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Development of a Solar Water Desalination Plant

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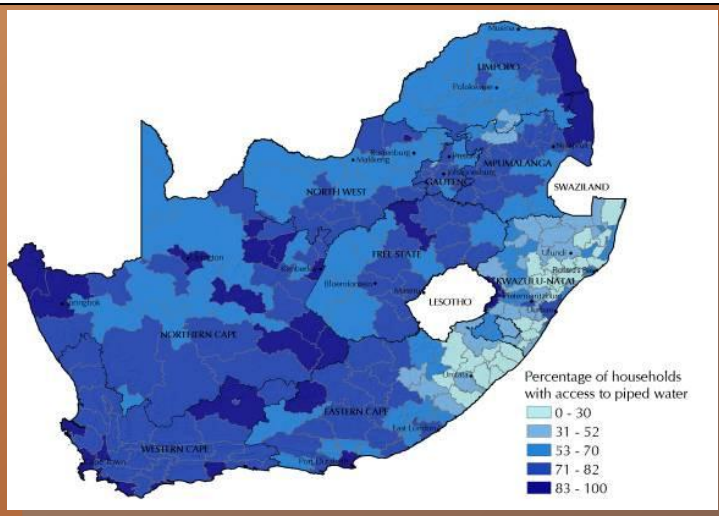
OUTLINE

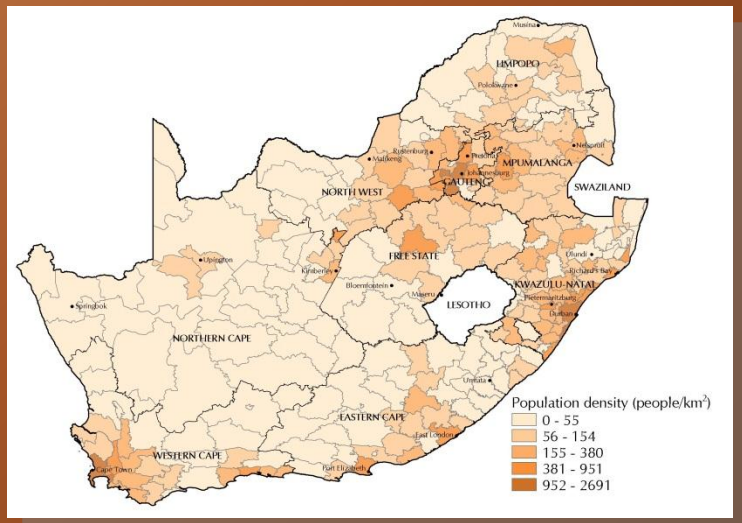
- Background
- Development of a pilot plant
- Methodology
- Preliminary results and discussion
- Conclusion

Background

- Rural communities
- Access to clean drinking water
- Saline groundwater
- Concerns regarding the quality of the groundwater resource
- Desalination of brackish water and seawater an options to reduce pressure on the country's water supply.
- Northern and Eastern Cape Provinces -generally least access to piped water



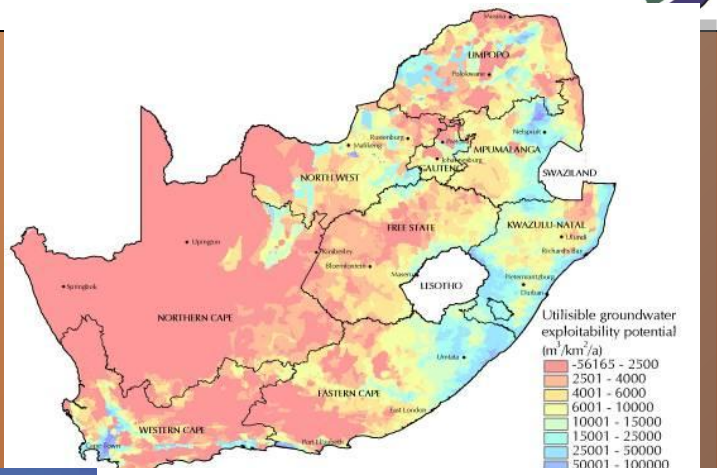
Access to piped water

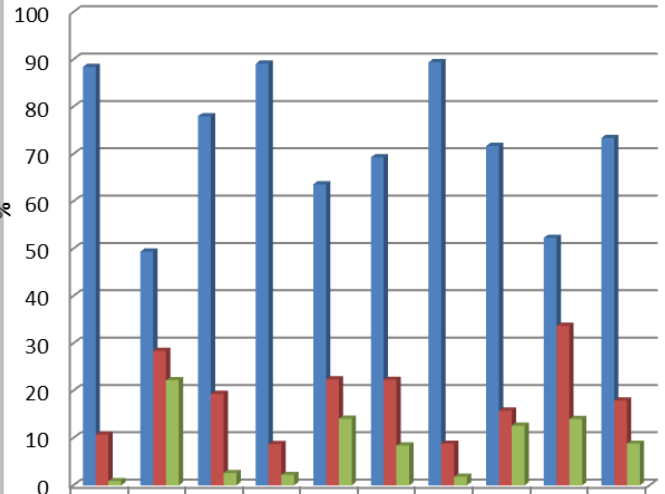


Population density (SSA, 2006)

