Unlimited Energy, Unlimited Water.

Siwa Conference on Sustainable Water Management, Cairo November 16, 2017

Spoken text.

Energy

On May 24 in the year 2016 an event took place of historic dimension.

The leader of one of the largest oill companies in the world, Ben van Beurden, CEO of Royal Dutch Shell made the following statement:

Solar power is the cheapest way to produce electricity.

It is to be compared with the boss of a slaughterhouse making the statement that vegetarian food is better for your health.

If a man in this position makes this statement, is must be the truth.

The statement was made after I told him that just before financial closure was made for a 800 MW PV-power plant in Dubai, which will sell electricity for only 3 dollarcents per kilowatthour.

Solar Energy

Solar energy is not only the cheapest, but also most abundant.

In all red and orange areas the sun shines bright enough, and long enough to be able to feed the whole world with all sorts of energy, using PV as well as CSP.

Solar Electricity

There are three methods to generate electricity from solar rays.

In PV, Photo Voltaics, solar cells and solar panels are used, that are the welll-known blue-shiny panels. Electric current is produced immediately, but stops also immediately when the sun sets, are when a cloud comes over. So no production at night, and less production in winter than in summer.

CSP, Concentrating Solar Power, is applied in solar thermal power plants, where parabolic mirrors concentrate the rays from the sun, you get a very high temperature, make steam, and run steam turbines and generators.

The heat can be stored, and the steam turbines also run at night.

The last method is growing plants ot trees, and burning them in order to produce steam, and run steam turbines.

The big difference is the efficiency in utilising the energy from the sun.

How much electic power do we get relative to the power from the solar rays?

For PV and CSP is varies between 15 and 25%, but for biomass it is much and much less, just 0.3%.

Or, in other words, you need 60 times more land with biomass burning than with PV and CSP.

The main difference between CSP and PV is, that a CSP-plant produces electricity at any time, because of the storage of heat.

A PV-plant that would be able to produce in dispatchable way, that is at any time, would need an enormous amount of batteries, and these batteries are much to expensive.

CSP Technology

Now I will elaborate more on CSP technology, because this solar energy technique is much less known than PV.

All CSP apply parabolic mirrors. The basis idea is that the solar rays are absorbed at a very small surface, and because it is small, it will not lose much heat through radiation or wind cooling. So the temperature of the absorber, or receiver becomes very high.

There are 4 methods:

parabolic trough mirrors, reflecting to a receiver tube

a field of nearly flat mirrors reflecting to the top of a tower,

rows of flat mirrors reflecting to a receiver tube

and

the parabolic dish

At the moment the total capacity of parabolic trough plants, and solar towers is about 5 GW.

The other techniques are much less applied.

Parabolic trough mirrors

All solar mirrors must rotate slowly in order to follow the sun, as the sun has the irritating habit to move along the sky. (in the earth coordinate system).

In the morning they point to the East, at noon the point to the zenith, and in the evening they point to the west.

Volgende

Here, in Cairo, we are at a historical location (of course, we all know). But not only in the cultural, religious and political history of mankind, but also in the history of science and technique. The first parabolic trough plant in the world was located right here, at Al Ma'adi. A steam engine, driven by a large field of parabolic trough mirrors, was used to pump irrigation water, in the years around 1915.

Nevada Solar One

Modern parabolic trough mirrors look rather diferent. They are 5 meters wide, in long rows. The reciever tube is isolated from the wind by a glass tube and vacuum. A special mineral oil is heated up from 318 centigrade tot 393 degrees Celsius.

Shams 1, Abu Dhabi

Here you see the CSP plant near Abu Dhabi. Although the desert is really sandy over there, the mirrors are protected by wind fences. Bulldozers push away sand dunes if they come to nearby.

Floating parabolic trough mirrors

A different approach for following the sun, is to make a pond, or using the water from a lake, to rotate a complete field of trough mirrors collectively.

This field of 80 square meters was tested by us in the Netherlands.

Solar Tower

This is the GEMASOLAR tower in Southern Spain, with a huge storage capacity, 15 hours. This is a real base-load solar power station.

CSP technology – Day operation

Here is a very simplified scheme of a complete solar thermal power plant during the day.

A pump pushes water to a high pressure, the water is heated in the receiver of a solar mirror field and becomes steam at high pressure.

The steam expands in the steam turbine, and mechanical energy is produced. The generator transforms the mechanical energy in electrical energy.

Finally the low-pressure steam is transformed into water in the condenser, and the circle is closed. The technical name of this is Rankine cycle.

The condensor needs cooling. Normally in thermal power stations water is evaporated in cooling towers, but in most locations where CSP plants are viable, water is to scarce. So the condenser is generally cooled by air.

Not all heat is used to produce electricity, but part of the heat is transported to liquid salt, salt pumped from the cold tank is heated in this heat exchanger and stored in the hot tank.

CSP technology – Night operation

During the night the hot salt delivers heat in this heat exchanger, where the water boils, and the power station can continue to produce electricity.

