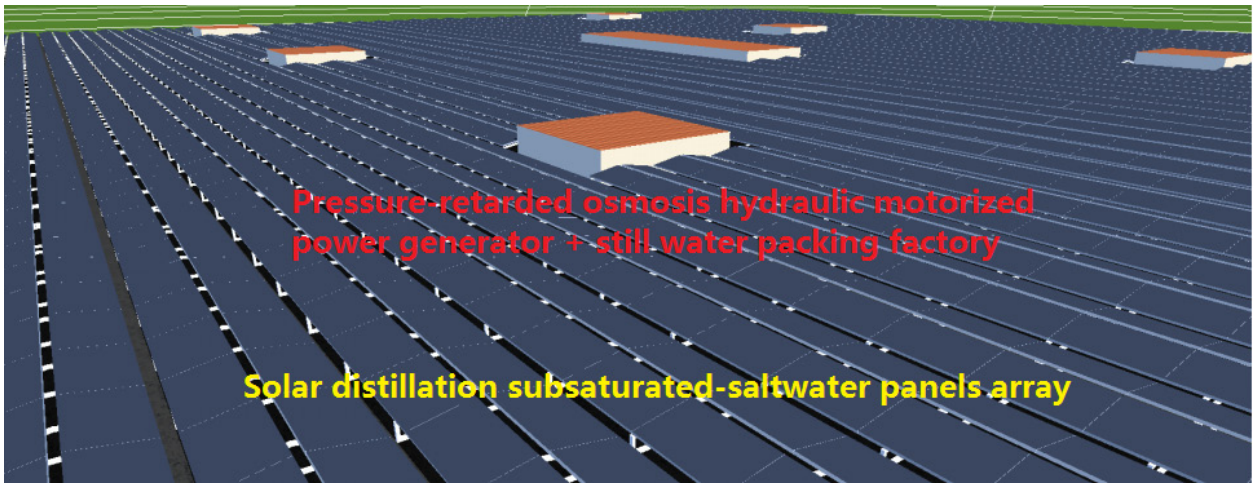

Co-generation of power and distilled water on big land by solar-osmosis closed-loop system

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Abstract

This paper presents up-conversion methods on whatever available big land, e.g. backyard or vacant land or farmland for booming green economy with new invention of solar-osmosis tandem technology so as to maximize multi goals: co-harvest of summer solar distilled or winter frozen potable water + pressure retarded fluid power, as well as pool buffered energy storage. By estimation, 1 km^2 land annual yield: 88 GWH energy + 1 million tons H2O in average zones. Also interlaced with some relevant political views.

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1. Technical solution

It is a perfect idea to co-generate power & fresh water with some my new patents: Pressure Retarded forward Osmosis (PRO) hydraulic energy storage & recovery solar powerplant + automatic gearless hydrostatic Continuously Variable Transmission (CVT) + solar distillation farm.

Power generation by PRO will convert lots of quasi saturated saltwater to exhaust diluted saltwater, and a reverse conversion is needed for sustainable power output.

There is a free method to do the reverse conversion: by solar evaporation then condensation to re-concentrate subsaturated saltwater.

Usually, therein solar evaporation pond is open air for low capital investment, and let "atmosphere heat engine" condensate vapor to rain in God's convenient time. Usually the precipitation average interval is about 9 days, and raindrop is polluted undrinkable water.

But if wish instant artificial "rain" for pure water production, then a closed-loop solar distillation configuration should be used. It may increase some cost, but profit is remarkably greater & specially fit for scarce water resource districts, where there probably are factories of drinkable water.

Even such a co-generation station can replace a big desalination plant if abundant land available!

In fact, solar distillation is free or almost free if considering casual maintenance, despite it needs big land sprawl. In contrast, per same average annual harvest, the prevailing reverse osmosis needs far less land for factory, but production cost may be > $1/ton.

By improvement of wick manifold, evaporation rate can be significantly increased, so as to make pure water production density & rate equivalent to, even greater than average one of the God's global precipitation -- 1000 mm/year or 2.74 mm/day.

