Dew Condensation College-Level Projects

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I have been inspired by the WaterBoxx, which is a dew harvester. However, it is too expensive for large-scale use in India. So, I am looking for a better and cheaper Indian dew harvester. This new harvester will be a key element of my idea of growing trees in a water-efficient way in arid India.

By this note, **I seek to involve you in the process of designing a workable, cheap dew harvesting system for saplings of trees during the first 12 months of their lives.**[1]

I estimate that the amount of water that a sapling of the type that I think should be planted needs about 0.6 – 1.0 litres of water per month. To be safe, we should target to collect 1.0 litre per month for the time being.

There are two branches in dew harvesting technologies.

Method 1: Passive radiation

Here there are two main components.

- A condenser, on whose surface dew forms.
- A dew collector which ensures that the bulk of dew formed is captured for feeding the roots of a sapling.

In the Water Boxx, the condenser's surface is coated with a costly superhydrophobic film that allows dew drops to roll into the collection bottle.

The present technology seems to favour creating a hydrophilic surface that ensures that there is no drop formed. Instead, a water film is made that flows into the collection bottle. These are much cheaper technologies than using a superhydrophobic film.

Three papers and a video constitute the initial reading material needed for understanding the subject. They are enclosed.

Method 2. Active condensation

Here the dew condensing surface is cooled by a refrigerant cooling against it. This calls for power input, which may come from solar panels/solar heating etc.

I have had some preliminary talks with Prof Milan Rane of Heat Pump Lab at IIT Mumbai. It seems they are experienced in active condensation technology and would welcome working with BAIF Pune. BAIF is a well-known, decades-old, organization working in the field of agriculture and livestock with many branches spread over India.

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[1] The BAIF Foundation and I are currently conducing a scientific trial of a planting/growing method that uses very little water. This trial does not include a dew harvester, but we would like to include it in the future.

For the moment I want to exclude active condensation projects from the College level work as most of the equipment needed may not be available at a college. But if anybody is interested, I can re-examine the issue.

Passive Radiation Projects

A passive radiation condenser has three components:

- the condensing surface itself
- the geometry of the surface, and
- the mechanism for quickly putting the condensed dew into a storage water bottle.

For our project purposes, we will assume that dew condenses when the relative humidity is more than 70%, and the difference between the surface temperature and ambient temperature is 5 degrees Celsius or more.

The reference condensing surface:

- has an area of 1 square metre
- is inclined to 30 degrees to the horizon and
- its back is insulated from thermal radiation emanating from Earth.

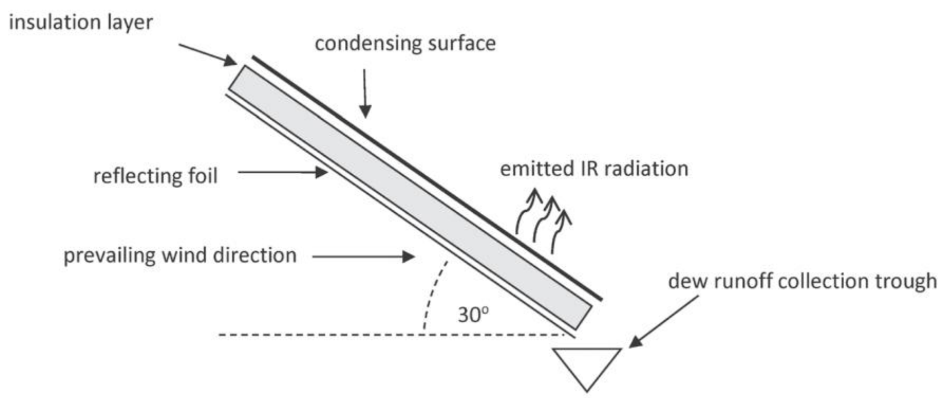

FIGURE 1. Schematic diagram (cross section) of a dew condenser

Colleges should consider three alternate surfaces that are economical to use and may serve the purpose. Within each surface, there are variations that may be considered.

- ***Galvanized iron*** or Mild Steel. If blue coated steel is available, consider that too.

- ***Thin aluminium sheets*** of size 65 cm by 55 cm (or thereabouts) that were used to print a newspaper page. They have a shiny surface and a painted dull blue surface with backward newspaper matter printed on them.