Background

- Groundwater contributes 15% of the total volume available
- Over 300 towns and 65% of the rural population are entirely dependent on this resource for their water supply
- Rural households travel in excess of 500 m
- Ground water potential map - large parts of the Northern and Eastern Cape provinces have very limited exploitable ground water

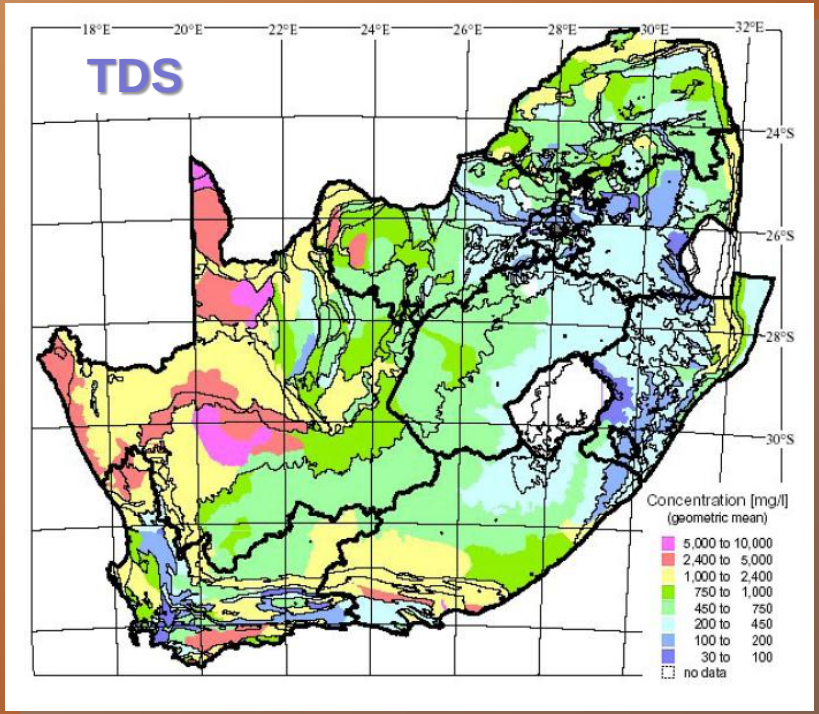




	WC	EC	NC	OFS	KZN	NW	GP	MP	LP	SA
Piped water inside dwelling	88.4	49.4	78	89.1	63.6	69.3	89.4	71.7	52.3	73.4
Piped water close to dwelling	10.7	28.4	19.3	8.7	22.4	22.3	8.8	15.8	33.7	17.9
No access to piped water	0.9	22.2	2.6	2.2	14.1	8.4	1.8	12.6	14	8.8

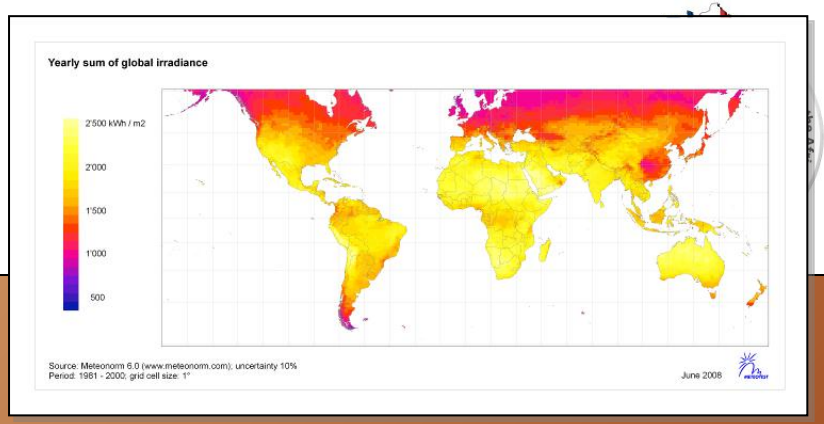
Background

- **Semi-arid to arid regions** - significant **salt load** in groundwater
- **High fluoride** concentrations - Northern Cape, Limpopo, Northwest Province and Orange Free State
- **Elevated nitrate** concentrations in the **semi-arid to arid regions of the Northern Cape Province, Northwest Province**, **Limpopo Province** and **Karoo**
- **Anthropogenic generation of nitrate**
- **Microbiological water quality**