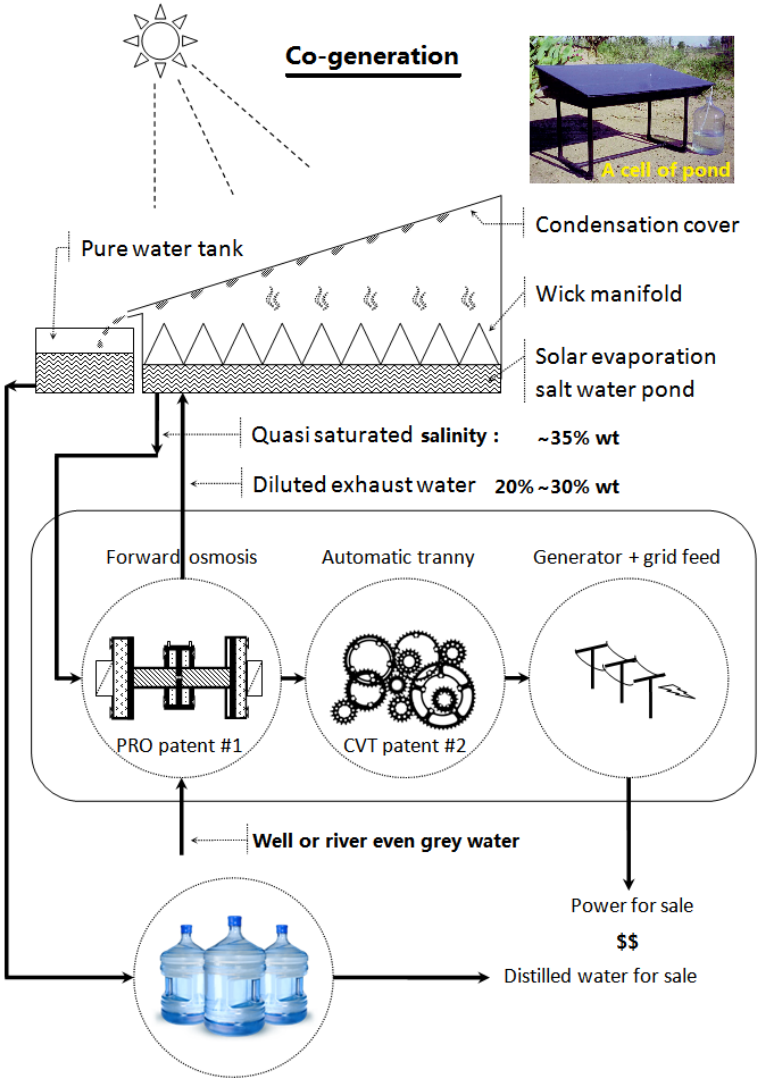
Thank Dr. Eric Torbet's pioneering work (ref #1), his solar distillation panel does apply wick technology for evaporation acceleration. Daily production rate in California is about 4 quarts per square meter.

Even recent best wick-sped product (ref #2) can have 0.86 L/m^2/sun-hour, then for summer daily 10 hour sunshine, max rate 8.6 L/m^2/day.

As to the power areal density performance, it is determined by the evaporation capacity, and as

per result of many experiments, the least harvestable solar power density by yearly average, is circa 3 w/m^2 in high latitude zones to 12 w/m^2 in tropic zones. If evaporation is accelerated by advanced wick technology, more higher capacity will be rendered.

So 1 km^2 solar-distillation-panels-cogen-farm can give city about 88 GWh/year + potable water for 1 million population. Thank capillary effect of wick material, for pure water production density & rate at least: 1 ton/m^2/year.



The system sketch is illustrated above, and even works too in frigid zones, e.g. Canada

If only in purpose of solar distillation, no need of saltwater, but the water from drilled-well is good enough as source input, even **grey water** can be used, and production rate will be increased by about 10%, because the evaporation rate of saturated saltwater is 10% less than natural water, according to Raoult's law.

