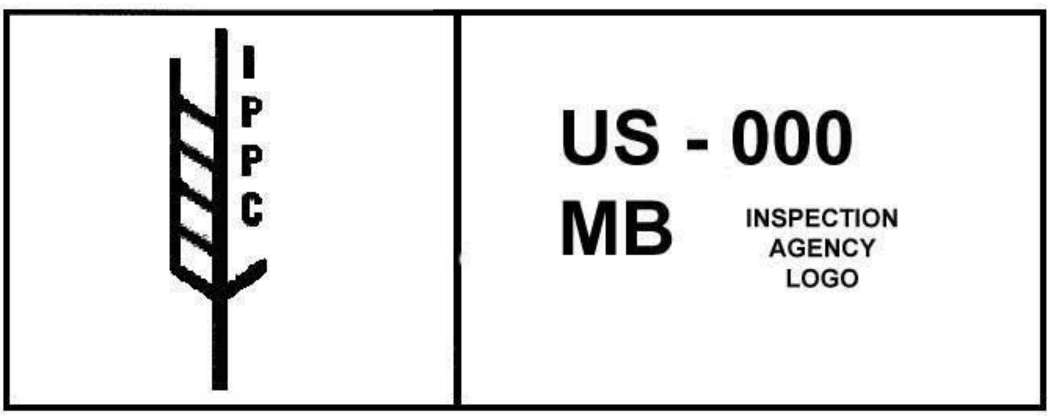
Governments are very concerned with the shipment of cargo, as it may bring security risks to a country. Therefore, many governments have enacted rules and regulations, administered by a customs agency, to the handling of cargo to minimize risks of terrorism and other crime. Governments are particularly concerned with cargo entering through a country's borders.

4.3.5.Stabilization

There are many different ways and materials available to stabilize and secure cargo in various modes of transport. Conventional load securing methods and materials such as steel strapping and plastic/wood blocking & bracing have been used for decades and are still widely used. Present load securing methods offer several other options including polyester strapping and lashing, synthetic webbings and dunnage bags, also known as air bags or inflatable bags.

<u>4.4.Ispm 15</u>

International Standards For Phytosanitary Measures No. 15 (ISPM 15) is an International Phytosanitary Measure developed by the International Plant Protection Convention (IPPC) that directly addresses the need to treat wood materials of a thickness greater than 6mm, used to ship products between countries. Its main purpose is to prevent the international transport and spread of disease and insects that could negatively affect plants or ecosystems. ISPM 15 affects all wood packaging material (pallets, crates, dunnages, etc.) requiring that they be debarked and then heat treated or fumigated with methyl bromide and stamped or branded, with a mark of compliance. Products exempt from the ISPM 15 are made from alternative material, like paper, plastic or wood panel products (i.e. OSB, hardboard, and plywood).



- IPPC certification symbol.
- XX: represents the two letter ISO country code or ISO 3166-1 alpha-2 code (e.g. AU for Australia, US for United States, NZ for New Zealand, GB for United Kingdom).
- 00: represents the unique certification number issued to NPPOs (regulating agencies that oversee the individual wood packaging manufacturers). Inclusion of this certification number ensures that the wood packaging material can be traced back to the NPPO/auditing agency.
- 1111: represents the unique certification number issued to the treatment provider and/or manufacturer. Inclusion of this certification number ensures that the wood packaging material can be traced back to the treatment provider and/or the manufacturer.
- YY: represents the treatment applied to the wood packaging material:

  HT is the code for heat treatment to a minimum of 56°C (133°F) for a minimum of 30 minutes.
- MB is the code for methyl bromide fumigation.
- DUN: represents the code for when the solid wood material is used for dunnage. The "DUN" Dunnage code is not applied to manufactured wood packaging, only loose lumber/timbers to help secure products being shipped.

The ISPM 15 compliant stamp may include further information as producers and suppliers may choose to include additional information for identification purposes.

4.5.Fumigation

Fumigation is a method of pest control that completely fills an area with gaseous pesticides, or fumigants, to suffocate or poison the pests within. It is used to control pests in buildings (structural fumigation), soil, grain, and produce, and is also used during processing of goods to be imported or exported to prevent transfer of exotic organisms. This method also affects the structure itself, affecting pests that inhabit the physical structure, such as wood borers and dry wood termites.

4.5.1.Process

Fumigation generally involves the following phases: First the area intended to be fumigated is usually covered to create a sealed environment; next the fumigant is released into the space to be fumigated; then, the space is held for a set period while the fumigant gas percolates through the space and acts on and kills any infestation in the product, next the space is ventilated so that the poisonous gases are allowed to escape from the space, and render it safe for humans to enter. If successful, the fumigated area is now safe and pest free.

4.5.2.Safety

Fumigation is a hazardous operation. Generally it is a legal requirement that the operator who carries out the fumigation operation holds official certification to perform the fumigation as the chemicals used are toxic to most forms of life, including humans.

Post operation ventilation of the area is a critical safety aspect of fumigation. It is important to distinguish between the pack or source of the fumigant gas and the environment which has been fumigated. While the fumigant pack may be safe and spent, the space will still hold the fumigant gas until it has been ventilated.

CHAPTER 5

The solar water system

WATERBOX is a complete “plug&play” solution for the most simple installation of a solar borehole pumping system.

5.Introduction to the system

5.1.The 4hs pump: the heart

The 4hs pump is a multisource submersible, all in one pump. The pumping unit includes the centrifugal pump, the motor and the inverter.
Each component of the pumping unit has been developed for ease of use and absolute minimum maintenance requirements:
Only stainless steel AISI 304 for maximum durability.

- Water rotor motor conceived with respect for the environment.
- Built in inverter for a maintenance free system even in situations of temperature fluctuations.
- Only one cable for both DC and AC power supply.
- High water flow performance ratio.
- Developed and made completely in Vicenza (Italy).

5.2.Photovoltaic modules: the engine

- Designed specifically for 4hs pumps. We developed and made solar modules with the right output voltage and current to work in perfect harmony with our multisource pumps.
- Strong alloy profiles for high mechanical resistance and 4 mm tempered, shock resistant glass.
- Dimensions and weight designed to be transported easily in any van or pickup.