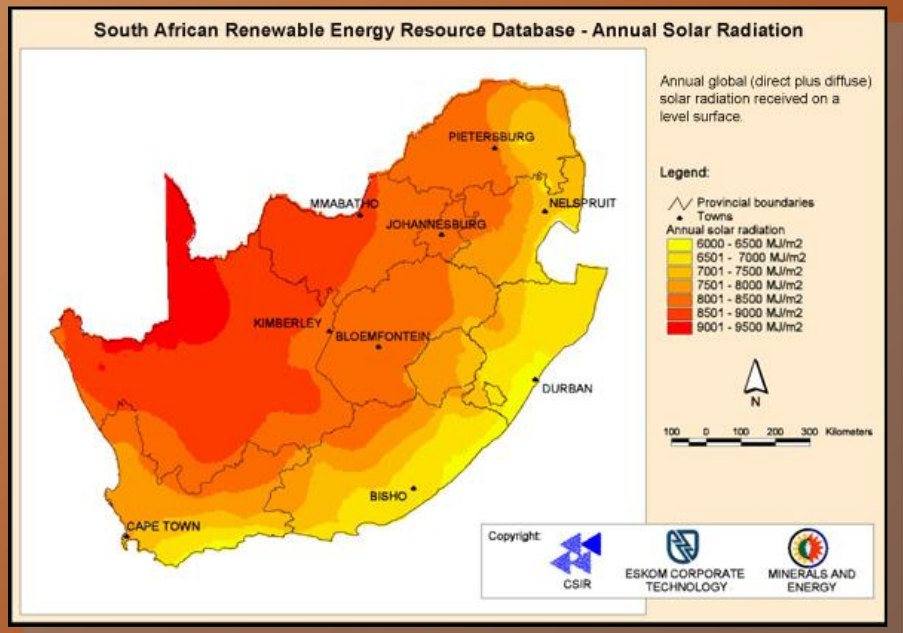


Salinity refers to the total dissolved non-toxic inorganic compounds in the water and is measured by total dissolved solids (TDS) and electrical conductivity (EC)

Background



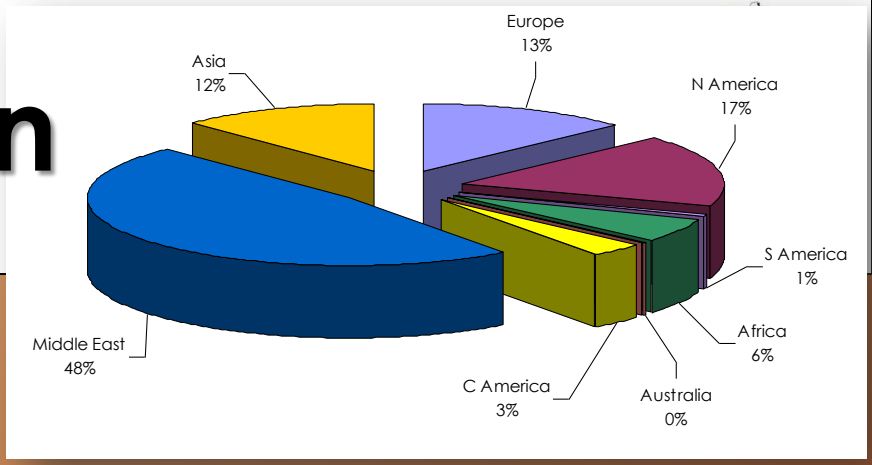
- SA's local resource one of the highest in the world
- average >2 500 sunshine hours per year
- average solar radiation levels range 4.5 to 6.5kWh/m^2 in one day
- geographical areas where the annual solar radiation levels are high
- Solar radiation
  - lowest in KZN
  - highest in Northern Cape and Limpopo



Pta: 1900-2000 kWh/m^2

Matjies: 2000-2100 kWh/m^2

Desalination



- Two main technologies:
  - **thermal technologies**
  - **membrane technologies.**
- Thermal technologies
  - **heat water and collect condensed vapour** (distillation) to produce pure water
- Distillation processes - rarely used to desalinate brackish water (<10,000 mg/l TDS), as it is not cost effective
- Thermal desalination is **energy intensive** - most commonly practiced on large scale in areas with abundant fossil fuel such as in the Middle East

Background

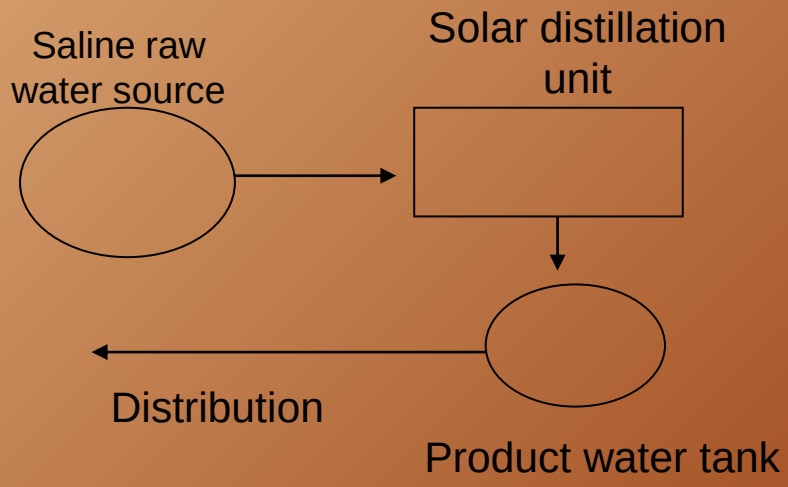
- Most widely used solar thermal desalination→ **simple solar still**
- Distillation → heating a liquid until it vaporizes, condensate collected in a separate container
- Main disadvantage is low yield efficiency
- Two demonstration plants using small solar still plants near Ladysmith, Klein Karoo– **Kerkplaas** and Algerynskraal