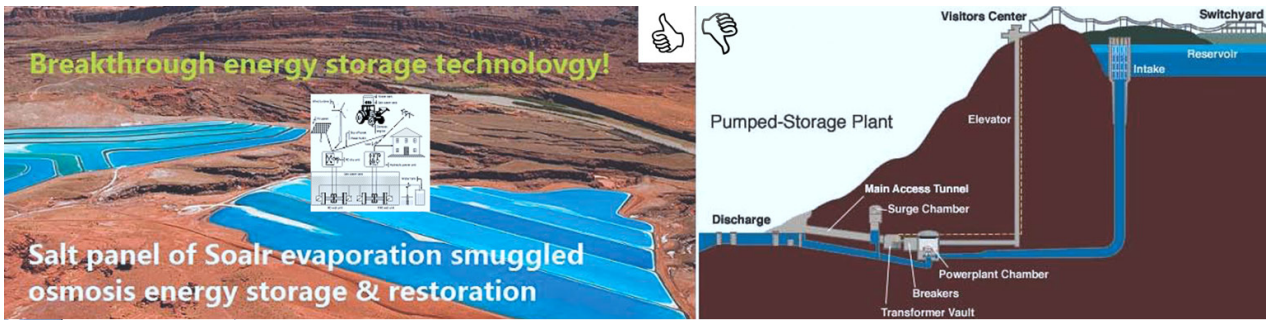
Assuming still water sale at $0.25/gallon, i.e. $66/ton, the sales income will be at least 4047*66 = $267100/acre, though main cost is HDPE or other recyclable bottles + labor.

In contrast, a soybean farmer can only get sales valve as miserable as about $650/acre.

Therefore, even not include power generation, the pure water sales per acre is 411 times more lucrative than crop produce!

Now that I have this "power + freshwater" co-generation technology of Forward Osmosis + wick-sped evaporation with solar energy harvest & energy storage, why still waste money to build Reverse Osmosis desalination plant for drinkable water with energy consumption?!

Further profoundly, with my improved PRO invention, the saturated salt water can cheaply store energy as well as harvest solar energy in large scale, even cheaper than the geologic- & location-picky Pumped Storage Hydroelectricity (PSH), so why to promote PSH?!



It is the CVT between osmotic engine & generator that enables capacity of energy storage, because adaptivity to large pressure fluctuation caused by wide salinity differential, can endure short term low or zero evaporation in cloudy weather or night.

If needless of solar help, Reverse Osmosis recharger is needed, but have to buy external power, then this application case can be modeled as **exclusive energy storage & recovery** to take **time-of-use** advantage by dodging hydro peak price and hugging valley price. For such dedicated application, big land is not necessary, but a big tank or cavern is OK.

2. How about maturity of technology?

Some guys may doubt the maturity of PRO technology, though I have enough confidence on my breakthrough invention, because they witnessed the lowest economical competitivity of a pioneer's first-of-its-kind pilot project in Norway by Statkraft, to all other harnessable renewable energy, though the pilot did successfully prove the technical feasibility.

I have learnt lesson of Statkraft "failure", and believe that it only proves sea + river mix NO commercial value. Too many membrane usage, too low energy density, even the Pelton turbine therein is so impossible!

But quasi SATURATED saltwater + freshwater PRO, which osmotic pressure is 20x higher than sea + river mix, can still render great commercial value, with lead-acid battery sub-equivalent (20%) decent energy density.

In physics, pressure directly reflects energy density, as manifested by the identicality of their dimensions PressurePascal = Newton/m^2 = Jule/m^3 = EnergyDensity, and low energy density

may seriously affect economical efficiency.

In fact, without a pilot project, even only by a gedanken experiment with rigorous calculation, the same correct conclusion can be made: the sea + river mix is not viable!

If the pressure behind the piss equivalent flow rate is in level of commercial hydraulic, then the embodiment by a small hydraulic motor will defeat the low pressure monster pelton turbine in economy performance, as illustrated in following figure:

Currently membrane technology is the "neck-of-bottle", and needs to fix the key issue of low breakdown pressure; another issue is the concentration polarization, though this issue not too serious.