- ***Frosted glass*** is to be used with the frosted side facing upward. Frosted glass has built-in micro-channels so that its effective area is a multiple of its measured area. Even though glass is breakable and large sheets of glass, even more so, we can apply an engineering trick to deal with this. The trick is that if you suspect that something can break during use, design it so that it is already broken at the starting time. So, use frosted glass in small blocks of 6 inches by 9 inches and joined with M Seal or its equivalent in the gutter. Thin and relatively cheap frosted glass can be used in this way.

There is a requirement that the surfaces radiate in the atmospheric window wavelengths. That is satisfied by these surfaces.

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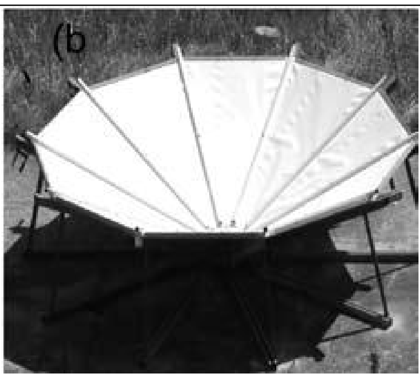
There is also a requirement of high emissivity, but we will ignore it here as the best material emissivity at 0.91 is nearly matched by these materials whose emissivity is about 0.90

Creating corrugations by various means on a surface increases its effective area for dew condensation. Some ideas are included for this approach as the cost of creating corrugation can be kept low.

The geometry of the surface

Using Computational Fluid Dynamics, Beysens Daniel et all have found two sets of shapes that yield dew about 20% to 40% more than the standard reference surface.
These shapes are a funnel and an Origami shape and are illustrated below.

Funnel	**Origami shape**
	

The origami shape is modular and is composed of six identical units joined together by tubing to drain dew. From the matter in Beysens' paper, I have derived the dimensions of each unit and am in the process of checking with him that the derivation is correct. Whether or not we get the confirmation/ correction, we will make such units at a smaller scale and see how well they condense dew.

I propose that we do not replicate the funnel shape because another shape similar to it appears to have better properties.

Paraboloid Instead of Funnel

It's well known that a parabola concentrates all incident radiation to its focal point. What is less well known is that its surface radiates all emissions straight into the sky without the emissions hitting any part of the parabola. In other words, whatever the radiation that parabola emits, it goes away forever.

The process of making a parabola out of cut flat plates is within the skills of a college student.

There is software available. See this for the first insight
http://solarcooking.org/plans/parabolic-from-flat-sheet.htm .

Then consult this and download the excel sheet from the bottom of the page.
http://www.bio.umass.edu/biology/kunkel/gjk/parabola/cardboard.htm

See this video also

The mathematical details of drawing the parabola and deriving the paraboloid are given in Maths Note 1 in Annex 1.

