

Cloud potential as the Biggest Source of Renewable Energy and Fresh Water

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Abstract

Nikola Tesla's ingenious idea to use the potential of clouds as the biggest source of renewable energy on Earth can be implemented by raising a water collection tank to cloud height. The collection tank would be kept at the designated height by tethered balloons and aerodynamic forces. A special pipe would drain the collected water to an impulse turbine fitted with a electro generator. The same process would provide pristine fresh water. Examples of technical implementation of low and average capacity pilot power plants are provided below.

Key words:

energy renewed source, pure water, clouds water, collector, balloon, impulse turbine, laser.

1. Introduction

The water cycle is the most powerful natural process. It consumes a quarter of all the solar energy that hits the Earth's surface. The most intensive accumulation and concentration of potential mechanical energy produced by this process occur when clouds yield atmospheric water. Given that the average cloud height is 3 km, each kilogram of water in a cloud has a potential specific energy of 29,400 J/kg. A water column of this height develops pressure amounting to 300 bar. On average, around 28.5 kg of water hover above each square metre of the Earth's surface!

Ingenious inventor and innovator Nikola Tesla (Tesla,1919) was the first to notice this back in the early 20th century. The energy density per unit of cloud mass by far exceeds that of solar, wind, hydraulic and tidal sources of renewable energy. Its value is equivalent to the energy density in a diesel engine or a steam turbine. Essentially, the plant is a hydropower plant with a useful head of 3,000 metres instead of the conventional 30-60 m. A high concentration of energy leads to a substantial reduction of the materials required, as well as the size and cost of power plant. Yet there was no way to put Tesla's ideas into practice until the arrival of 21st century technologies.

2. Delivering clouds water to ground level

The key challenge is collecting and delivering clouds water to ground level, avoiding enormous energy losses resulting from aerodynamic friction of the falling water droplets. This requires concentration of tiny cloud droplets in a single mass. Collected water may flow inside a pipe towards the ground with minimum losses. As an example, let us look at two pilot power plants with respective capacities of 27 and 2,100 kW: a fixed plant used to supply power and water to a small residential community and a mobile plant for commercial generation of power and fresh water.

3. Pilot plant with 27 kW capacity (Kazantsev, 2012)

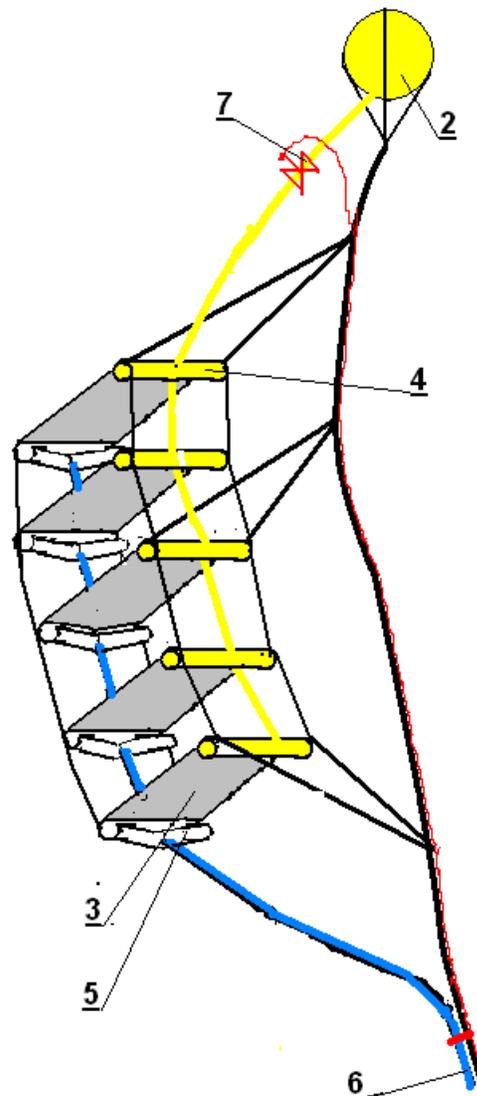


Fig.1 Small-capacity renewable energy and fresh water plant

3.1. Design and energy analysis (Fig.1)

Tethered balloon 2 lifts to cloud height one or more mesh collectors 3 with total surface area A of around 15,000 sqm. Collectors are expanded on the ground or at cloud height by filling cylindrical balloons 4 with gas and attaching them to the collector to edges. These balloons are connected by hoses 7 to the main can or a special gas balloon. The lift force of these cylinder balloons supports the top edges of the collectors. Overcooled cloud moisture concentrates and precipitates on the surface of the collectors. Gravity and wind make the water flow into gutter 5 attached to the lower edge of the collector. The gutter has a concave shape to collect water in its centre. Collected water drains through apertures in the centres of the gutters and connecting flexible tubes into the common pipe 6. Multi-level mesh allows falling droplets to be collected on bottom meshes. A passive water collector made from plastic mesh (Renee, 2011) produces 3 to 13 litres of water per square metre a day. The amount of collected water increases substantially at higher wind speeds (over 2 m/sec). Maximum daily water collection of 300 l/sqm was achieved in mountainous areas. The mesh may also be partially or completely metal coated to supply electricity, thus enabling hydrophobic property control, solar heating reduction and ice-cover reduction. Given $q = 10$ litres of water/sqm per day, the following average quantity of water may be produced by the collector's overall surface area A:

$$Q = qA = 150000 \text{ l/day} = 6.25\text{m}^3/\text{h}. \quad (1)$$

With an average cloud height $H=3,000$ m, this water quantity may generate potential power

$$N = \rho gQH/1000/3600 = 51\text{kW}, \quad (2)$$

where ρ is water density, and

g is the gravitation constant.