Similar dilemma appeared in semiconductor industry long time ago, then-diodes suffered from low breakdown voltage, e.g. 1N4001 only 50 VDC, luckily soon later, 1N4007 debuted, with big leap to 1000 VDC.

I believe it will be same lucky to improve forward osmosis membrane up to 5000 psi breakdown pressure in near future.

Practically, current membranes can endure 80 bars or 1200 psi, that is beyond 3 times osmotic pressure of sea/river pair, despite still far less than 20 times of water vs saturated saltwater pair.

In analogy with electric equation of Power = Voltage^2/Resistance, for the realizable low-pitched 3 times increase of pressure, and for same membranes usage, the economical efficiency will 9 times higher than the Norway pilot project.

Supposedly, there exists a **threshold** pressure or salinity differential for economical viability, and even current imperfect membranes should make osmotic power competent to other trending renewables, while running on a compromised salinity differential yet moderately larger than sea/river pair.

Therefore, the fading Norway pilot project should NEVER discourage & deter mankind further R&D of osmotic energy -- the promising Blue Power!

Anyway, even the PRO power generation is not given a chance to try at all, or leave it as a place holder for future update, this closed-loop system can be still profitable, because of the cost-free (except packing material cost) drinkable water.

3. How farmers are globally exploited by modern society?

Craving for this real 100% clean energy, land is aimed; dealing with land, farmers have to be dealt with; concerning about farmers, their status quo has to be understood.

Farmers are taken advantage for long time! Look at this table:

Table 1. Corn and Soybean Returns, Central Illinois High-Productivity Farmland, 2015, Forecasts for 2016 and 2017

	Corn			Soybeans		
	2015	2016P	2017P	2015	2016P	2017P
Yield per acre	200	231	200	66	71	61
Price per bu	$3.77	$3.30	$3.50	$9.08	$9.20	$9.00
Crop revenue	$754	$762	$700	$599	$653	$549
ARC	45	20	0	45	20	0
Crop insurance proceeds	31	5	0	7	4	0
Gross revenue	**$830**	**$787**	**$700**	**$651**	**$677**	**$549**
Fertilizers	166	125	113	56	32	23
Pesticides	66	66	66	40	40	39
Seed	118	116	113	76	76	74
Drying	15	15	15	1	1	1
Storage	14	14	14	8	8	8
Crop insurance	24	24	22	16	16	16
Total direct costs	**$403**	**$360**	**$343**	**$197**	**$173**	**$161**
Machine hire/lease	12	12	12	11	11	10
Utilities	5	5	5	4	4	4
Machine repair	22	22	21	19	20	18
Fuel and oil	17	17	16	15	17	15
Light vehicle	1	1	1	1	1	1
Mach. depreciation	65	64	60	57	55	51
Total power costs	**$122**	**$121**	**$115**	**$107**	**$108**	**$99**
Hired labor	17	17	16	16	16	15
Building repair and rent	5	5	4	4	4	4
Building depreciation	12	12	12	10	11	10
Insurance	10	10	10	10	10	10
Misc	8	8	8	8	8	8
Interest (non-land)	13	14	15	11	12	13
Total overhead costs	**$65**	**$66**	**$65**	**$59**	**$61**	**$60**
Total non-land costs	**$590**	**$547**	**$523**	**$363**	**$342**	**$320**
Operator and land return	**$240**	**$240**	**$177**	**$288**	**$335**	**$229**
Land costs	278	268	245	278	268	245
Farmer return	**-$38**	**-$28**	**-$68**	**$10**	**$67**	**-$16**

In fact, growth photosynthetic energy yearly average 45w/m^2 is priced < 0.04¢/kwh or 1% of hydro 5¢/kwh, even assuming labor + seed + fertilizer + diesel + MachineDepreciation = $0.