5.3.Tree mounting system: the idea

A patented Italian idea to mount the PV modules free-standing with just a hammer. No need for any machinery or special tools and no need for special ballast to allow for high wind effect.
We just looked at nature!... And we fix our structure in the same way a tree fixes itself: with the roots.

5.4.Forget the tools

Inside the WATERBOX you will find all the tools and accessories necessary to assemble the system:

- DC cables
- IP65 switch with supplementary input for existing AC generators (if any)
- Clean, contaminants free cable certified for drinking water uses
- Waterproofing connection kit
- Fast DC and AC connectors
- Tool kit with hammer, keys, screwdrivers

5.5.Fixing system

The modules are fixed by arrays of 6 modules each. The anchoring system of modules, doesn't follow the traditional systems with anchor pile, but by a tree system, which guarantees the same results. A pole anchor is generally inserted to a depth of about 1600mm to ensure the necessary resistance. The system with inserts oblique inside of the ground avoids excavation and casting in the installation of the system and a simple and complete disposal at end of life. The maximum depth of fixing is around 60 cm depth, thus allowing the installation even in shallow soil.

Doesn't require the use of machinery for the fixing, but a simple hammer, which is included in the shipment.

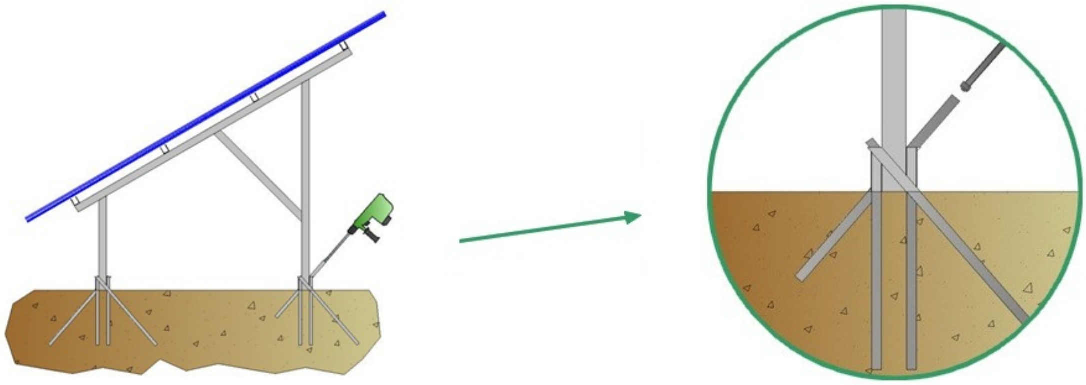


Fig.17 Fixing

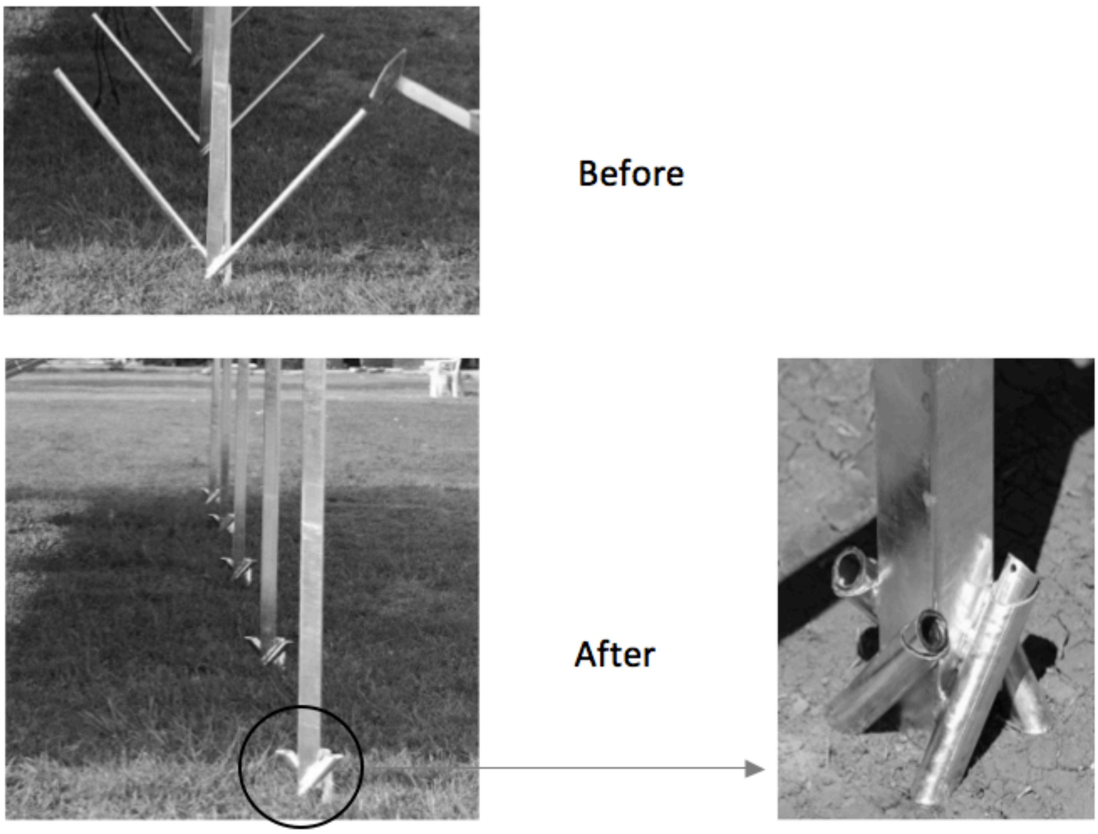


Fig.18 Fixing

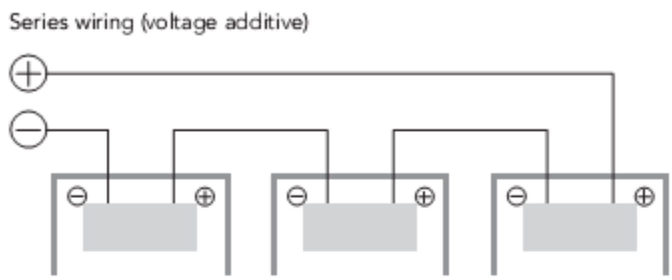
5.6.The modules

PV modules are designed to meet the requirements for the standards IEC 61215 and IEC 61730, application class A. Modules are made following IEC 61730-1 and IEC 61730-2 and within this application class are considered to meet the requirements for safety class II.