Common pipe with internal diameter $d=40$ mm may be used to deliver this water to ground level.

Head loss in a pipe of $l=3,000$ m will be as follows:

$$\Delta h = \lambda l/d \times Q^2/(0.785d^2)^2/g/2 = \lambda l/d \times V^2/2g = 110\text{m}, \quad (3)$$

where $\lambda(= 0.04)$ is the pipe friction coefficient.

Head loss may be reduced significantly if a superhydrophobic coating is applied to the inner pipe surface to repel water molecules (Boinovich, 2008).

At ground level, water with an approximate head of 3,000 m is supplied from the common pipe into a bucket-shaped impulse turbine (Drtna and Sallaberger, 1999). Inside the turbine nozzle, the static head is transformed into velocity

$$V=\phi \times \text{sqrt}(2g(H-\Delta h))=233\text{m/sec}, \quad (4)$$

where ϕ is the feed factor of nozzle ($= 0.98$)

Given such capacity, the required nozzle diameter d is

$$d = \sqrt{4/\pi \times Q/V} = 0.003\text{m} = 3\text{mm} \quad (5)$$

Required circumferential velocity on the periphery of impeller

$$U = \psi V = 105\text{m/sec}, \quad (6)$$

where ψ is the velocity factor ($\psi_{\text{opt}} = 0.44-0.47$).

Maximum diameter of impeller given rotation speed $n=12,000\text{rpm}$ is

$$D=60U/(\pi \times n) = 0.167\text{m} \quad (7)$$

Specific speed coefficient n_s of this one-stage turbine will equal 4.5 (which is a lot less than the optimal 13-18). This is why the efficiency of this turbine η_t with a little is below 0.6. Also, a reduction for coupling with a standard-frequency electro generator or a high-frequency generator with standard-frequency converter will be required. Due to low internal pressure equal to the atmospheric pressure, the turbine casing may be made light and with thin walls. Ultimately, the electric power of the power plant will be as follows:

$$N_p = \eta_t \eta_g N (H-\Delta h)/H = 27\text{kW}, \quad (8)$$

where $\eta_g = 0.92$ is the efficiency of the generator with reduction gear.

A much greater efficiency (up to 0.85) at $n=3,000\text{rpm}$ and input head of 2,890m may be achieved by using a screw machine such as a bore screw hydraulic engine or the standard screw pump running in turbine mode. On the other hand, owing to high internal pressure, the casing and the entire machine will be significantly heavier than the turbine drive.

3.2. Assessing the material requirements and forces acting on key aerial elements

To determine the required lift force of the balloon and tethered rope, we must calculate the mass of the air part plants of the plant and working forces. Table 1 contains masses of key components, mass of water in the common pipe and external forces working on these components. The following specific qualities of components must be taken into consideration:

The common flexible pipe consists of several elements. The low pressure top part (length $l_t = 300\text{m}$) of the common pipe may be made of light air fabric. The bottom part of the common pipe with diameter $d = 40\text{mm}$ and wall thickness $\delta = 0.5\text{ mm}$ may be made from firm superhigh-molecular polyethylene (long-time strength $\sigma_b = 2.4\text{ GPa}$). This will be capable of withstanding the pressure produced by head H_b

$$H_b = 2\delta\sigma_b/(g\rho d) \approx 6,000\text{m}. \quad (9)$$

The pipe must be attached to the balloon's tethered rope, which takes up most of the mass and aerodynamic forces acting on the pipe.

Lightmass rope made from superhigh-molecule polyethylene with diameter $d_c=12\text{mm}$ may be used as the tethered rope. Its maximum load is 3,500 kN. A 5-8 mm rope may be used for strapping the balloon and collector.

The key components may be lifted by a balloon filled with helium or hydrogen with 15% helium for displacement of the explosive air ratio. The balloon must have unit lift $f=11.06\text{ N/m}^3$. The theoretical load of the balloon is $F = 7,840\text{ N}$ at a volume of 709m^3 .

If the pipe is positioned strictly vertically, the mass of the water in the pipe is taken up by the ground art of the plant. If the pipe is inclined, a portion of the water mass must be supported by the balloon.