∵ 365*24*0.045*0.0004*4047 = $638/acre = normal crop sales

Of course, the zero cost assumption is not correct. Usually cost will take ~90% of crop sales, so the real growth solar energy may be sold at tiny as 0.004¢/kwh.

∴ comparing with hydrogrid energy price 5¢/kwh, everyone will see this almost zero 0.004¢/kwh i.e. 0.08% of hydro price, rendering how extreme unfair to our lovely farmers!

By the way, **if you ate today, please thank a farmer**, because the food is almost free, though you paid per the market price, which is not even cover 1% of input photosynthesis energy.

Someone may argue the solar energy for photosynthesis is God's free gift. However, the private farmland is never free, but high price capital, which is more expensive than PV (PhotoVoltaic) panels, on which the same free gift sunshine converted energy is priced as high as ~20¢/kwh with government subsidy.

Further, **not all eaters created grateful**, even food almost free.

Farmers work hard to supply cheap beef, but ungrateful gluttonous guys may berate your cows big emitter of flatulent bio-**methane**, one of the culprit of global warming like **carbon dioxide**, even they intentionally stigmatize the crude food producers as **redneck**.

Do you know a cash crop farmer how hardly to make same money with a **sunshine-listed** government officer, i.e. > $100,000 annual salary?

Generally speaking, per net profit $50 to $100/acre, shall the Lord have mercy with good weather, he or she has to farm at least 2000 to 1000 acres with use of expensive fleet of heavy duty machines (tractors, harvest combines, pesticide sprayers, etc. mostly have hydraulic power) in total weight 100+ tons; even a dairy farmer has to pay government about $36900 per 1 kg milk protein **quota** in our Canada, Yes, that is the answer!

Elite groups, policy makers, tax-sucking bureaucracies and highfalutin governments have been greedly exploiting farmers too much, and they also try to hide the scientific facts, so as to appease farmer's discontent.

It is a shame!

With miserable sweat-soaked marginal profit, many farmers are too vulnerable and risking of

bankrupt if hit by heavy retaliation of trade war.

This situation does not comply with the **Sustainable Development Goal** #8: decent work & economic growth of United Nations **2030 Agenda**, and must be changed, for no more hillbilly elegy, for no more victims of trade war!

It is the high time for farmers to rise up by land industrialization.

4. Obligation for US farmers to feed world as more as possible?

It seems that US farmers produce too much food far more than total domestic demands, so most produces have to be sold oversea to feed other countries.

In fact, US 3-million farmers have been feeding global 2-billion population!

But no obligation to do so, why not reduce farming, and industrialize surplus farmland to reconstruct then optimize domestic economic spectrum?

China provides a good example on such transformation.

Since accepted by WTO, China has mobilized surplus farmers 286M, i.e. ~1/3 of total agri-labors to factories, & many farmland is converted to high value industrial or residential use, so its domestic food supply is short of 1.3B population need, & has to depend on import.

The more export of farming produces, the more high value non-agri workforce in other countries, then the higher competitive stress of US global leadership, because rivals can transfer more resources from miserable agriculture to lucrative industry, and pay little to import dirty cheap food, even as trade war retaliation tool.

Once upon a time, this MIT-graduated talent Thomas Massie would dream of being a great farmer with decent income to support a large size family.

But perhaps felt impossible to realize his dream after long time fumble, now he becomes a prominent republican congressman with real decent salary, and doing a good job for MAGA.

This powerful genius president #Trump seems to love farmers very much, but if without a smart adviser, he may not really know how to create an epoch with great farmers.

5. Land size dependence for some commonest demanders

The Sun gently cooks our common Earth, and all creatures or man-made machines prosper with necessary solar energy consumption by direct or indirect means.

To sustain existence, there must be basic quote of land size that is supposed to receive sunshine to do whatever conversion for feeding:

> one man -- 400 (unit m^2, same for all other likes if unspecified)
>
> one woman -- 300
>
> one cattle -- 4000 ≈ 1 acre
>
> one car -- 450

Based on assumption:

> internal combustion engine efficiency 25% (burning ethanol from crops)

commuter's car usage 50km/day

body heat dissipation - cattle 1000w, man 100w, woman 75w.