Simple solar still

Algerynskraal

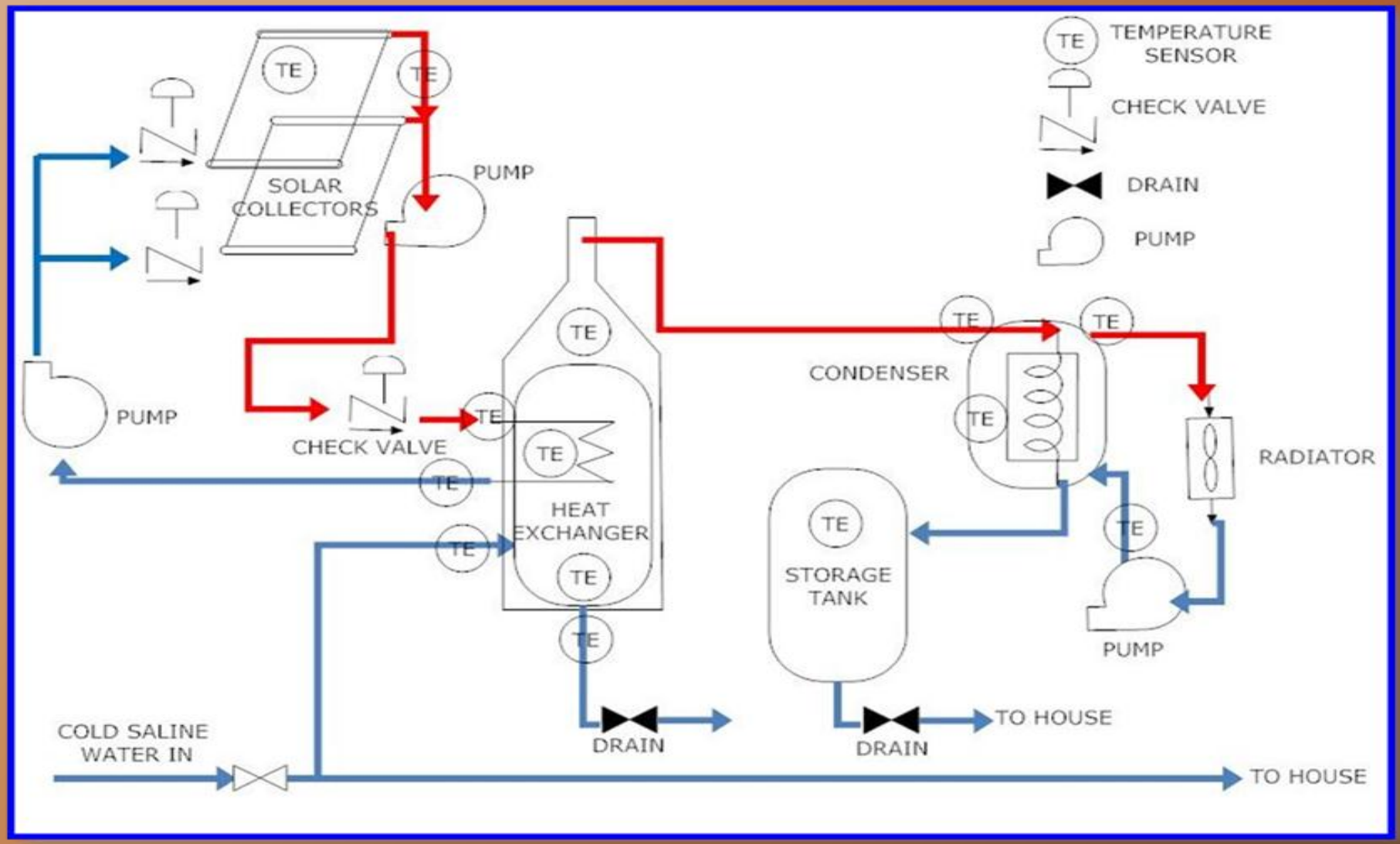
Pilot plant development

- Hot heat exchanger fluid leaves the solar panels at the top and the cold fluid enters the solar panels at the bottom
- Heated exchange fluid enters copper pipes, installed in the evaporation tank
- Heat exchange pipes transfer the heat energy to the salt water
- Circulated through this system by 12V pumps



- Heat exchanged will evaporate the salt water
- The evaporate needs a large cool area to condensate
- Design is currently a dome-shape fitted with an extraction fan
- Extracted humid air allowed to condense in a network of copper coils in a 50liter tank with circulating cooling water
- Distillate collected

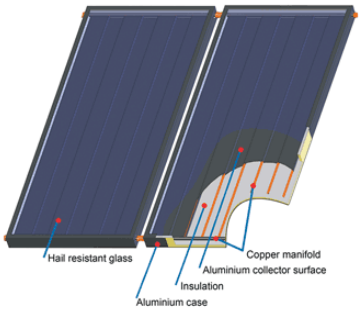
Pilot plant


TE
TEMPERATURE SENSOR
CHECK VALVE
DRAIN
PUMP
SOLAR COLLECTORS
PUMP
CONDENSER
RADIATOR
CHECK VALVE
HEAT EXCHANGER
STORAGE TANK
PUMP
COLD SALINE WATER IN
DRAIN
DRAIN
TO HOUSE
TO HOUSE