Wind creates a significant lift force and aerodynamic resistance. Under standard weather conditions at a height of 3,000 m in the mid-latitudes, wind speed reaches $v_a = 7.1\text{m/sec}$ with air density $\rho_a = 0.943\text{ kg/m}^3$. Given that the mesh is represented by flat-plane continuous plates with 15° horizontal deviation (which is close to optimal), we can calculate aerodynamic resistance F_x and lift force F_y under the specified conditions:

$$F_x = 0,5c_x \rho_a v_a^2 A = 71,300\text{ N} \quad (10)$$

$$F_y = 0,5c_y \rho_a v_a^2 A = 274,520\text{ N}, \quad (11)$$

where $c_x (=0.2)$ and $c_y (=0.77)$ are the plate's drag and lift force coefficients at the given inclination angle, based on Goettingen Institute measurements (Prandtl, 1923). Numerical simulation demonstrates that flow of air from the lower to the upper surface and roughness of the surfaces reduces circulation, causing lift force being reduced by an order of magnitude for the polyethylene mesh used in Chile (Schemenaur, 1994). For a metal mesh (Chandler, 2013) with much smaller wire diameters and distances between wires, the difference between these parameters is not as significant as in the case of a continuous plate. Cylindrical balloons made as rounded edges of plates increase the lift force and reduce the plate's sensitivity to the attack angle at a non-optimal flow direction. Also, bend of the mesh caused by wind effect slightly increases the lift force. As soon as the plant has been lifted to the desired height and buoyancy balloons filled with light gas keep the mesh afloat, the cumulative lift force increases substantially owing to the lift force of the mesh.

Wind also affects the common pipe. The tethered rope with a smaller diameter than the pipe is attached to and positioned in the air shadow of the pipe. Using average parameters of standard atmospheric conditions for the length of pipe in a vertical position, we can determine the pipe's aerodynamic resistance:

$$F_{xca} = 0.5c_x \rho_a v_a^2 d H \approx 1,500\text{N}, \quad (12)$$

where $c_x = 1.2$ – factor of aerodynamic resistance, and $v_a = 4.2$ m/sec.

If the pipe is inclined, aerodynamic resistance decreases and a force pressing the pipe to the ground applies. The external diameter and aerodynamic resistance of the pipe may be reduced substantially by using the special construction described below.

Lift force may be adjusted by mesh inclinations depending on the wind speed. The mesh may be controlled, for example, with a NAXRAD system (Saffle and Johnson, 2002) using special radars to determine cloud and wind speed at long distances and forecast approaching wind gusts stronger than 15 m/sec. This technology may also be used for precipitation forecasting.

When wind speed drops or the plant must be lowered, the gas is removed from the cylindrical balloons. Nets fold partially or completely and water is drained from the common pipe. The aerial element of the plant is then dragged to the ground by the tethered rope, using a hoist.

3.3. Assessing the mass of the ground parts and the entire plant

To determine the mass of the key parts of the ground element, we need to calculate the required capacity of hoist used to lower the aerial elements. Assuming that minimum time T required to lower the aerial element from a height of 3,000 metres is one hour, we calculate the desired power on the basis of the average pulling force, which equals the balloon's lifting capacity with a 1.5 margin to compensate for wind gusts:

$$N_h = 1.5F_g H / 3600 / 1000 = 8.5 \text{ kW.} \quad (13)$$

An electric hoist of this power with pulling force of 10,000 N used, for example, in drill rigs, will have a mass M_h of around 300 kg. Without question, the mass of the hoist may be reduced by at least half.

A standard synchronous generator with power 30 kW and rotation speed of 3,000 rpm weighs approximately 200 kg. Total mass M_e of the plant with a hydraulic turbine and reduction gear or screw engine will be 300 or 450 kg, respectively.

Therefore, the overall mass of the plant will be $M = 960 \dots 1,110$ kg. The specific mass per unit of power will be $m_y = M / N_p = 35 \dots 41$ kg/kW.

For reference, a standard fixed diesel generator with equivalent power and fuel consumption rate of 10 l/h weighs approximately 1,100 kg without the fuel tank.

4. Pilot plant with 2,100 kW power (Baibikov, 2009a)

4.1. Design and energy analysis (Fig.2)

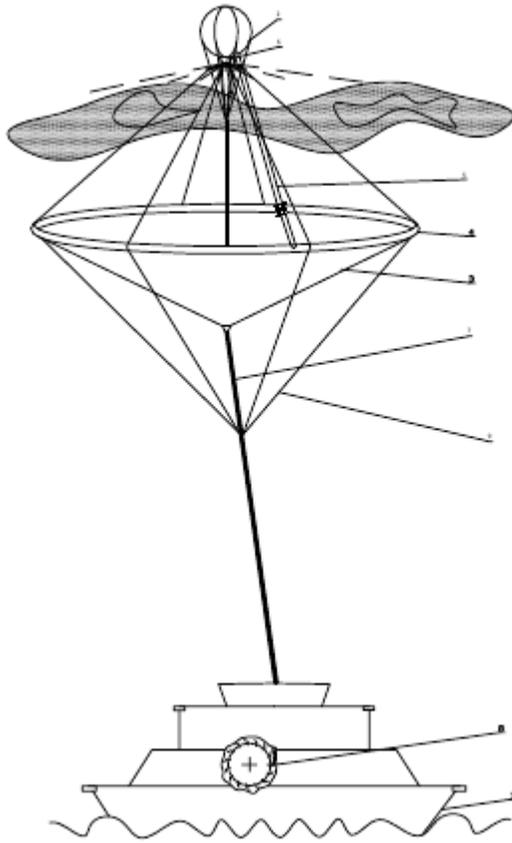


Fig.2 Medium-capacity renewable energy and fresh water plant

This plant may be based on a sea tanker 1 that follows the clouds. From the tanker, a standard helium-filled tethered balloon 2 with a lifting capacity of 3,000 kg lifts to cloud height a tapered fabric collector 3 that is wider at the top and gathers rainwater with its revolving surface. For example, an ATC-3.5 teardrop balloon produced by the Russian company DTSV Aeros with a casing mass of around 100 kg may be used. The preferred deployment method for this sort of collector is to lift it folded (Baibikov, 2013) and unfold it in the sky by filling gas into the annular balloon 4 located at the edge of the collector (Fig3).