All above reference data are backed by substantial scientific study, readers can google it.

6. Industrialize farmland & reformulate economic spectrum

As productivity of US agriculture is far more than domestic demands, even keep 1/6 farmers can still feed USA & let 5/6 become non-farm workforce, & surplus land can be for solar energy &/| drinkable water production or other purpose.

Now farmers will eventually have a rude awakening, they should partially convert their dirty-cheap use of precious farmland to high value use of energy production, or the equivalent one, so as to play fair with other walks of life.

Planting ethanol crop or algae for biofuel may be a choice, but not as good as my proposal: land for power + potable water co-generation.

PV should not be a choice, because high capital is hardly affordable for any farmer.

If energy from farmland is fairly priced 5¢/kwh, farmers don't have to use my solar-osmotic energy + water co-gen patent for farmland value upconversion, and can use whatever zerotech or cheapest/free method to make same sales value with grains, by scraping tiny 0.36w/m^2 from solar standard 1360 w/m^2.

∵ 365*24*0.00036*0.05*4047 = $638/acre = normal crop sales.

Therefore the net profit will be some times higher than crop's, as the cost is quite low.

With lowered expectation, even picking up as tiny as yearly average 0.18 w/m^2 from sunshine , then $330/acre, still may be better than farming.

Above estimation even does not include the cash-printer-like production of drinkable water, otherwise the acceptable minimal harvestable yearly average power density may further lower to 0.05 w/m^2.

The Sun offers power density 1360 w/m^2 for free, how is a humblest guy not able to get yearly

average 0.05 w/m^2 for making a living?! I believe everyone can if sticks to do it.

Of course, my advanced CleanTech can guarantee harvestable solar power density yearly average 3 w/m^2 at least even in extreme frigid zone, or 9 w/m^2 in most regular zones.

Good choice: let land be lucrative co-generator of solar energy + distilled water with luxury expectation of gross profit $17K/acre/year, even without consideration of water value, by my disruptive invention:

Pressure Retarded forward Osmosis energy storage & recovery hydraulic engine with SOLAR wick-sped evaporation saltwater panels farm.

1 km^2 cogen-land = (Solar Energy 88 GWh + distilled water 1 MM tons)/year.

The harvestable power density of my invention depends less on membrane, as hydraulic output high pressure ~4000 psi, then low flow rate; but highly depends on evaporation rate of subsaturated saltwater, as forward osmosis dilutes & solar energy periodically concentrates exhaust solution.

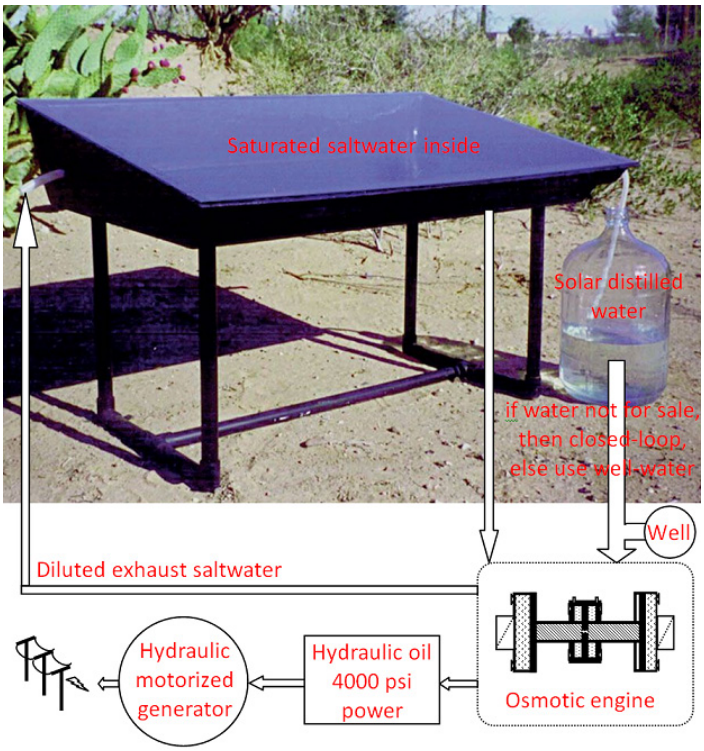
Also, tiny harvestable solar power density doesn't mean tiny output, the backend hydraulic engine can output as high as huge MW power if the osmosis flow rate high enough, but backlog storage will be quickly drained.