Pilot plant

SunTank Collector Specifications

Manifold Tubing Risers	Copper 8x15 mm
Manifold Tubing Headers	Copper 2x22 mm
Collector Plate	Aluminium - heat coated (black)
Case	Aluminium - heat coated (black)
Insulation	High density polyurethane
Reflective Coat	Aluminium foil (moulded on PU)
Max Working Pressure	800 kPa
Cover	3.2mm tempered solar glass
Inlets / Outlets	22 mm copper female
Length	1800 mm
Width	850 mm
Height	95 mm
Weight empty	25 kg
Weight full	28 kg
Volume	3 litres
Recommended Ratio (Africa)	1 Collector per 100 litres



Face north inclined at 23.5 degrees to ensure maximum transfer of radiation

Pilot plant

Methodology: Evaluation of pilot plant

- Production rate
  - Typical late winter's day
  - Variation in water depth
  - Increased surface area
- Water quality

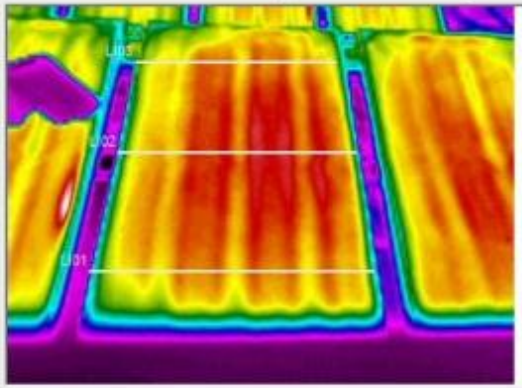
Methodology

G:\CUT experiment - Daniel

ID0001_20120224_2270

11:29:25.378 11:17:58.454

21.3 – 65.0 °C

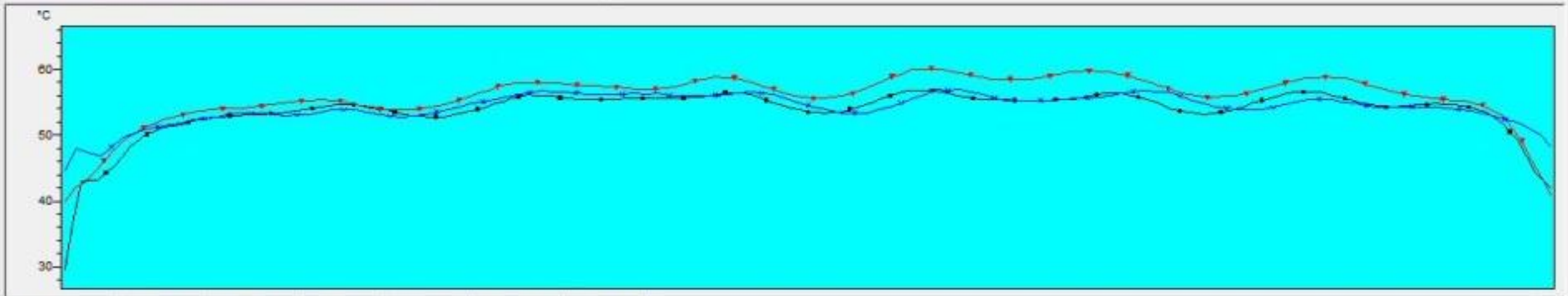


65.0°C

21.3°C

Analysis | Position | Obj. Par | Image | Text comment

Label	Value [°C]	Min	Max	Max - Min	Avg	Stdev	Result	Expression
Image		20.9	66.9	46.1				
L101		29.6	56.9	27.2	53.7	3.6		
L102		39.9	60.1	20.2	55.8	3.8		
L103		44.7	56.9	12.2	54.2	2.2		