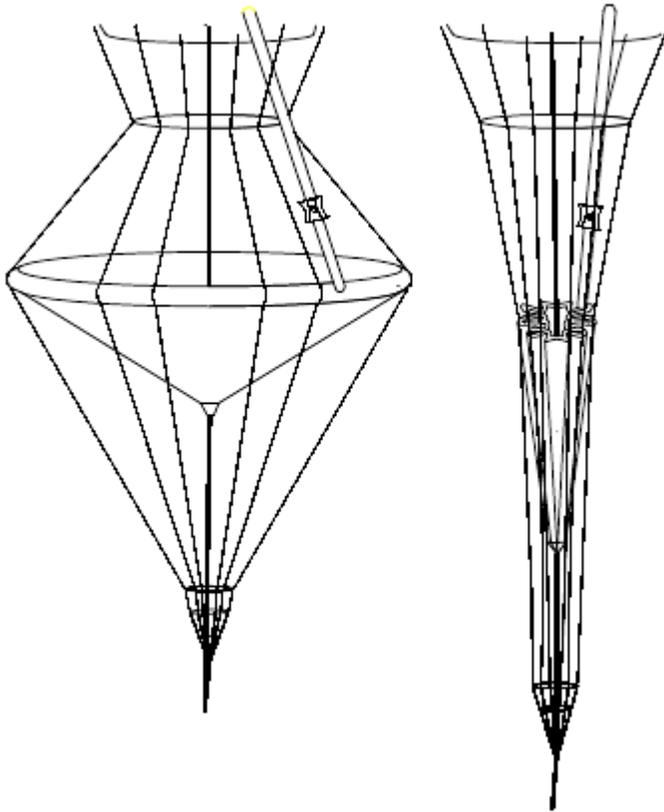


Fig. 3. The cone-shaped collector in expanded and folded positions

It is connected to the main balloon or special gas sphere via hose 5 with a pinch valve. In plain view, the collector with an annular edge, which may be filled with a light gas to prevent inadvertent change of shape, has radius $R = 47$ m (approximately the area of a football field). The volumetric flow of water gathered by such a collector from a normal, naturally occurring or forced rain shower (approximately $b = 25$ mm of rainfall in $t = 20$ -30 min) may be calculated as follows:

$$Q = \frac{\pi R^2 b}{t} = 350 \text{ m}^3/\text{h} \quad (14)$$

Given an average cloud height $H=3,000$ m, this flow rate has potential power

$$N = g\rho QH = 2800 \text{ kW} \quad (15)$$

Considering this magnitude of power, active techniques are preferred to trigger rain: dispensing of a fine-grain agent (dry ice, etc.) from a balloon with subsequent refilling of the dispensed agent using a cable (space) lift, or irradiation of clouds using a high-performance ground based laser (Henis, 2011) or electromagnetic (Smirnov, 1993) radiator. The most effective technique is to suspend a rotating radiation source 5 to the balloon directly above the collector. Similar to the

Nobel Prize winning invention, i.e., the Wilson cloud chamber, the radiation passing through saturated cloud moisture creates droplet tracks. These tracks constitute the condensation centre. When the number of such centres increases to the right level, the quantity and size of droplets will increase like an avalanche, causing rainfall above the collector, just as happens in nature. However, only a small part of a cloud is subject to radiation. Also, significant energy losses are avoided, as long as radiation does not have to penetrate a thick layer of air. This leads to a significant reduction in the power required and the running time of the radiator and reduces the time until water begins to concentrate. To this end, the plant may be designed with exhausted American (Bendin, 2003) or Russian balloon-borne long-range radars with replaced radiator. Also, mobile ground-based equipment of these stations may be used.

The radiator 6 is powered from a ground source via a cable attached to tethered rope 7 or via a combination rope-cable. The cable may also be used as a static charge eliminator and for other purposes.

Rainwater falls and runs down the inner hydrophobic side of the collector towards attached common pipe 7. The shape of the collector must guarantee minimum aerodynamic resistance, time for water flow towards the centre and weight, as well as maximum lift force from the balloon for load relief. The designed collector material is air fabric with a lightened superhydrophobic coating as it is not required to be gas-impermeable. Calculations demonstrate that the optimal collector design must have a surface with a minimum surface area, such as catenoid or pseudocatenoid. The interface collector radius with the common pipe is $r_u = 0.1-0.075$ m.