CSP technology – Night operation, hot salt vessel empty

In case the all heat of the storage is consumed, we have a problem. If we want a guaranteed supply of electricity, we add a gas-fired steam boiler to the plant, and can continue to deliver power, not solar anymore, however.

Energy Storage

Het hot salt consists of a mixture of sodium nitrate and potassium nitrate, cheap, non-toxical materials with a high heat capacity.

The energy loss in this storage process is very low.

Solar Economy

There are two important criteria for judging energy.

First the production cost, the so called levelized cost of electricity LCO.

They are determined by three components: investment, land cost and exploitation cost. In solar energy, investment cost is by far the highest fraction.

The second criterium is the Energy Return On Energy Investment. EROEI

That is the total produced energy during the lifetime of the plant dividen by the energy that was needed to build the plant.

Solar energy in sunbelt countries

For Photo-Voltaic panels in large fields the costs have dropped very fast during the last years, this way of producing electric power is te cheapest of all, I mentioned this earlier in my talk.

The costs voor PV are 2.4 dollarcents in the Emirates and 1.7 dollarcents in Northers Chile.

For Concentrating Solar Power the costs are higher, but they are also going down fast, and are at the level of 7 cents per kilowatthour.

The Energy Return On Energy Investment of PV is rather low, 5 to 10, CSP is better with an Energy Return On Energy Investment of about 20.

The big difference is the availability. PV delivers during the day only, but CSP with thermal storage delivers day and night, and is therefore superior to PV.

If one wants to achieve a 100% solar power system in the cheapest way, a combination of PV and CSP is the best choice. During the day electricity is produced by the solar panels, and heat is produced by the parabolic mirrors and then stored. At sunset, the steam turbines are starting up, running on heat from the storage. The levilized cost of electricity will lie between those of pure PV and pure CSP.

The Energy Return On Energy Investment of the combined power plant will also be in between PV and CSP.

The alternative is PV with bateries. But this solution is extremely expensive.

Solving the water problem

After having solved the energy problem: with solar energy (and wit regard of Egypt also wind), let's look at the other major problem: Water.

Egypt relays completely on the Nile, but the supply of Nile water is limited.

So, just like with energy, we must handelen with the right sequence of measures:

- stop wasting water
- drip irrigation instead of splash irrigation (“raining”)

With open raining, half of the water is evaporated before it reaches the roots of the plants

- reduce evaporation from open water

Why not cover the Nasser lake, with plastic balls, or better: with floating solar power plants?

- process waste water (circular economy)

Apply the principles of the circular economy, clean the waste water and use it again.

New fresh water can be produced from salt water:

- desalination.   There are two thechnologies: RO (Reverse Osmosis), suitable for brackish water and seawater, and MED (Multiple-Effect Desalination), suitable for seawter and very salt water.

But what to do when there is no river, no ground water where we can dig a well, and the coast bis to far away to apply seawater desalination?

The technology of last resort is

- atmospheric water generation, and there are two methods: Cooling Condensation and Wet Desiccation

RO seawater desalination 1

Now I will give a short explanation of Reverse-Osmosis desalonation.

When we have fresh water at the right, and salt water at the left, and there woukd be no separating wall, the liquids would mix up, and finally there would be just as mush salt at the left as on the right.

But if we put a well in between, with holes which allow only the smaller water molecules to pass the filter, then more water flows towards the salt side than otherwise.   A pressure builds up, with seawater even 30 bar, that is a water column of 300 meters.

But if we push back harder than 30 bar, water flows from the seaside towards the frehs water side: waterproduction.

We need a lot of mechanical power tot do this, by means of pumps which are driven by electric mptores.

RO seawater desalination 2

The nanofilters are always rolled in a spiral, as you see at the left side. In a RP-factory, it is full of tubes with these spirals.

And here you see a big seawater desalination plant, together with the gas burning powerplants delivering the power for the desalination pumps.

It is typical for the MENA region: many desalination plants, amd practically all of them are running onfossile fuel

That is not the right way, burning gas, oil ot coal in order to produce water.

The right way is of course to produce solar electricity

RO seawater desalination 3

The power plants are PV-fields and CSP plants, more in land, where the sun is bright, and where the desert has the space for the solar fields.

In this picture you can see the parabolic trough mirrors, the storage vessels of the liquid salt, the steam turbine. Cooling will be done with air, not with water, as in this picture.

Not shown in the picture the field of PV panels, producing power during the day.

The trnasmission lines transport he electric power to the coast, to the pumps of the RO desalinator. At the coast the RO facture is processing the seawater, and the waste water, the brine, is pumped back into the sea.

An alternative is to build the CSP plant at the coast, and to use the waste heat of the steam cycle to distill seawater. It can be done in many steps, the same amount of heat is utilised to boil seawater and condense the water vapour, again and again, this is called MED, Multiple-Effect Desalination.

MED desalination can be done with water with very high solar concentration, like in the Dead Sea, en in saltlakes in Egypt.

RO economy

RO desalination is dominant in the world.

The energy consumption is about 3 kWh per m3.