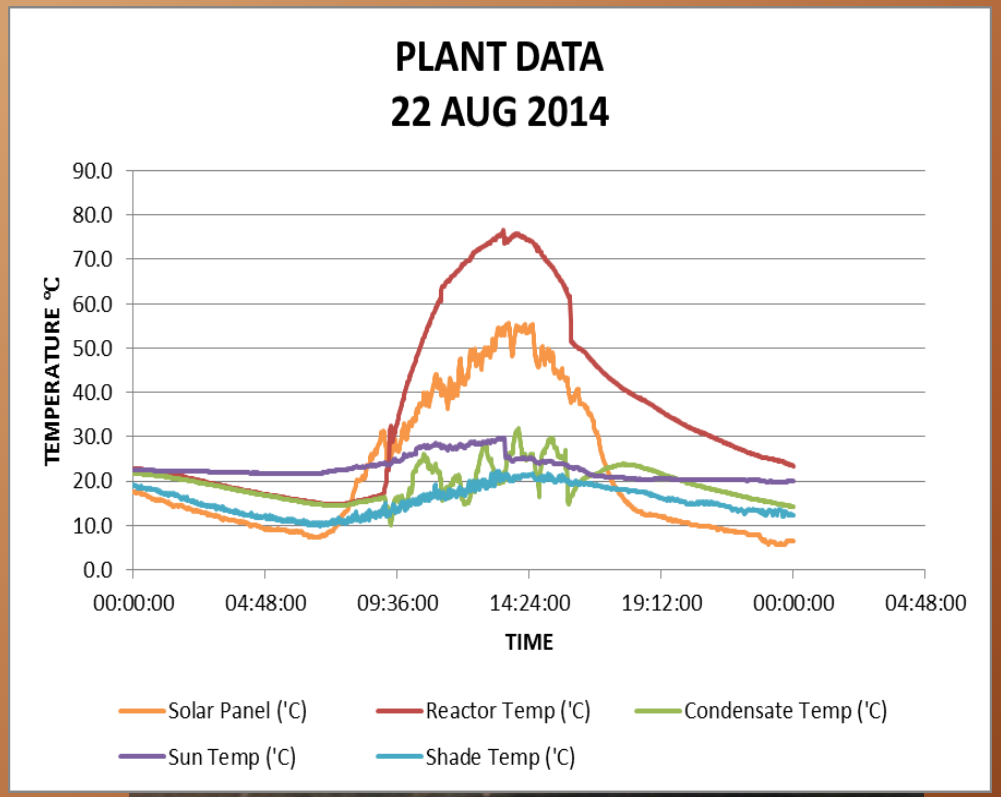


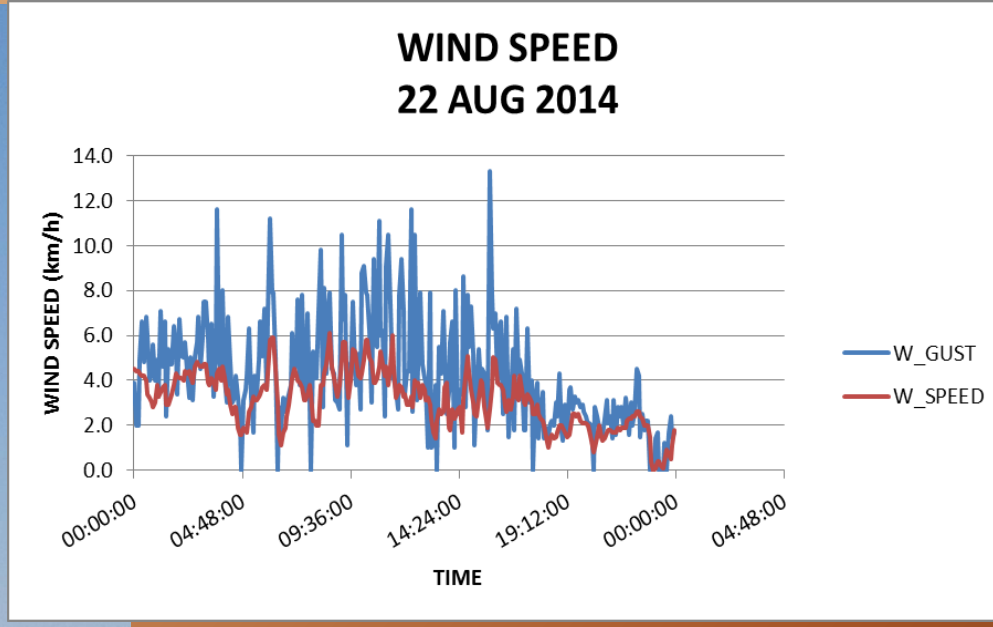
Label	Cursor	Min	Max	Avg	Cursor X	Cursor Y
L101	-	29.6	56.9	53.7	-	-
L102	-	39.9	60.1	55.8	-	-
L103	-	44.7	56.9	54.2	-	-

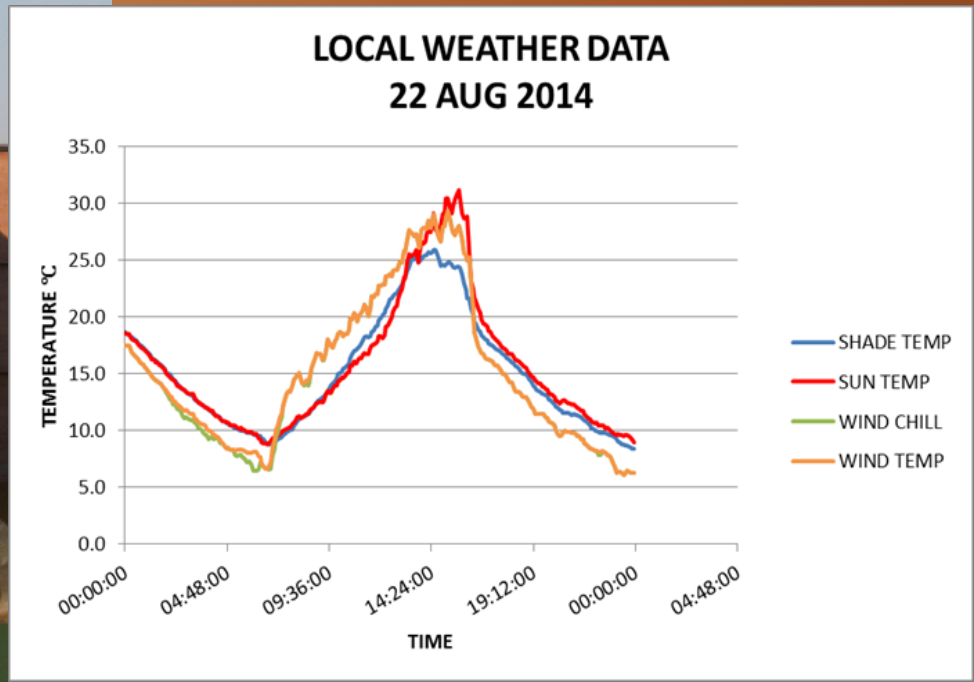
IR | Results | Profile | Histogram | Plot | Multi