Origami shape

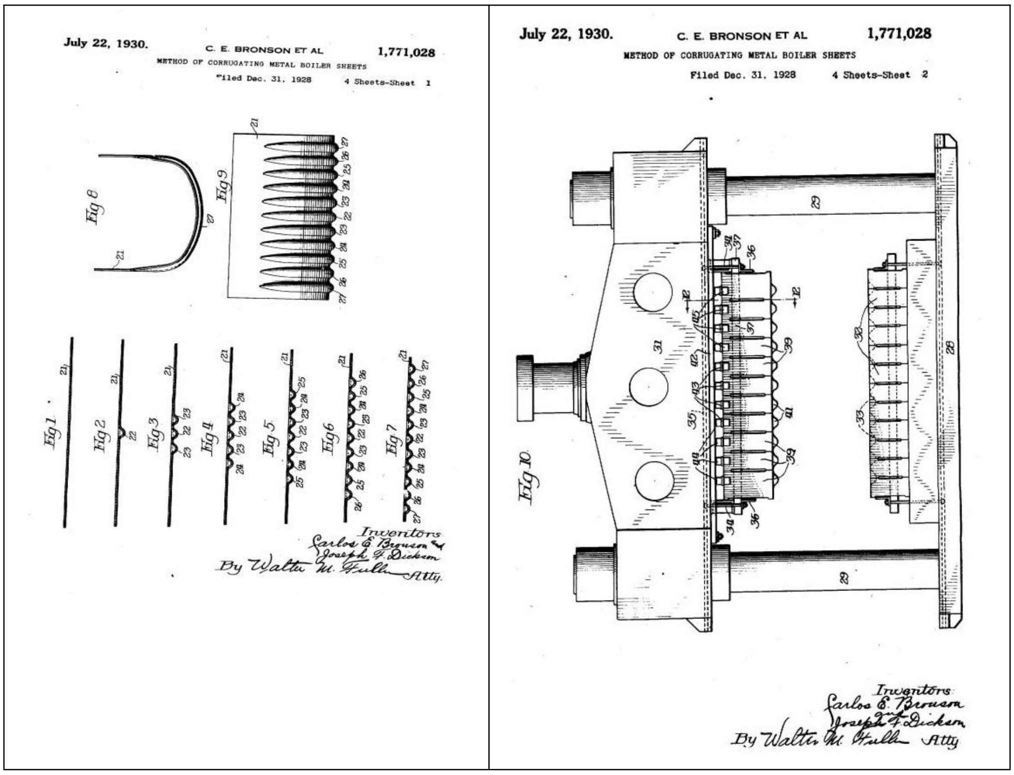
My understanding of the origami shape is that it consists of 6 equilateral triangles inside a circle. The apex of each triangle lying on the circumference is lifted to make a 45-degree incline. Of the two other vertices, one is lifted slightly more than the other to tilt the water channel either towards the centre or towards the circumference. In the photographs, the tilt is towards the centre.

The disadvantage of that arrangement is that fetching condensed dew is a slight problem. If it is tilted towards the circumference, then it is also possible to treat the outer surface running down from the vertical triangular surface as a dew condensing surface and increase the yield.

The mathematical details of drawing the parabola and deriving the paraboloid are given in Maths Note 2 in Annex 1.

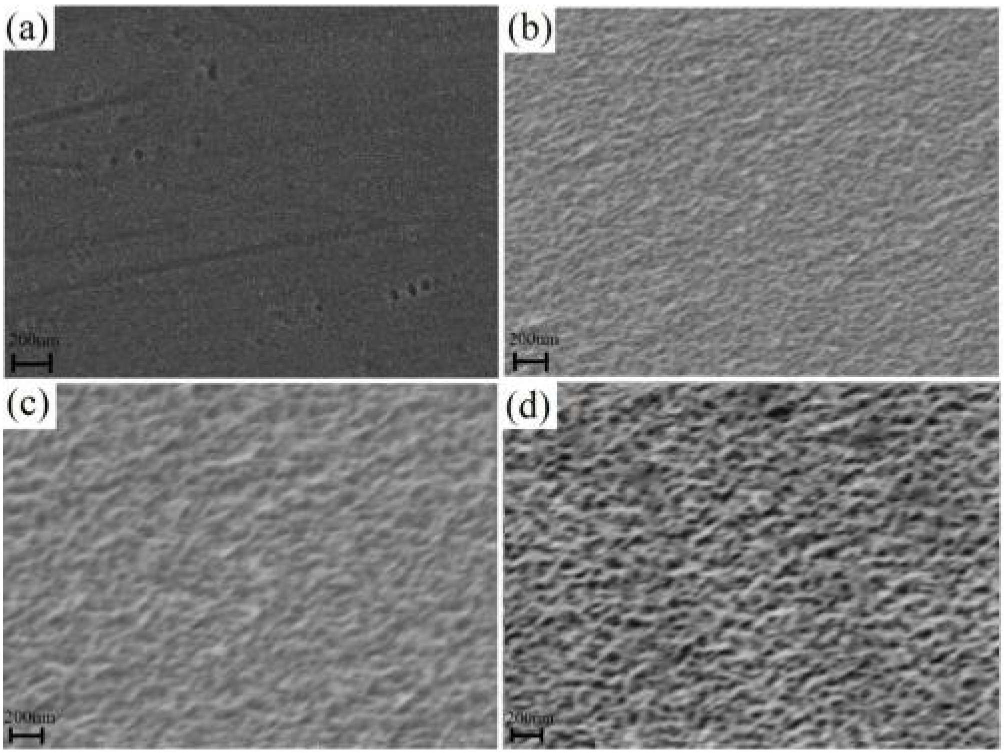
Increasing Surface area with a constant footprint

If a sheet of metal is pressed between wavy rollers and its side-wards expansion is limited, it develops corrugations that increase the surface area without increasing the footprint. Below are two images from a 1930 patent that illustrate the process.