Loss of head in the common pipe attached to the tethered rope and ground-based hydraulic turbine 8 is as follows:

$$\Delta h = \lambda l / (2r) \times Q^2 / (2g(\pi r_u^2)^2) = 109 \text{ m} \quad (16)$$

Similar to the first type of plant, losses may be reduced by applying a superhydrophobic coating on to the inner surface of the pipe to repel water molecules. On the other hand, a pipe with such a large diameter will be subject to significant wind loads. The pipe and water flowing inside have a considerable weight and huge ground-based hoists will be required. Increasing pressure in the bottom part of the pipe requires thicker pipe walls and an increase of the pipe weight. If the pipe diameter is simply reduced, hydraulic losses will rise steeply, which is unacceptable.

Innovative technologies allow the pipe to be made with a much smaller diameter at minimum hydraulic loss. The article (Loytsjansky, 1942, Fedjaevsky, 1943) demonstrates that hydraulic friction may be reduced substantially by injecting air into the boundary layer. This is explained

by the fact that water viscosity is two orders of magnitude greater than air viscosity.

Consequently, reduction of hydraulic losses is achieved (Virk, 1975). This effect is used in Russian Squall high-speed torpedoes (Karpenko, 2005, Kuptsov, 2013).

The required pipe consists of two parts. To achieve flow acceleration due to gravity, the top conic part with upper internal radius $r_u = 0.075\text{m}$ and lower internal radius $r_l = 0.020\text{m}$ has length $l_u = 300\text{m}$. The bottom part with length $l_l = 2,700\text{m}$ may have a internal radius tapering to 0.013 m . The pipe wall is made of a $23\text{-}50\ \mu\text{m}$ -thick polyethylenterephthalate (PET) film with external superhydrophobic coating. On the outside, the pipe is reinforced with a armour spring made from $\sim 1\text{ mm}$ diameter fibres. Meshed clamps are used to attach the pipe to the tethered rope, which takes up all the applied forces. There is almost no internal pressure acting on the pipe wall, because all the potential water energy is continuously transformed into kinetic energy inside the pipe. Ionic-track nanotechnology (Reutov, 2002) may be used to make a network of orifices in the pipe wall with a minimum diameter of $0.1\text{-}1\ \mu\text{m}$ and density of $9 \times 10^9\text{ holes/cm}^2$. Significant differences in the ionic-track technology are in the stability of diameter, arrangement and shape of orifices, as well as the possibility of creating such penetrations at a sharp angle to the pipe's axis. Films of this sort are produced in large quantities for industrial and household use with the help of special accelerators (Lensky, 2014). Orifices may also be made convergent to reduce hydraulic resistance.

The pressure inside a confined, free-falling, accelerating water flow is lower than atmospheric pressure. This causes air to be sucked into the pipe's boundary layer through the orifices, whose diameter must be significantly smaller than the thickness of the boundary sublayer. The orifices must be made with sufficient density to isolate water from the pipe wall. The ejection effect is enhanced by the sharp angle between the water flow line and the axes of the orifices through which the air is sucked in. The speed of the blown air must be much lower than the water flow speed. The internal superhydrophobic coating prevents accidental contact between the water with the pipe wall. Hydraulic loss in a pipe with this design is below 300 m .

The common pipe is attached directly to the turbine 8 nozzle. Pelton impulse turbines are used for such dynamic head values, such as the hydraulic turbine at the mountain power plant in Ceuson-Dixence (Switzerland) with a head of $1,870\text{ metres}$. Given the loss in the common pipe, approximate nozzle diameter d for such a turbine may be calculated as follows (see definition of velocity above):

$$d = \sqrt{4/\pi \times Q/V} = 0.023\text{ m}. \quad (17)$$

Necessary impeller circumferential velocity (see above):

$$U = \psi V = 105 \text{ m/sec.} \quad (18)$$

Impeller diameter at rotational speed $n=3,000$ rpm:

$$D = 60U/(\pi n) = 0.668 \text{ m} \quad (19)$$

The specific speed n_s of such single-stage turbine will equal 9, which is close to the optimal value. This is why such a turbine's efficiency is ~ 0.9 . This turbine may be directly coupled with a standard frequency electro generator. The resulting power of the plant is as follows:

$$N_p = \eta_t \eta_g N (H - \Delta h)/H = 2,100 \text{ kW} \quad (20)$$

Power supplied to the radiator and auxiliary circuits must be subtracted from the resulting power. Ultimately, a turbine with an external diameter below 1 m and mass below 600 kg will be a fairly compact thin-wall unit with low internal pressure.

4.2. Assessing the masses and forces acting on key aerial elements

The masses of the part of the plant must be calculated to determine the required lift force of the balloon. Table 2 contains the masses and external forces acting on the aerial element. The following specific qualities of the components must be taken into consideration:

The collector is made of light-mass air fabric without typical gas-impermeable coating.

The common pipe consists of two parts, as described above.

Tethered rope 7 may be represented by a superhigh-molecular polyethylene rope with diameter $d_c=16$ mm, maximum loading of 5,000 kN and running mass of 0.195 kg/m. A much thinner rope (5-8 mm in diameter) may be used for strapping 9 of the collector and balloon.

Radiator mass includes the mass of the rotary platform for circular irradiation.

According to Table 2, the total mass of the aerial element is less than the carrying capacity of the balloon.