PV modules can produce current and voltage when exposed to light of any intensity. Electrical current increases with higher light intensity. DC voltage of 30 Volts or higher is potentially lethal. Contacting the live circuitry of a PV system operating under light can result in lethal electric shock.

PV modules are provided with two (2) stranded, sunlight resistant output cables that are terminated with PV connectors ready for most installations. The positive (+) terminal has a female connector while the negative (-) terminal has a male connector. The module wiring is intended for series connections [i.e. female (+) to male (-) interconnections]; The minimum wire size should be 4mm2.

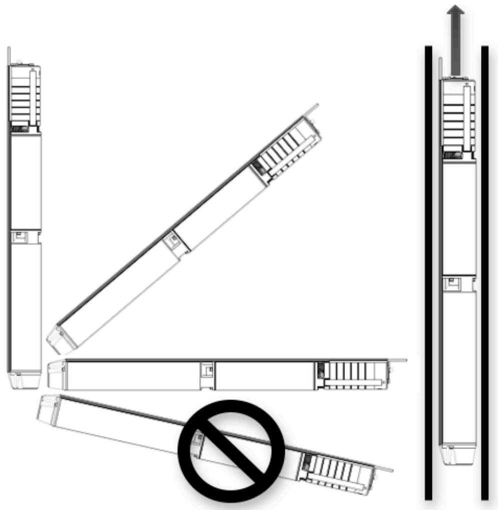
All the modules must be connected in series as showed in the below image

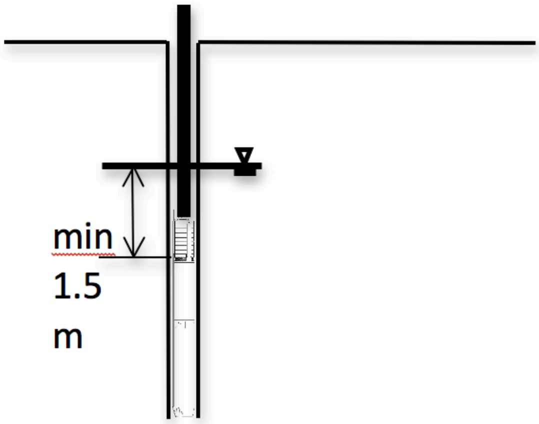


5.7.The pump

Pump can be installed both vertically and horizontally, but the outlet should never be below the horizontal line. Minimum head of 10% than max pump head must be granted.

If the pump is not installed in a well, to grant a proper cooling, a cooling sleeve must be used; doing so the minimum speed of the pumped liquid has to be granted.





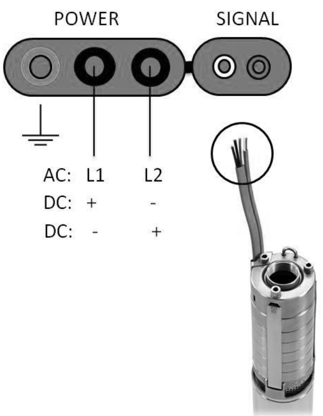
To reduce noise transmission it is advised to use plastic pipes.

The pump must always be secured in the well through a special rope attached to loop on the pump head.

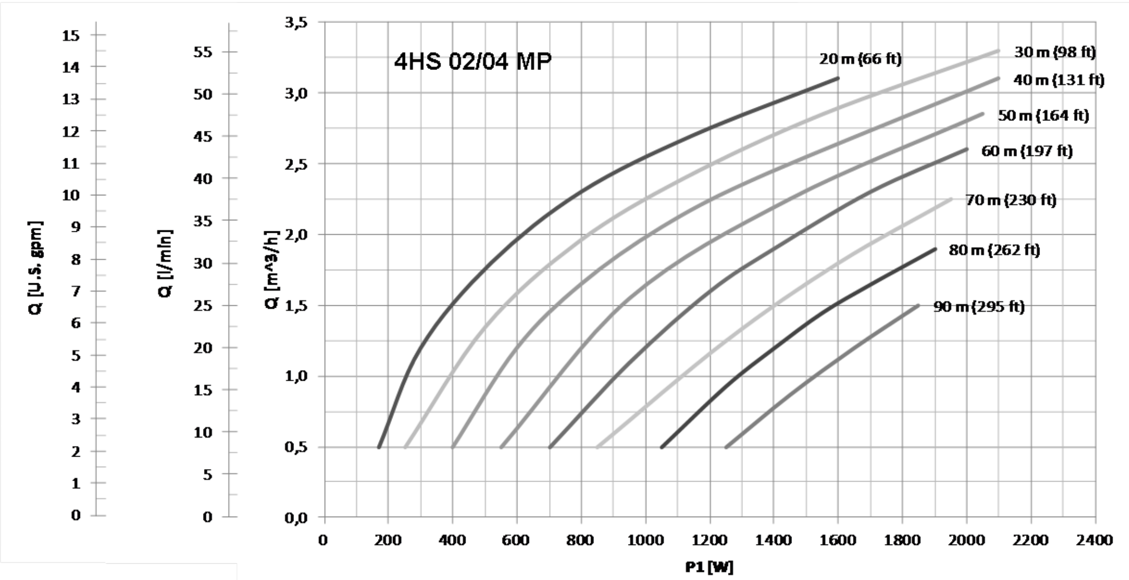
It is recommended not to drop the pump in the well by using the electric cable, its integrity must be preserved in all operations. In this regard it is recommended to fix the cable on cable support or on the pipe.