Pilot plant

- PT100 temperature probes
- typical late winter's day with sun temperatures reaching a high of 30℃ around 15:30
- maximum evaporation tank temperatures (> 60 ℃) reached between 11:00 and 16:00 correspond to the ambient temperature between 20 and 30 ℃




WIND SPEED
22 AUG 2014
WIND SPEED (km/h)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
00:00:00
04:48:00
09:36:00
14:24:00
19:12:00
00:00:00
04:48:00
TIME
W_GUST
W_SPEED

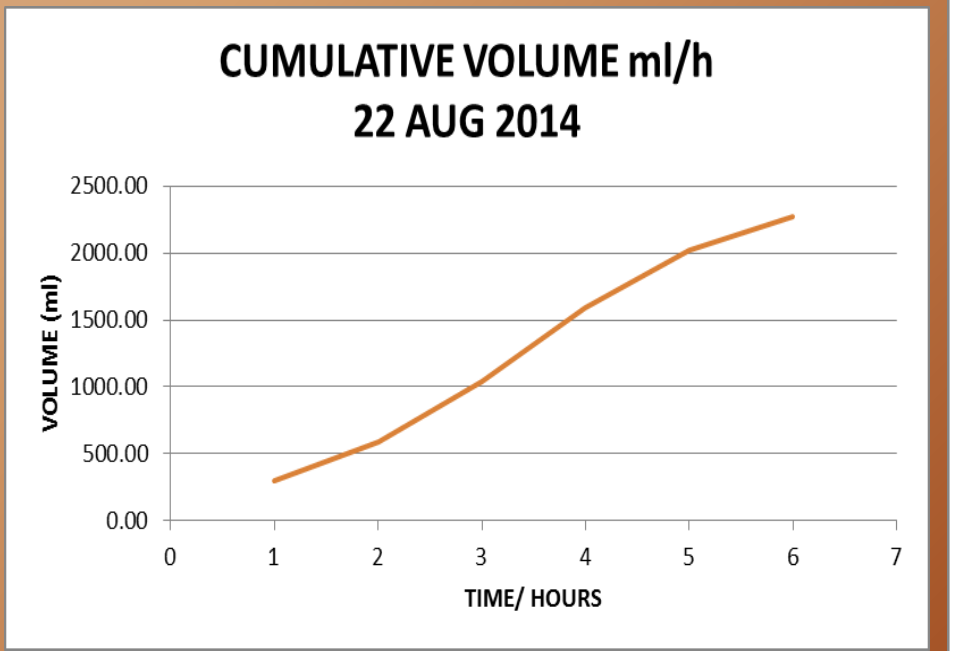

LOCAL WEATHER DATA
22 AUG 2014
TEMPERATURE ℃
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
00:00:00
04:48:00
09:36:00
14:24:00
19:12:00
00:00:00
04:48:00
TIME
SHADE TEMP
SUN TEMP
WIND CHILL
WIND TEMP