When the moisture collection process begins and the pipe is filled with water, part of the mass of the water in the common pipe will be added to the common pipe mass. The full mass of this water is as follows:

$$M_w = \pi r_t^2 H_t \rho_w + \pi (r_t^2 + r_t r_u + r_u^2) H_u \rho_w / 3 = 5,760 \text{ kg} \quad (21)$$

When the pipe is strictly vertical, the weight of this water must be accommodated by the ground element of the part, but when the pipe is inclined, the portion of its weight proportionate to the cosine of horizon inclination must be compensated by the lift force.

If we consider airflow around a cone as airflow around an infinite number of cylinders with a gliding angle, with reducing diameters under standard weather conditions in mid-latitudes at a height of 3,000 m, wind speed $v_a = 7.1$ m/sec and density $\rho_a = 0.943$ kg/m³, we may determine

approximate values of drag F_x and lift force F_y (Dievnin, 1983):

$$F_x = c_x \cos^3 60^\circ \times 0,5 \rho_a v_a^2 A_{60} + c_x \cos^3 30^\circ \times 0,5 \rho_a v_a^2 A_{30} = 3,090 \text{ N} \quad (22)$$

$$F_y = c_x \cos^2 60^\circ \sin 60^\circ \times 0,5 \rho_a v_a^2 A_{60} + c_x \cos^2 30^\circ \sin 30^\circ \times 0,5 \rho_a v_a^2 A_{30} = 5,270 \text{ N} \quad (23)$$

where c_x is the average factor of aerodynamic resistance ($=0.8$),

A_{60} and A_{30} – surface areas of middle of the collector's upper and lower components.

Thus, the deployed collector's lift force may support the mass of water in the air art plants.

Another force acting on the common pipe is the wind. Tethered rope and power cable of smaller diameters are attached and positioned in the aerodynamic air shadow of the pipe. Maximum aerodynamic force acts on the top conic part of the pipe ($H_u = 300 \text{ m}$)

$$F_{xca} = 0.5 c_x \rho_a v_a^2 (r_u + r_t) H_u = 810 \text{ N}, \quad (24)$$

where c_x is the average factor of aerodynamic resistance of the cylinder ($=1.2$) and ρ_a, v_a are standard density and velocity of the air at a height of 3,000 metres.

Using mean parameters of standard atmospheric conditions for the given pipe length, we may determine aerodynamic resistance for the lower part of the pipe:

$$F_{xca} = 0.5 c_x \rho_a v_a^2 \times 2 r_t H_t = 1,404 \text{ N}. \quad (25)$$

When the pipe is tilted, aerodynamic resistance declines and aerodynamic force applies, pressing the pipe towards the ground. Wind resistance of the balloon also produces a force with the same vector, causing horizontal drift of aerial elements of the plant. Experience of using tethered balloons shows that this does not inhibit their service (Bilave, 2008).

A superhigh-molecule polyethylene cable is capable of taking all the calculated loads. In emergency situations and during rapid descent, the toroidal balloon is freed from gas, the collector folds back, and the entire plant is dragged to the ground by the tethered rope, using a hoist (see Fig. 3).

4.3. Assessing the material requirements for the ground elements and complete plant

The required capacity of the hoist used to lower the aerial elements is calculated on the basis of time $T=1$ hour to lower the aerial element from a height of 3,000 m and given the lift force of the air balloon with a 1.5 margin to compensate for wind gusts. The resulting hoist capacity is as follows:

$$N_f = 1.5 F H g / 3600 / 1000 = 37 \text{ kW}, \quad (26)$$

where 1.5 is the wind gust coefficient.

An electric hoist of this capacity with a pulling force of 30,000 N and an integrated braking device has an approximate mass $M_h = 600 \text{ kg}$.

A synchronous generator with a power of 2,200 kW has an approximate mass $M_e = 9,500\text{kg}$.

Given the thin-wall casing of the Pelton turbine with atmospheric pressure inside the casing, the total mass of the machine is approximately 9,800 kg.

The overall mass of the plant is estimated at 11,800 kg.

The total specific materials intensity of the plant per unit of power may be defined as follows:

$$m_y = M / N_p = 5.8 \text{ kg/kW.} \quad (27)$$

For reference, a standard fixed diesel generator with equivalent power and a fuel consumption rate of 2,225 l/hr weighs approximately 20,600 kg without the fuel tank.

4.4. Specifics of use

The plant may be based on a sea tanker that follows the clouds. The tanker must be equipped with a remote control panel and instrument panel, radar and telescope to monitor the status of aerial elements and weather conditions.

Power from the generator may be transmitted to land via an unreeling cable. On the other hand, a cable ties the tanker down to a certain region. Today, energy may be accumulated in hydrogen produced on board the tanker from pure water using electrolytic reduction. Hydrogen is an environmentally friendly fuel with a high calorific value. Researchers claim that the hydrogen age is just around the corner (Bockris, Vizioglu, 1991). Hydrogen may be stored in cutting-edge metal-hydride or carbon batteries – nanotube cells (Bennington, 2011). For compact and inexpensive long-term storage, hydrogen may be preserved compressed inside high-pressure cylinders or, as a safer option, in microcapsules placed in a thixotropic fluid to prevent damage, or in microcapillary tubes (Chabak, 2007), (Chabak, 2008). The property of certain materials (e.g., glass) to become permeable to hydrogen only at a high temperature may be used for filling the microcapsules with hydrogen.