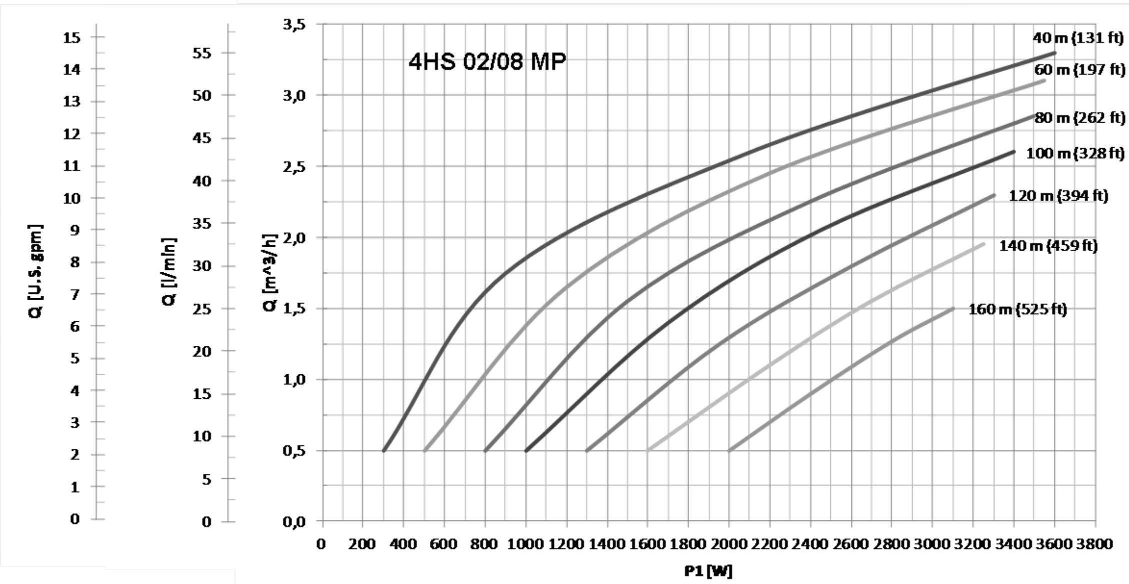
During operation the pump suction must always remains at least 1.5 meters below the dynamic water level.

4HS Multipower are equipped, in their standard configuration, with 2,5 meter flat cable length.