Corrugations can be developed in an aluminium sheet with very little force being applied. MS or GI sheets may require more force.

Frosted glass cannot be corrugated any further. But it has a surface that has nano /micro-channels on it. An SEM photo is placed below that shows structures being developed with time (From an article by Dongkai Chu, et all)



Variants with recycled aluminium sheets

Aluminium sheets have two surfaces, one a shiny face and the other a dull blue painted side. The shiny side helps the drops slide down rapidly so the shiny side should be the first surface to be tried.

In order to increase the area of the surface, three variations of corrugations may be tried.

- In the first variation create corrugation by taking a fresh portion of 200/220-grade sandpaper and fix it against a block of wood the size of a shoe brush or slightly bigger. Keep the shiny side of the aluminium sheet facing up on a tabletop and with some pressure, run the sandpaper over the shiny side. One single steady stroke is to be used to cover the sheet from top to bottom. Repeat the stroke on the adjoining area until the whole sheet is covered with parallel strokes of sandpaper that has created dug-in corrugations of an average size of 50-60 microns.

- In the second variation take sandpaper of the same grade, i.e., 200/220, and first do the procedure given above creating dug-in corrugations. Then rotate the sheet by 90 degrees and run the sandpaper, in the same way, creating fresh corrugations that are perpendicular to the original corrugations. While this process will mostly create a rectangular grid, in some cases, the old channel will be partially blocked. Testing will reveal how much improvement we have got by either of the two methods.

- In the third variation take sandpaper of 400 grade that creates micro-channels of an average size of 23 microns. Fix it on a rectangular wooden block that you can easily hold in your palm. Now rub the sandpaper repeatedly in a swirling motion over the whole surface. We are trying to create short-length, shallow, swirling microchannels that may increase the area of the sheet and facilitate converting dew condensation into a film that flows down the channels. The overlap of rubbing action is perfectly fine.

Dull side variations As a first step try using the dull side, as it is, and note how much dew condenses on it.

- For the first variation, we will spray **a glossy black pain**t over the dull surface and test its ability to condense dew. It should be a good improvement over just the dull side.

- For further variations that are based on corrugations, we cannot use sandpaper over the painted side as clear corrugations do not happen within the elastic painted surface. Instead, we will create corrugations using two types of cloth.

    - First, take a piece from a polyester/rayon saree preferably crepe or chiffon that will cover the dull side of the sheet. In crepe and chiffon sarees, the count is high facilitating the formation of many thin corrugations and the yarn is hard twisted which shape will add to the area generated. Lightly spray glossy black paint on the dull side, wait for a short while so that the paint does not have the full time to dry, and paint a second coat. As soon as the second coat is sprayed, place the saree piece over it and rub it down into the paint. Next cover the saree piece with one more layer of glossy black paint. Wait for substantial time for the paint to dry, but not completely dry. With both hands slowly pull the piece of saree away from the sheet. The sheet should have corrugated paint channels formed on top of it.

- One more variation for generating corrugation can be tried. We take the opposite type of cloth, low count cotton floor swab, and apply the saree type treatment given above. Though the count is low and therefore the number of channels that will be formed, will be proportionately lower, each channel will have a greater area. Besides, the floor swab has microscopic cotton fibers sticking out from the threads. These will create additional very microscopic channels that will suck dewdrops and convert them into films.

If students dream up other ways to create corrugations, they should be encouraged to do so and evaluate the surfaces generated.

Frosted Glass
There are two variants worth trying with frosted glass. In one variant the plain side of the frosted glass is painted with glossy black paint. This may improve the radiative capacity of the frosted glass. In the second variation, we add an additional layer of styrofoam below the black painted surface and a shiny reflective foil below such that the shiny side faces the ground.

MS/GI /Blue Coated sheets

These sheets are tough and sandpaper will not be able to create effective corrugations. Corrugations of visible sizes can be created by mechanical rollers or die that is pressed by an archimedean screw.