Delivered on shore, high-energy fuel helps decentralise and increase the dependability of the energy supply in the region. Compression energy may be partly recovered (up to 1,000-2,000 bar) during hydrogen expansion inside the expansion machine. Supply of hydrogen to relatively small local power plants using hydrogen fuel cells, which are more cost-effective than diesel and highly assimilated by industry, is just as easy as delivery of natural gas to gas filling stations. Hydrogen may also be used by motor vehicles (Baibikov, 2009b) and other transport without any environmental damage. The amount of energy stored in hydrogen and the travel distance to the next refill for equivalent volumes by far exceed the parameters of electric cars with the most powerful batteries. Moreover, hydrogen is extremely safe to use owing to rapid evaporation,

provided there are no spaces where it may accumulate.

In addition to electricity, this technology may be used to produce large quantities of fresh or more expensive distilled water, which is in very short supply in the modern world. A single-hull supertanker will approach the energy ship occasionally to extract and deliver the collected fresh water and, possibly, hydrogen to customer. Such supertankers lie idle now owing to the risk of oil pollution. These vessels offer the cheapest and safest way to transport neutral liquids today.

Such tankers, together with their personnel, may be put together to form an entire industry for harvesting electricity and fresh water, similar to deep-sea fishing. The mobility of a tanker-based power plant allows the vessel to be sent to places with the highest concentration of moisture, to areas with clouds that are most likely to precipitate soon. In addition, significant wind load may be compensated for by the speed of the vessel keeping to the wind. Also, the plant may be operated year-round. In the warm season, the ship operates near the consumption regions. In winter, when frozen water is hard to collect, the energy ship will relocate to warmer latitudes. The pioneer in building this industry, macrostructure and maintenance infrastructure will gain significant benefits and maximum revenue, create new jobs and receive gratitude from mankind for preserving nature.

In addition to tanker-based plants, much simpler and cheaper fixed plants may be used in rainy regions (e.g., in the foothills of India) without rain triggering systems that would supply electricity and water directly into the power mains and utility water lines. Such plants may be much cheaper to build.

5. Comparison with other renewable sources

The main characteristics of various renewable energy sources are provided in Table 1. According to the table, the key advantages of the plants discussed here include the possibility of being used without environmental damage, small territories of countries for minimum rental charges and the vast expanse of the ocean at no charge at all (these parameters make the proposed technology unique!), as well as their small size, acceptable material intensity per unit of generated power and, consequently, fairly small initial cost of primary components, flexibility of application and mobility of the plants.

Another advantage is cheap production of more expensive highly pure distilled water that does not cause clogging of pipeline systems and filters and may be used without extra treatment for electrolysis and in steam turbines. Also, there is an opportunity to use the aerial element of the plants for telecommunications, video surveillance, advertising, air defence, protection of vast

territories against thunderstorms, and local climate control.

Performance and economic benefits of such plants will improve with development of high-strength (carbon, aramid) fibre materials for collectors and lifting balloons. It should also be noted that such plants essentially represent a combination of currently available solutions, so the possibility of their development and operation, achievement of the desired results and, consequently, minimum investment risks is undeniable.

6. Essential regions of use and potential end markets for the plants

Today, all the leading economies have adopted programmes for developing renewable energy sources. To this end, such countries have established tax benefits that apply to developers of renewable power plants. Power that is generated by such plants and supplied to national power mains is also subsidised.

The regions those are most likely to become potential customers for the proposed plants have been determined on the basis of the following criteria:

- locally growing electricity deficit;
- growing shortage of fresh water and electricity;
- cheap transport costs;
- opportunity to make the proposed plants cheaper due to local conditions that allow some components to be left out or simplified;
- possibility of rapid clearance of the above deficits.

In general, such regions include:

1. Coastal countries with a shortage of energy sources (Europe, Asia (India), America, etc.).
2. Coastal countries with a shortage of fresh water (Africa, Australia, Saudi Arabia, Asia, etc.). For example, high-capacity fresh water generators with high energy consumption rates are operated on the coast of Australia.
3. Foothills and other regions with excessive precipitation rates (e.g., Cherrapunji (India) – the place with the highest annual rainfall rate: more than 11 metres. By the way, electricity demand in emerging India was 13.8% higher than supply in 2009). The cheapest modifications of fixed plants without energy accumulators (direct connection to a power grid!), water storage facilities (direct connection to water mains without need for expensive treatment!) and rain-triggering components may be supplied to such regions.
4. USA, China, India and Europe, i.e., countries that have passed national laws and allocated

huge financial resources to support development of renewable energy sources and reduced taxes on generated renewable power.