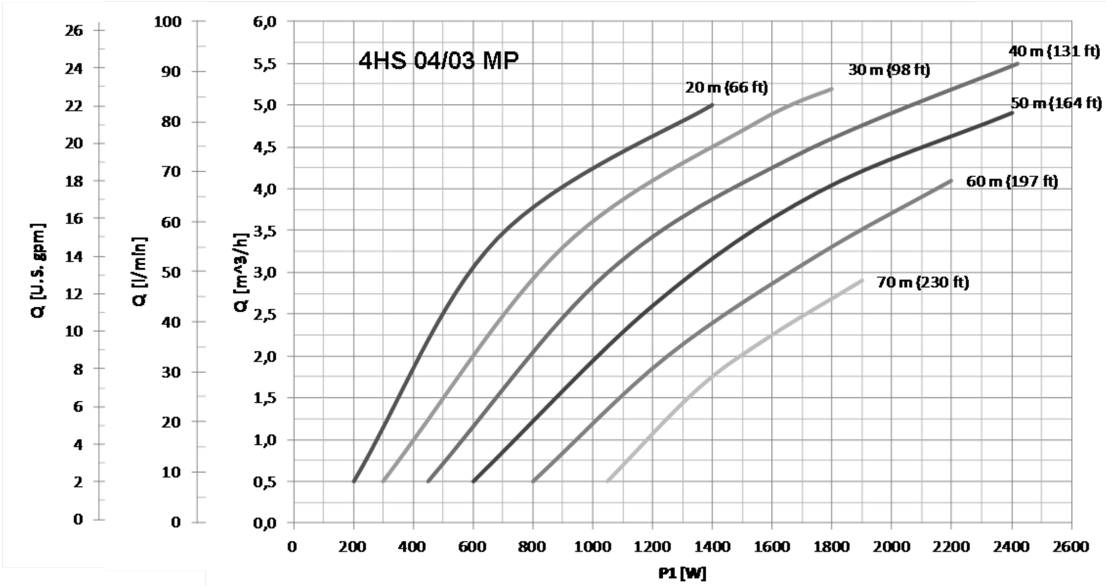


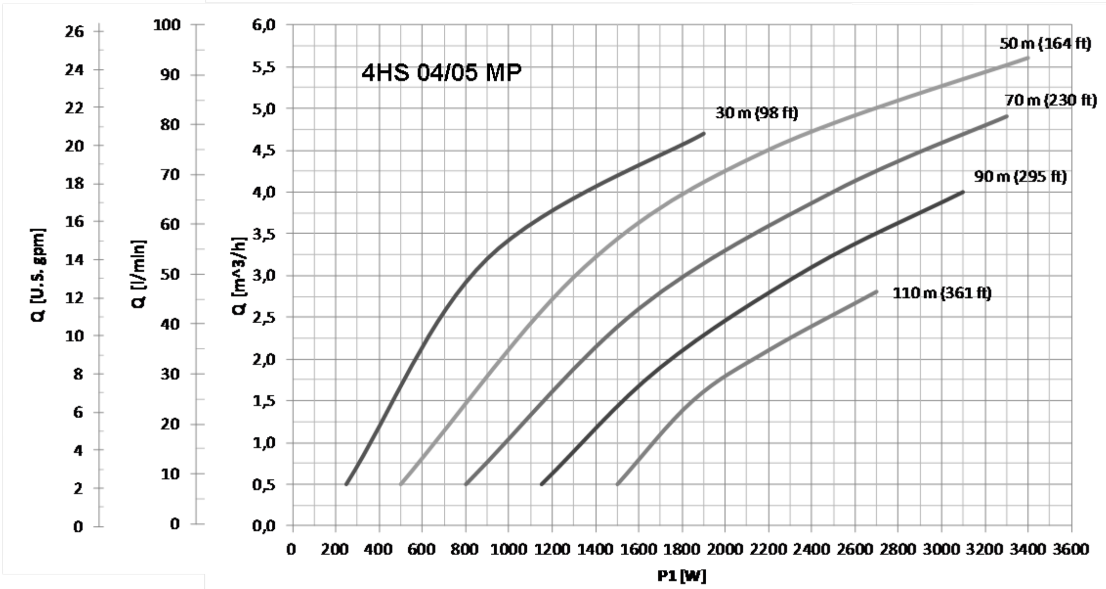
5.8.Model and Performance



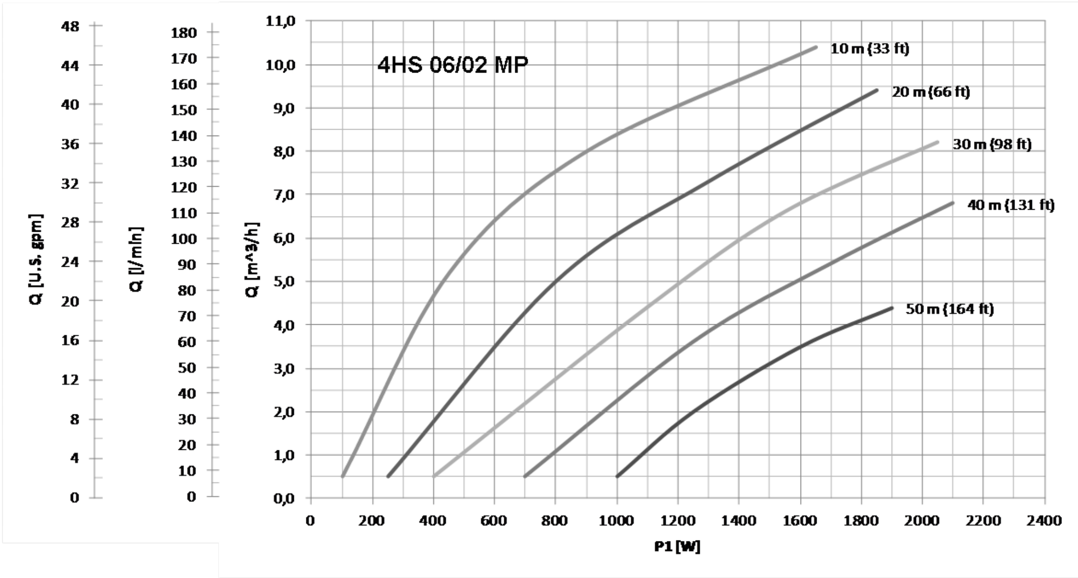


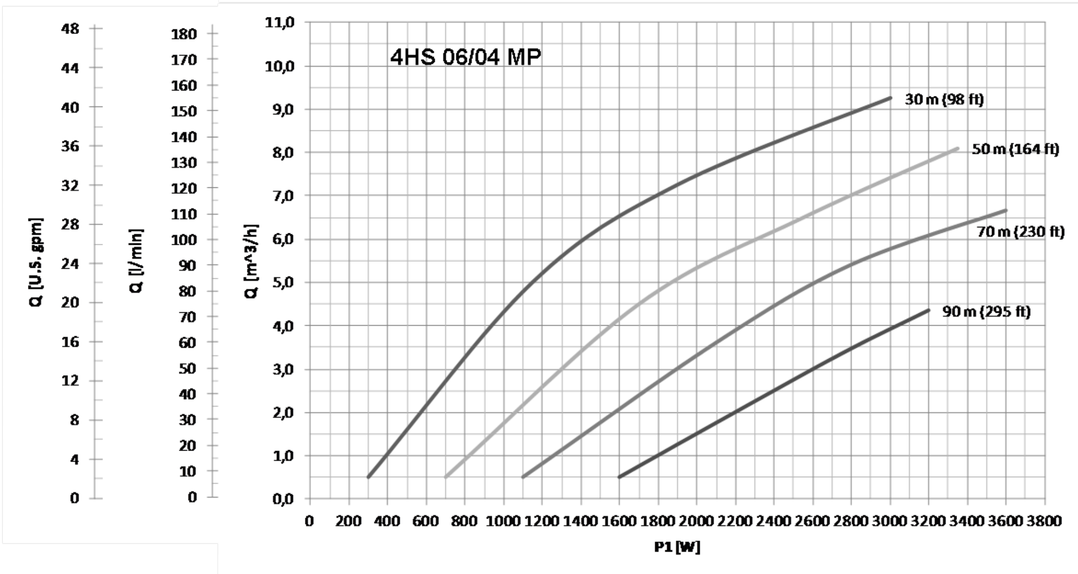
Model	Voltage	Max. absorbed current	Power factor	Max absorbed power	Length	Delivery	Pump weight	Max. diameter	Packing size	Total weight
4HS		[A]		P1 [W]	[mm]		[kg]	[mm]	[cm]	[Kg]
02/04 MP	90 - 340 VDC 90 - 265 VAC	16 (130 VDC) 16 (130 VAC)	1	2100	936	1 1/4 “	19,5	101 **	120x20x 29	20,5
02/08 MP	90 - 340 VDC 90 - 265 VAC	16 (220 VDC) 16 (220 VAC)	1	3500	1065	1 1/4 “	22	101 **	120x20x 29	23





Model	Voltage	Max. absorbed current	Power factor	Max absorbed power	Length	Delivery	Pump weight	Max. diameter	Packing size	Total weight
4HS		[A]		P1 [W]	[mm]		[kg]	[mm]	[cm]	[Kg]
04/03 MP	90 - 340 VDC 90 - 265 VAC	16 (150 VDC) 16 (150 VAC)	1	2400	915	1 1/4 "	19,4	101 **	120x20 x29	20
04/05 MP	90 - 340 VDC 90 - 265 VAC	16 (207 VDC) 16 (207 VAC)	1	3300	1002	1 1/4 "	21	101 **	120x20 x29	22





Model	Voltage	Max. absorbed current	Power factor	Max absorbed power	Length	Delivery	Pump weight	Max. diameter	Packing size	Total weight
4HS		[A]		P1 [W]	[mm]		[kg]	[mm]	[cm]	[Kg]
06/02 MP	90 - 340 VDC 90 - 265 VAC	16 (130 VDC) 16 (130 VAC)	1	2100	894	1 1/2 “	19,5	101 **	120x20 x29	20,5
06/04 MP	90 - 340 VDC 90 - 265 VAC	16 (225 VDC) 16 (225 VAC)	1	3600	981	1 1/2 “	21,4	101 **	120x20 x29	22