All sheets should be tried as obtained from the market and then painted with black glossy paint.

Just like the dull side aluminium sheet, all these sheets will show corrugations when processed with a saree piece or cloth swab as detailed above.

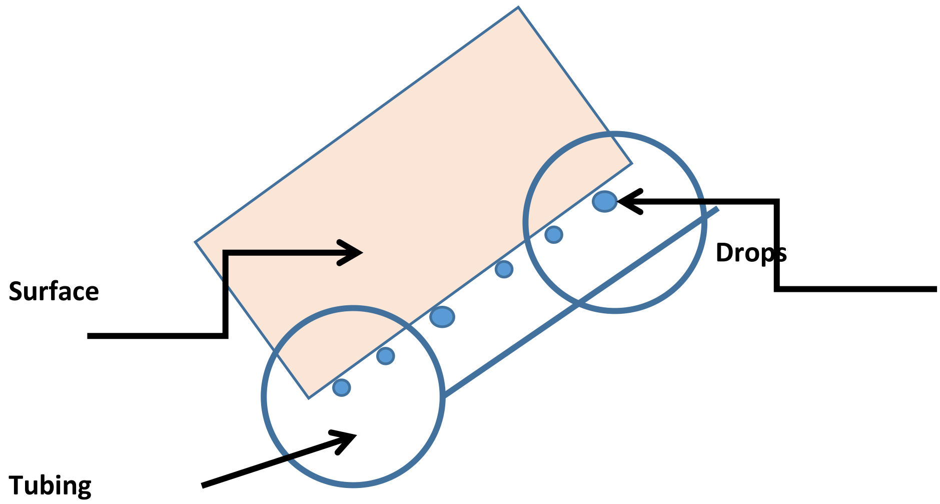
Structural Material: A readily usable structural framework material that can be used to join sheets, could be half-inch or one-inch PVC water pipes. They do not conduct heat, are lightweight, retain screws, and have a life of over 5 years.

Tubing and Joining of tubing to surfaces.
In nature, dew condenses as drops. These drops, which are mostly of the same size and the same distance apart from each other, need to coalesce and roll down into the bottle trap for successful harvesting of dew.

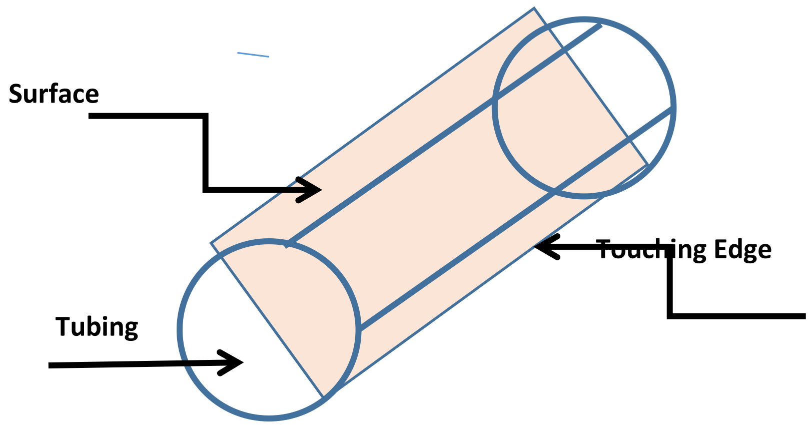
It is strongly suggested that as soon as possible, the dewdrops should be converted into films and that film should flow into the bottle trap without it ever forming back into a drop.

Flow by drops, compared to flow by films, is slower by magnitudes. All that is required to convert the dew drops to films on the condensing surface has been outlined above.