As of now, these markets only use traditional alternative energy sources with fairly high prices of generated power (hydro-, wind, solar, tidal and geothermal power plants). If the proposed project is put into practice, its customers, especially in coastal countries, will be provided with a renewable source of cheap energy or clean fuel – hydrogen, as well as fresh or distilled water. Revenue from the project may be fairly high owing to absence of any government constraints and sea operations taxes, the small areas occupied, relatively small initial and operating costs, constantly growing demand for the products, and absence of product certification costs. The project may involve both small firms with limited financial resources producing small-capacity plants for power and fresh water supply to small communities, and large enterprises manufacturing high-performance plants to supply electricity and water on a larger regional scale. Supertankers transporting fresh water do not need special terminals. Water may be pumped to shore anywhere, using flexible floating pipes extended from the ship.

7. Conclusion

As you may see, the latest technological achievements enable effective utilisation of the most powerful natural source of concentrated renewable energy – atmospheric water from the clouds. The proposed plants may be built by small firms and large enterprises. Large quantities of fresh water may be produced in addition to power being generated. Clean power plants may make a considerable contribution to building the future anthroposphere for mankind based on Nikola Tesla's concepts (Subetto, 2014).

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Table 1**Masses and forces characteristics of 27 kW plant**

	Component	Parameter	Mass, kg (Force, N)
	<i>1. Basic components</i>		
1	Mesh	area 15,000m ² mass per 1 m ² - 0.01kg	150
2	Cylinder ballon	length 150m diameter 0.25m mass per 1 m ² - 0.08kg	9.5
3	Top common pipe	length 300m diameter 0.4m mass per 1 m ² - 0.08kg	6.5
4	Bottom common pipe	length 2,700m diameter 0.4m wall 0.0005m mass per 1 m ³ - 970kg	165
5	Rope	length 3,000m diameter 0.012m mass per 1 m - 0.115kg	344
6	Rope + hose	length 500m diameter 0.006m	15
7	Balloon casing	radius 5.6m mass per 1 m ² - 0.08kg	31.5
	Total mass of air parts		722
	<i>2. Extra masses and forces</i>		
8	Water in common pipe		3,770
9	Aerodynamic resistance of pipe	length 3,000m	1,400 N
10	Ultimate aerodynamic resistance of nets at 15° incidence angle	area 15,000 m ²	71,300N
11	Ultimate lift force of nets at 15° incidence angle	area 15,000 m ²	274,520N

Table 2**Masses and forces characteristics of 2,100 kW plant**

№	Component, force	Parameter	Mass, kg (Force, N)
	<i>1. Basic components</i>		
1	Collector	area 15,000 m ² mass per 1 m ² - 0.05kg	750
2	Toroidal ballon	outer radius 47m diameter 0.4m mass per 1 m ² - 0.08kg	30
3	Top common pipe	length 300m top radius 0.075m bottom radius 0.02m mass per 1 m ² - 0.088kg	14
4	Bottom common pipe	length 2700m diameter 0.02m mass per 1 m ³ - 0.088kg	53.5
5	Rope-cable	length 3,000m diameter 0.016m mass per 1 m - 0.195kg	585
6	Rope + pressurazation hose	length 500m diameter 0.006m	15
7	Radiator		5
8	Balloon casing		100
9	Total mass of air parts		1672
	<i>2. Extra masses and forces</i>		
	Water in collector		410
10	Water in common pipe		5750
11	Aerodynamic resistance – top of pipe	length 300m in and out radius 0.075 and 0.02m	813N
12	Aerodynamic resistance of bottom of pipe	length 2,700m radius 0.02m	1,404N
13	Aerodynamic resistance of collector	midpart 1,270+5.5m ²	3,087N
14	Lift force of collector	midpart 1,270+5.5m ²	5,268N

Table 3**Comparison with other renewable energy sources**

Energy from:	Clouds	Rivers (hydroPP)	Wind (windturbine)	Radiation (heliostations)	Tide
Available resources	<u>+large</u>	small	small	+large	small
Energy concentration	<u>+large</u>	average	small	small	small
Size, mass and cost of power plant	<u>+small</u>	large	large	large	large
Cost of land lease	<u>+none</u> (sea) or small	large	large or none (sea)	large	+none
Initial cost	<u>+small</u>	large	large	large	large
Initial costs per 1 kW of installed capacity	<u>+small</u>	average	large	large	large
Mobility	<u>+large</u>	small	small	small	small
Service life	short	<u>+long</u>	average	average	<u>+long</u>
Development experience (background)	small	<u>+large</u>	average	average	average
Upgrading prospects	<u>+large</u> (nanotech)	small	small	average	average
Integration (+fresh water)	<u>+large</u>	<u>+large</u>	small	small	small
Environmental hazard	<u>+small</u>	large	average	small	average

Fig.1

Small-capacity renewable energy and fresh water plant

- 1 - ground part (not shown)
- 2 - balloon
- 3 - collector
- 4 - cylindrical balloons
- 5 - gutter
- 6 - common pipe with tethered rope and power cable
- 7 - a hose and a valve for balloons feed with electrical control

Fig.2

Medium-capacity renewable energy and fresh water plant

- 1 - tanker
- 2 - balloon
- 3 - collector
- 4 - annular balloon
- 5 - air boost hose with valve
- 6 - radiator
- 7 - rope with common pipe and power cable
- 8 - hydraulic turbine with electro generator (not shown)

Fig. 3

The cone-shaped collector in expanded and folded positions