5.9.Size of a Waterbox

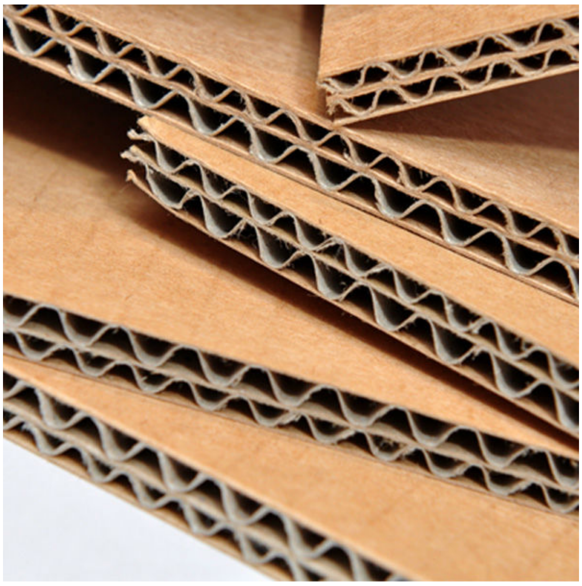
The whole system is integrated within a single box, specifically designed to optimize transport.

There are different types of Waterbox, according to the situation of necessity.

For marine expeditions is possible to use containers, we have designed packaging to maximize space inside the container.

A container has internal dimensions of 2310mm in width for a length of 12010 mm.

In addition to the power it's also been studied the packaging, such as, with fit for air shipments, in fact, do not exceed the size required 158h, or marine o by road. In addition to the size, it's work in an environmentally friendly, completely avoiding the presence of plastic materials, and choosing packaging with all safety approvals for shipments.



The packaging is made by Corrugated fiberboard, a paper-based material consisting of a fluted corrugated sheet and one or two flat linerboards. It is made on "flute lamination machines" or "corrugators" and is used in the manufacture of shipping containers and corrugated boxes.

The corrugated medium and linerboard board are made of containerboard, a paperboard material usually over 0.25 mm thick. Corrugated fiberboard is sometimes called corrugated cardboard, although cardboard might be any heavy paper-pulp based board. Old corrugated containers are an excellent source of fiber for recycling. They can be compressed and baled for cost effective transport. The baled boxes are put in a hydropulper, which is a large vat of warm water for cleaning and processing. The pulp slurry is then used to make new paper and fiber products.

5.10.Designing of a Waterbox

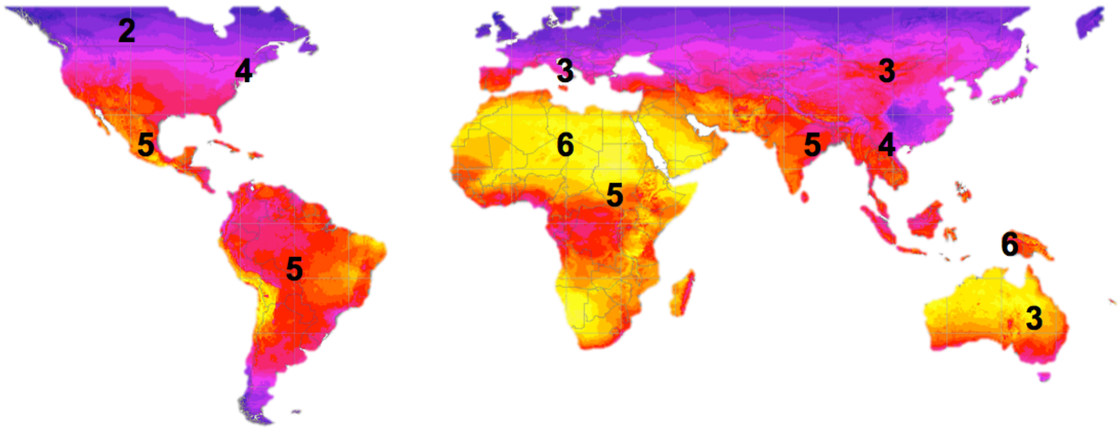
Starting from the choice of the pump; in the curves above is possible to see the flow in relation of power (P1). This type of power indicates that it's used by the motor and the inverter. That corresponds to the power required by the system. To get the best performance it's considered the power at the center curve.

5.11.Example

Consider the graph of the pump MP 4HS 06/04 and more particularly to the curve corresponding to a prevalence of 50m.
The value of power at the center curve is about 2100W.

5.11.1.Dimensioning of the photovoltaic module

The power of the photovoltaic panels, for have the references identical for all producers, is calculated under the conditions STC (Standard Test Condition), with irradiation of 1000W / m^2, temperature of 25 ° C, spectral distribution = 1.5.
All manufacturers test their panels, in order to define the power, in the same conditions, for have a unique data. The efficiency of a panel is the amount of solar energy that a panel can convert into electrical energy per unit area, and is always the maximum yield under the conditions STC above.
From the conditions of the STC, there are errors, the first of which was due by the temperature. This error said temperature derating ΔV (t) that affects the output power from the panel by about 0.5% / ° C for each degree above the 25 ° C defined by the STC. Considering an average work of the modules to temperatures of 65 ° C, there is a power loss of 20% from the total. A further error is due to the pressure drops caused by the non-ideality of the connecting cables, which influence in total for a value of about 3% of the total power.
So, to have a total voltage of 2100W, the plant to be installed must be:
2100/0,77= 2700W.
Once sized photovoltaic system, need to consider the maps of solar radiation, to see how much kW / h the system can produce, and the equivalent hours under the standard conditions.



From the map of irradiation with the hours equivalent in different territory, it's possible to arrive to define the table of models Waterbox.