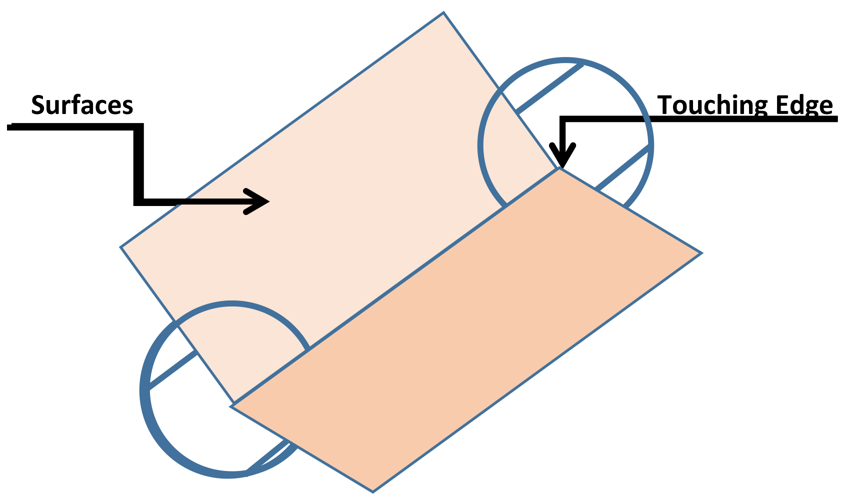
When the film reaches the lower edge of the surface, if permitted, it forms itself back into a series of drops and that hang on there while slowly growing in size, till gravity wins over surface tension. This edge drop formation can be depicted as shown below but is not desirable.



The arrangement of one surface joining a tubing should be such that the edge of the surface touches the tubing leaving no gap between them.



If there are two surfaces and one tubing, the surfaces must touch each other.



M Tech level Project Ideas

1. Simulation of shapes and surfaces using Computational Fluid Dynamics

The two papers below jointly describe how CFD is used to reach a shape that, on average collects about 38% more dew than a reference plane.

The papers are:

- Dew architectures “Dew announces the good weather” Beysens Danie l1 , Broggini Filippo2, Milimouk-Melnytchouk Iryna &Ouazzani Jalil3 Tixier Nicolas4
- Computational Fluid Dynamic (CFD) Applied to Radiative Cooled Dew Condensers By Clus Owen SILVALT Et a

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Both papers do not hide behind a paywall and can be freely downloaded or obtained from me.

The two papers are integrated with Beysens being the link.

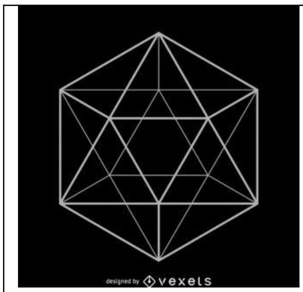
The software used for CFD analysis is Phoneics (CHAM | PHOENICS (rhinocfd.com) which is paid for software available for non -profit organizations at a different rate. It's UK-based. Many other software have similar functions and a college should be able to choose what it wants to use.

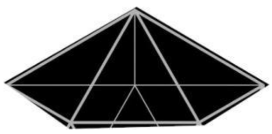
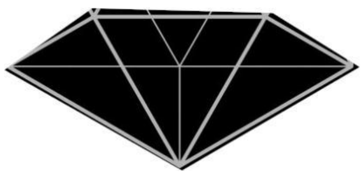
The first paper describes the shapes that were chosen.
The second paper describes in detail the procedures that were carried out.

The key findings are that shapes should be hollow such that they block the wind and they should have steep descent paths avoiding nearly flat surfaces throughout.

1 Re-verification: The M. Tech project could re-verify the work done previously using the Western Ghat data and North Indian plane date for RH, ambient temperature etc. Such data is readily available.

It could simulate and explore shapes like the (1) paraboloid with an average slope of 60 degrees (1a) Structure built using the solid of revolution of a catenary. A catenary is much easier to fabricate compared to a the parabola. (2) The top five triangles of an icosahedron that form its shallow cap (3) A structure based on a 2V geodesic dome shallow cap. (4) All these shapes but inverted and the outside surface is radiative and collection takes place at the periphery instead of the centre of the shape.

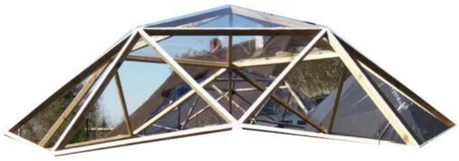


An Icosahedron	Shallow cap	Inverted Shallow cap

Mathematical numbers can be picked up from here among many other places

Desert Domes - The 1v Dome Calculator

	
2v Dome	**2V Shallow Cap**

For 2v shallow cap, the data can be picked from here

Desert Domes - The 2v Dome Calculator

2. Continuous harvesting of air moisture for growing trees.

Passive dew condensers work for about 4 hours at night in about 130 days during a year. Active moisture harvesters can work 24 hours a day but are very capital intensive and nonviable for common agroforestry projects. The potentially best, funded by DARPA, technology is based on **Metallic Organic Frameworks.**

Metallic Organic Frameworks are nano-structures that have holes where ions can be trapped. One noble prize winner is the leading researcher in a firm awarded a huge contract by DARPA to manufacture units based on this technology that can provide potable water and cooking water for a soldier. Other firms are also working on it. But MOFs are very capital intensive.