Here you a cost break-down.

Electric power and capital costs are dominant, about 40%, but O&M costs are also not negligible.

The production costs for the water are 50 to 80 eurocents per m3.

In the future, when solar electricity will be cheaper than fossil electricity now, the costs of desalinated will become cheaper too.

To my opinion, solar RO desalination can become the source for large scale agriculture along all Egyption coasts, when drip irrigation is applied.

RO is very suitable to desalinate the brackish water that is available around Siwa.

Atmospheric water generation

There are many places in the world where wells are absent or extinguished, and the sea is far away.

The only way to bring water to the people is either trucking over hundreds of kilometers along bad or absent roads, or atmospheric water generation.

Let us take Siwa as an example (although there is ground water available).

The average humiditu is 45%, and the average temperature 21 degrees.

Under these conditions the air contains 8 grams of water vapour per cubic meter.

Lets take one square meter of desert. The total amount of water vapour above this square meter contains 73 kg of water.

When this water would be liquid, it is a layer of 7 cm of water.

Imagine, we make an installation which pulls this water completely out of the air. There is always some wind, just assume a speed of just 1 meter per hour.

We get a production of 7 cm per hour, which is 600 meter of rain per year.

An Atmospheric Water Generator with just a tiny efficiency could produce enormous amounts of water.

Up till now two types of AWG are made:

Cooling Condensation and Wet Desiccation.

AWG with cooling condensation

In Cooling condensation a number of planes are cooled down some 10 degrees below the so-called dew-point. The temperatures are for the Siwa situation. Air comes in at 20 degrees, the dew-pint is 10 degrees, we cool down to 1 degree.

The air is blown to the cold planes by ventilators, and water vapour conddenses in the planes, the water rolls of the the collecting vessel. The planes must be supplied with cold in order to prevent heating up because of the condensation heat of the water. This is done with a heat pump, of the same type as in the fridge in your kitchen. The heat must be pumped up in temperature some 50 degrees in order to obtain enough air cooling here, to get rid of it.

A major problem is, that enormous amounts of air must be cooled down too, over some 20 degrees. Therefore the heat-pump must pump 3 to 4 times more heat than the condensation heat.

Atmospheric Water Generators using Cooling Condensation consume very much electricity.

ASWG with wet desiccation

With Wet Desiccation we apply a two-step proces. We utilise the fact that at night the humidity is rather high. So at night we pass large amounts of air along a spray of an hygroscopic liquid. The liquid soaks op the vapour, the water condenses in the liquid, and the air gets heated some 5 degrees.

In the following day, the wet liquid is admitted to a distillation vessel. The sun shines on a field of flat solar collectors, and the solar heat boils the liquid. The water vapour condenses on planes which are cooled by colde water. That water was cooled down the night before by means of radiating of infra-red rays towards the black sky, so-called night-sky cooling.

Compared to Cooling Condensation we have don't need cold for cooling down large amounts of air.

And we don't need to supply the energy in the expensive electric form, but can suffice with the cheapest energy of all: modest temperature heat from flat solar collectors.

With Solaq we are developing Wet Desiccation AWG, and the first field tests of our prototype will be made in Siwa.

Atmospheric water economy

Atmospheric Water Generation is expensive, it is a new technology.

Cooling Condensation is more expensive than Solar Wet Desiccation.

The costs are so high that it seems unlikely that AWG will become as cheap as desalination.

But AWG is an reliable source for modest quantities of water

for

etc.

Climate change is already hitting mankind

At the Paris conference, a lot of discussion was about the goal of climate policy. Should the world aim at a temperature increase of 1.5 or 2.0 degrees ?

Anyway, we are now at 1.0 degrees, and we observe already many symptoms of climate change:

Look at the list, and Egypt the red effects are especially applicable.

It is of the utmost importance that all countries become ally in a war against climate change. If mankind looses this war, it will end the human civilisation.

Carbon Countdown

According to the climate models of IPCC one can calutate how many years the world has left while poluting the atmosphere with CO_2.

For instance, we have 28 years left if we want to stop heating op the earth more than 2 degrees with 50% probability.

However, in Paris it is agreed that we should stay well below 2 degrees, preferably at 1.5 degrees. But then we have only 10 years left!

Threats and Chances of Egypt

Solar map of Egypt.

Most CO_2 comes from burning gas, coal and oil in power plants.

But we don't need do do this anymore, solar power is just as reliable.

Egypts has huge possibilities, and I said before, solar power hes become cheaper than fossilpower.

So stop further investments in gas-powered plantsnand coal plants, invest in solar only (it is certainly cheaper than nuclear power). And start replacing old plants by solar plants. And, of course, wind plants at those places where the wind

Costs of 100% solar electricity system in Egypt

Benban Solar Park   near Aswan

planned 2 GW of PV plants.

The first part, 750 MW of PV has just received financing

of a group of banks.

The plants will cost a total of $823 million to build, IFC

said in a release.

1.1 $/Watt, or 1.1 billion dollar for 1 GW of solar power.