HEAD	 0,9 kWp		 1,35 kWp		 2,7 kWp	
10 m			WATERBOX 06/02	9,5 m^3/h		
20 m			WATERBOX 06/02	7,5 m^3/h		
30 m			WATERBOX 06/02	5,7 m^3/h	WATERBOX 06/04	8,6 m^3/h
40 m			WATERBOX 04/03	3,7 m^3/h	WATERBOX 06/04	8 m^3/h
50 m			WATERBOX 04/03	3 m^3/h	WATERBOX 06/04	6,9 m^3/h
60 m	WATERBOX 02/02	2,7 m^3/h			WATERBOX 06/04	6 m^3/h
70 m	WATERBOX 02/02	2,3 m^3/h			WATERBOX 04/05	4,2 m^3/h
80 m	WATERBOX 02/02	1,8 m^3/h			WATERBOX 04/05	3,8 m^3/h
90 m	WATERBOX 02/02	1,6 m^3/h			WATERBOX 04/05	3,5 m^3/h
100 m	WATERBOX 02/02	1,3 m^3/h				

CHAPTER 6
The project

6.1.Collaborations

Companies that have supported the project:

6.1.1.LAP

Lap Srl is an Italian company providing cost effective, field tested, complete "plug and play" systems for the extraction of water though hybrid submerged pumps powered by solar energy for Humanitarian Emergencies and Development Programs, as well as for Public Infrastructure. Lap provides also "plug and play" Off Grid Systems, designed to make use of solar energy anywhere, anytime. They allow each user to create a solar photovoltaic system that generates electricity in any area of the world, providing independent and the benefit of a continuous service over the years.

6.1.2.Nastec

Nastec was founded in 2007 with the purpose of achieving a range of pumps and accessories in which the knowledge of electronics and hydraulics could give birth to a new generation of products with increased reliability, simplicity, flexibility and user comfort together with lower energy consumption.

The technical department is composed of engineers, electronic and mechanical. The knowledge on electrical motors and, in particular way of submersible motors, allows to develop products to 'cutting-edge in terms of performance, reliability and efficiency. Internal software development is conducted through continuous updates aimed at meeting the growing needs of applications.

The production is characterized by strict controls input and output tests.

The test stations are connected to the company computer system for continuously monitor the quality performance of the production process. In most cases, the test time is 30% of the total production time.

6.1.3.Intersos

INTERSOS is a non-profit humanitarian aid organization that works to bring assistance to people in danger, victims of natural disasters and armed conflicts. Established in 1992 with support from the Italian Federation of Trade Unions, its actions are based on the values of solidarity, justice, human dignity, equal rights and opportunities for all people and respect for diversity and coexistence, paying particular attention to the most vulnerable and the unprotected.

INTERSOS identifies with the core values of CONCORD, the European Confederation of NGOs; it adheres to international codes of conduct for humanitarian organizations and the values and principles expressed within those codes.

INTERSOS is recognized by the Italian Ministry for Foreign Affairs, the European Commission and the principal UN agencies; it is privileged to hold an advisory status with the United Nations Economic and Social Council (ECOSOC).

INTERSOS is an independent association which, through its own humanitarian operators, intervenes to effectively answer the needs of people in serious crises situations, mainly in the world's poorest regions, who are suffering, deprived of rights, dignity and essentials goods. It maintains a flexible operating structure. The head office in Italy coordinates, supports and monitors the planned activities in the countries of intervention carried out by decentralized offices.

The statutory bodies that guide, decide and monitor the interventions, activities, and finances of INTERSOS, are: the Members Assembly, the Council, the Society for Auditing and Certification of Accounts.

6.2.The installation

Napere borehole is located in Yambio town payam in Yambio County, it is located in south of Yambio town with a distance of about 4km from the main town, Western Equatoria State – one of the most peaceful states in troubled and torn by violence South Sudan.

This water point has been suggested by DWSS as suitable to be motorized with solar water pump

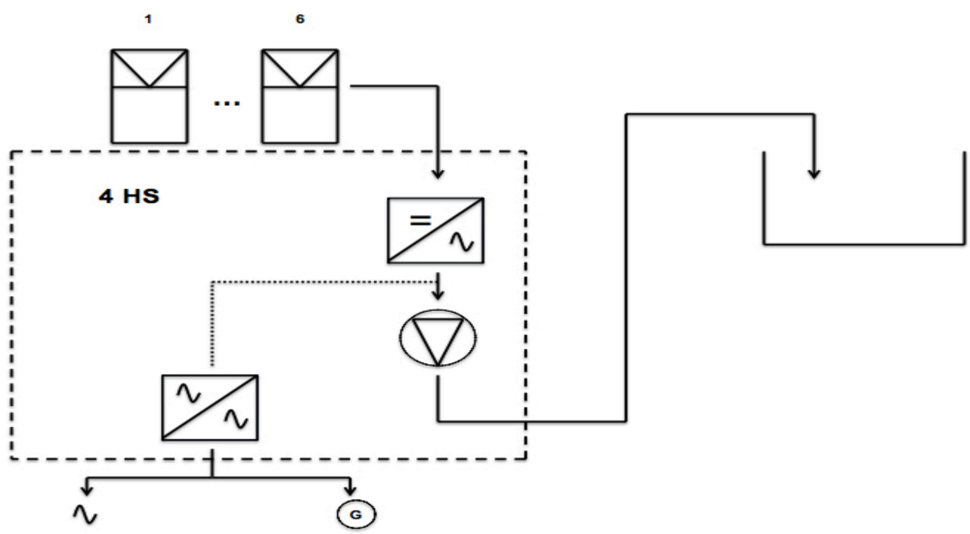
The community has about 700 households with a total population of about 3500 people living in the area. Report from the host states that since this water point was drilled, and the pedestal fixed, it has not been installed with a hand pump. Therefore, the community collects water from the nearby source which is an open source.

According to DWSS, the borehole was drilled as a test in search for deep seated aquifers in Yambio area Western Equatoria State that could produce enough water. During pump testing, the borehole was able to produce 5.45m^3/h.

Regarding the big population in the area, it is highly recommended by INTERSOS team (Victor; WASH Officer) and DWSS team (Sam; Drilling supervisor) to install a motorized water point with solar water pump for the community to allow an easy access to safe potable water for the crowded indigenous.

The Waterbox installed is a 04/03.