Cheap wick-accelerated distillation will improve this system upto even more than photovoltaic level, i.e. >20 w/m^2 yearly average, as wick manifold is simply to multiply evaporation area, which is linearly proportional to evaporation rate!

By reducing farmland & ag-labors, then industrializing land for solar-osmosis energy+distilled water, gradually, food price will significantly hike, so as to increase landowner's income & protect vulnerable farmers, as well as to lower clean energy price, then cleanly power whole country, because power from farmland is so cheap & easy to defeat traditional hydropower 5¢/kwh.

Imagining scaleup of solar-osmotic panels to cover most farmland, then renewable energy will be tremendously abundant & convenient of accessibility everywhere, and its wake effect will attract US-originated but global-oriented manufacturers to relocate factories home, then foreign investors will troop in, next then boom economic ecology, eventually make America great again!

Following figure illustrates cellular scheme of solar-osmotic co-generator of power + drinkable water with inborn energy storage to buffer short time weather change:



7. Co-harvest cold energy & ice in frigid countries

With tandem cooperation of landscape solution concentrator and Pressure Retarded forward Osmosis (PRO) power generator sucking flowable water from well or reservoir, not only hot is harvestable energy, but also COLD, because at frontend of tandem, either hot or cold can re-concentrate the diluted exhaust of backend.

As water evaporation heat 2.4MJ/kg is 7x fusion heat 0.33MJ/kg, therefore cold energy efficiency of heat-to-work is 7x higher.

Winter wind speed is far higher than summer, it credits more higher areal power density, because chilling effect enhances the heat transfer coefficient, easy >> 10 w/m^2/K, so as to quicken icing rate.

In -30 °C deep winter days, ice thickness growth rate 10 cm/d is possible, & it means the fulltime continuous harvestable power density 52 w/m^2 pond, multiples of summer time!

The thicker the ice sheet, the lower the followup icing rate, as ruled by itself insulation.

So to keep high energy density, some labor should input to rake out ice sheet, them dump in crushed ice pit by a reasonable schedule;

As the labor is not difficult, automation machine can save labor cost to do same job.

Provided pit is large enough, no worry of ice in pit, it is drinkable quality, just leave it there, and wait for spring or summer season to melt it, or sell ice anytime.

In Canada, if good maintenance job or frequent ice harvestation, total ice accumulation can reach 1.5 meters per winter, even Rideau canal natural as-is skating rink 60 cm thick.

Even an operator is lazy or loves to use it for skating sport, free cold energy can still be harvested, though less amount, as long as the pond can hold all winter ice.

Imagination of the **nameplate** on your topsoil-embedding pond co-generator for cold weather: one meter thick ice is equivalent to 15 kwh/m^2 kinetic energy, as well as potable water in ice form. Sounds cool?

The colder the weather, the higher the harvestable cold energy; but it may be not fit to year-round extreme cold zones, such as arctic or antarctic, because forever no chance to solarly melt ice for recycle.

As freezing point of saltwater is lower than freshwater, the real chart of harvestable cold energy versus temperature may need substantial downshift along temperature axis.

Of course, for this application scenario, saltwater panels are not recommended, and no production of solar distilled water in summer, except only backend PRO power output, or say, recovery of frontend evaporation energy; just let it be an open-air shallow pond open-loop system with wall-less transparent low roof for rain/snow shedding, and enjoy the cheaper capital investment than distillation panels closed-loop system.