What follows is a low technology to 24 hours moisture harvester. What is losses in terms of efficiency, it may make up by scale.

Papercrete: Many years ago. I had introduced the papercrete technology to Vigyan Ashram. The easiest way to understand papercrete is to think of it as being concrete where the aggregate (rocks/stones) has been replaced by fiber from newspaper. In a large, specialized mixing bowl, water, old newspaper, and a little quantity of cement are mixed together. The mixer rotates at low speeds so that it does not cut the paper fibres but simply pulls them apart from each other. During the process of beating, a lot of air gets entrapped between the paper fibers. The ready mixture is poured into a form and excess water is allowed to slowly drain away. It sets in about 40 days and its compressive strength is much lower than cement blocks.

What is interesting is that papercrete has one property like MOF. It is full of holes in which water can be trapped. Newspaper by itself is hygroscopic and the hygroscopic nature can be enhanced by the addition of rice powder from cheap, unsuitable for the human condition, rice.

The weight of a panel that is 1 sq. mt. in the area and has a depth of 3- 4 cm is in hundreds of grams. It can be mounted as a panel(s) (straight or curved) facing the wind so that moist air passes through it. When enough moisture has been trapped, the panel can be rotated inside a closed enclosure, and the moisture extracted from it by centrifugal forces.

In a 24 hours cycle, the water from the panel can be repeatedly recycled.

No expensive desiccant, no latent heat of condensation, cheap to manufacture.
Power for centrifugal forces can be hand-applied or with little power.

3 If an M.Tech student wants to take up a project in this field with the intentions of pursuing it further, or conceive his own project, then there is another paper that should be looked at. The title of the paper is *"A review: dew water collection from radiative passive collectors to recent developments of active collectors" by B Khalil et al...*.The paper can be downloaded from here A review: dew water collection from radiative passive collectors to recent developments of active collectors (springer.com)
The paper reviews all types of dew condensers and describes several patented devices also, most of which are either in the public domain world-wide or are likely to be in the public domain in India. Please check carefully the status with the Indian Patent Office website.

Annexe 1 Maths Notes

[My maths is very rusty and the calculations could be wrong. Pl correct if need be.]

Math Note 1: Paraboloid
We want to create a paraboloid where the inner surface has a slope of 60 degrees and its vertical height is one meter. This means that the point (y*tan 60, and y) lie on the parabola. Given y = 100 cm, x will be 32 and if the parabola is of the equation y = aX^2, a = 0.097
The lateral surface area of the paraboloid will be 1.39 sq mt See a useful calculator Lateral surface area of Paraboloid given radius & Height Calculator | Calculate Lateral surface area of Paraboloid given radius & Height (calculatoratoz.com)

Math Note 2: Origami Shape
The origami shape in the photograph appears to start with a circle of radius 1.8 mt.
That circle has an area of nearly 10 sq mt.
The circle is divided into six equilateral triangles of sides 1.8 mt each with its height being 1.56
The area of each triangle is (0.5*1.8)*(1.56) = 1.4 sq mt and the area of the six triangles is 8.24 sq mt.
But the triangles are not lying flat on the ground. They have been tilted upward at an inclined angle of 45 degrees. This reduces the foot print area to 7.8 mt reported which is 92 percent of original. Tan Inv of 0.92 yields 43 degrees.
If these calculations are checked and found to be correct, then the following can be derived for a circle of radius one unit.
Calculations for any chosen area.
Sides of each triangle = 1
Height of each triangle = sq rt 0.75 0r 0.867
Area of each triangle = 0.5*0.867 =0.433
Area of six triangles = 2.601
Apex raised at an angle of 45 degrees. Tan(45) = 0.9
Foot Print area of origami shape =2.34