The structure of the system can be schematized by the following system blocks:



6.2.1.Preliminary data

Commitment	→	Intersos
Country	→	South Sudan

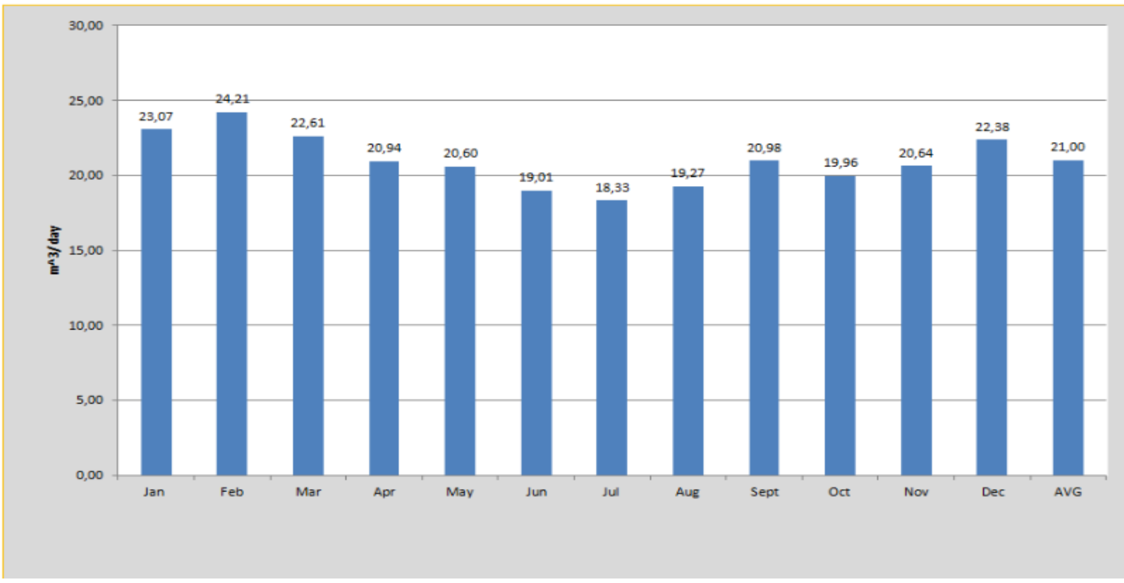
6.2.2.Project info

Project name	→	Water Pumping

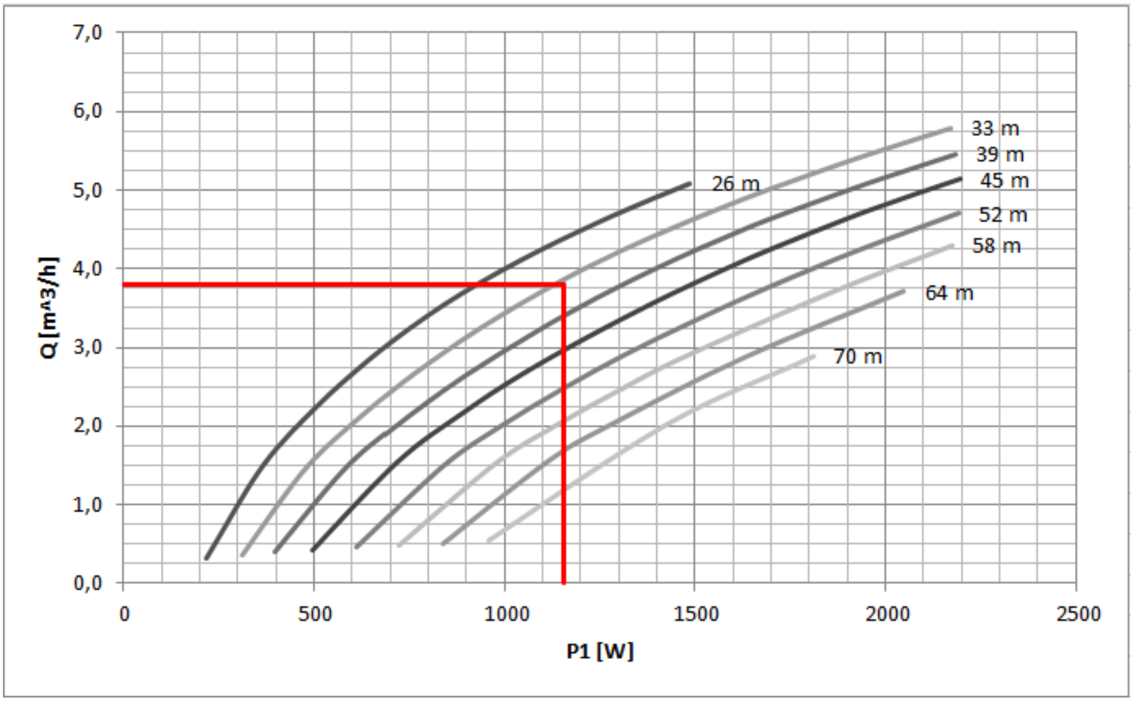
Location	→	Yambio
Automatic Latitude		4
Automatic Longitude		28
Performance estimated		
Delivery [m^3/day]		21
Dynamic Head [m]	→	31
Pipe specs		
Length [m]	→	50
Internal diameter [mm]	→	40
90° curves [qty]	→	2
Check valves [qty]	→	1
Valves [qty]	→	1
Cables specs		
Motor cable length [m]	→	50
Cable power loss [%]	→	4
PV panels specs (STC)		
Wp		225
Vmp		27,92
Voc		33,59
Imp		8,19
Temperature power loss [%]		1,2

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	AVG
Average daily solar irradiance	6,08	6,38	5,96	5,52	5,43	5,01	4,83	5,08	5,53	5,26	5,44	5,90	5,54
[kWh/m^2/day]													
Pump delivery required [m^3/h]	3,5	3,3	3,5	3,8	3,9	4,2	4,3	4,1	3,8	4,0	3,9	3,6	3,79
Total Head required B.E.P.[m]	32,4	32,3	32,5	32,7	32,8	33,1	33,2	33,0	32,7	32,9	32,8	32,5	32,7
Total Head required B.E.P.[m]	32,4	32,3	32,5	32,7	32,8	33,1	33,2	33,0	32,7	32,9	32,8	32,5	32,7

6.2.3.Performances chart



6.2.4.Performance graphic



6.2.5.Photo of installation

Bibliography

[1] Grundfos *"sp engineering manual"*

[2] LAP srl "*Water pumping system Waterbox*""

[3] Nastec "*4HS Installation and Operating Manual*"

[4] "The United Nations World Water Development Report 2014"

[5] *https://en.wikipedia.org/wiki/Corrugated_fiberboard*, 5 March 2015