By the way, another business of salt production, not only can use evaporation pond method, but also icing pond method. Although the icing method is more efficient, however the Great Nature never offer seaside frigid weather, thus the latter is rarely used. A few of inland salt lakes in cold zones use both methods in different seasons, as showed above.

8. Comparison of profitability vs land usage by purposes

Following picture tells the result of comparison at all dimensions:

Average power density & price comparison

Is PV the king? Let math speak: though 100 w/m^2 can be seen at moment of summer noon, because Earth sphere area = 4*π*Radius^2 = 4 times of area of max cross section circle, thus 100/4 = 25 w/m^2 daily average in summer, even assuming whole year only summer or so seasons, best PV may be 20 w/m^2 yearly average.

Considering that PV high energy consumption during manufacture is hardly recovered within 10 year service, so it is never the best, even not so-so deal for clean energy world.

In frigid zones, solar-osmosis may render higher energy density than PV in yearly average, because of potential extra phenomenal cold energy harvest in winter.

9. How to feed those motorized vehicles by solar-osmosis?

I'm R&D-ing car-fed-by-land too.

Above prototype is heavily dependent on home-base evaporation pool or solar distillation recharging backend. After exhausted, both water tank and saltwater tank of the vehicle must be refilled and replaced respectively.

In future improvement, the top surface of vehicle will be used for on-the-fly evaporation in summer or icing in winter, so as partially to or not to depend on home-base implement.

To feed a car with 50 km/day usage, the owner needs 450 square meter backyard, and the area size may reduce to 200 square meter in the future with technology evolvement.

10. Land zoning & policy maker's stance

In most countries, land use is usually regulated by zoning plan.

If wish use farmland for solar energy production, I suggest farmers to lobby policy makers or to fight for land zoning change with help of non-government organization!

Following photo: farmers setup sign "Back off government"

For national food security, policy makers could use below equation to calculate how many minimal total square meters farmland should be guaranteed for crops:

reserved farmland quote = population * 400 + cow/cattle heads * 4000 + hog heads * 600

11. Niche applications

a. Environment remedy on hydraulic fracking wastewater

Shale gas revolution is driving the widely application of hydraulic fracking method, but it is really not friend to environment, because lots of wastewater is generated.

If the tailings too muddy, as osmosis membrane is delicate, co-gen is not recommended, but the simplest solar distillation uni-generation is encouraged, so as to reclaim most water for nearby fracking project.

b. Greywater recycling

Residential waste water is most likely grey water that is relatively sub-clean, and my co-gen solution can be applied for household water saving plan, as well as producing drinkable water plus clean energy.

More applications can be possible if deeply delve.

12. Want to earn your credit in this cleantech revolution?

If you're membrane maker, please donate some forward osmosis cartridges; core should withstand 3000+ psi. As a quid pro quo, I'll designate you as OEM since market is ready;

If you're rich acreage land owner or farmer, we could build pilot project on your property;

If you're visional investor, please earmark your quota in our incorporation equity;

If you're deep-pocket philanthropist, please donate to support our R&D;

If you're university | national lab, let's collaborate;

If you are a candidate of master or doctorate degree, and interested in this realm forefront, please

ask your scholar advisor for setting co-op opportunity + letting me as co-tutor on your thesis of solar-osmosis tandem study;

If you **(**are a rich guy | have a rich daddy**) &** you graduated from university in STEM especially energy relevant engineering specialty **&** you are self-starter with entrepreneurship, I welcome you on our board as a co-founder;

If you only love highest harvest for quick money, this may be not for you.

All contributors, will be credited, while we speak out success story someday of future.

As a special deal, if you are government administration, I may be open to your buyout offer or other customized offer, and I believe this breakthrough invention can make your country great again and powerful again in the world!

No restrict on credit-earner's geographical locations or identity of countries, unless those active US-sanctioned countries or entities, all in all, we need your support, thank you!

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choice #1 Original pdf manuscript, 1.5 lines spacing, easy read version

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