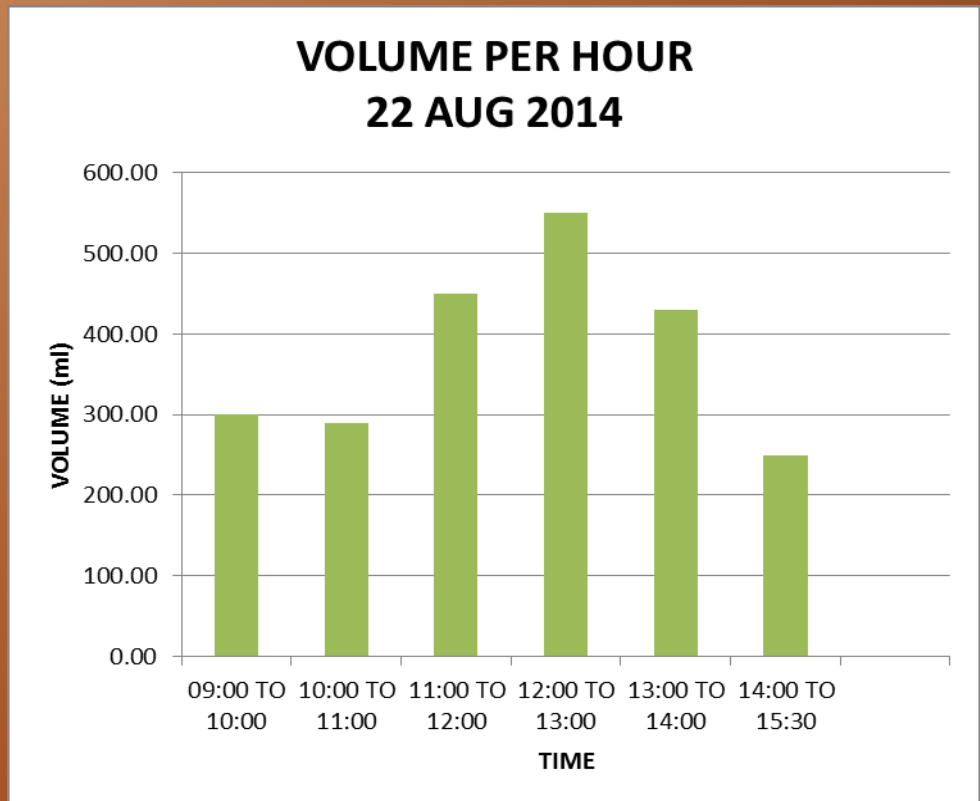
Preliminary results and discussion

- The warm-up time required to heat the ~50ℓ saline water is relatively short with temperatures rising to 30℃ within 15minutes and 60℃ within 120minutes after circulation pumps were activated.
- A similar pattern is reflected in the cooling-down period, after the circulation pumps have been switched-off around 16:00
- The initial volumes of distillate produced will also be low as most of the heat required for evaporation is taken from the water itself.
- To maintain the water temperature heat must be supplied.
- For molecules of a liquid to evaporate, they must be located near the surface and have sufficient kinetic energy to overcome liquid-phase intermolecular forces.
- Only a small proportion of the molecules meet this criteria, so the rate of evaporation is limited.
- Since the kinetic energy of a molecule is proportional to its temperature, evaporation proceeds more quickly at higher temperatures.

Preliminary results and discussion

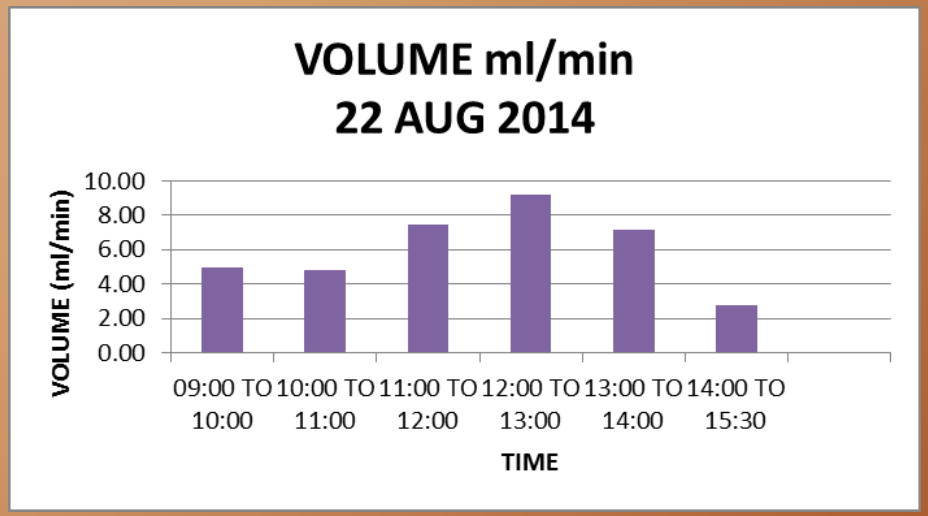
- The flow rate is measured after the initial warm up period.
- The average flow rates after the steady state 6.27ml/min
- maximum production rate of 9.17ml/min reached between 12:00 and 13:00
- minimum production rate for the day was 2.78ml/min.
- production rate is highest in mid-day - 550ml/h produced.

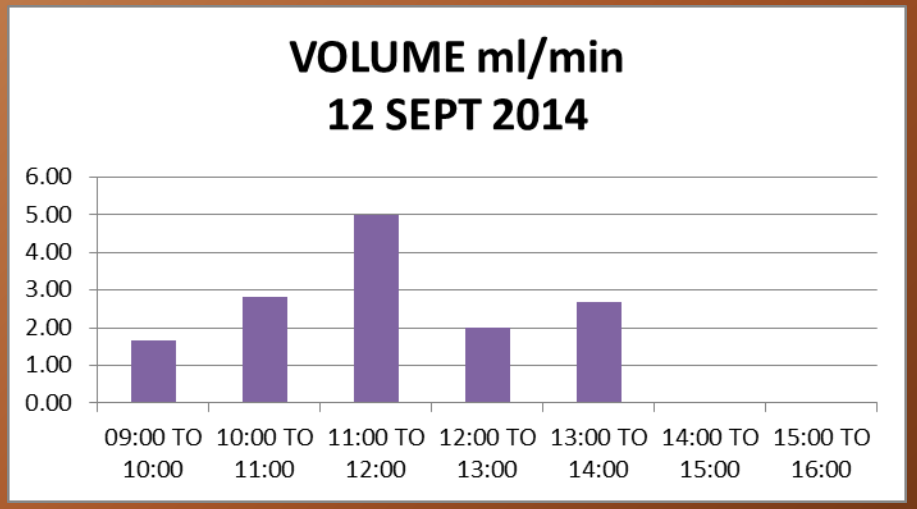




Preliminary results and discussion

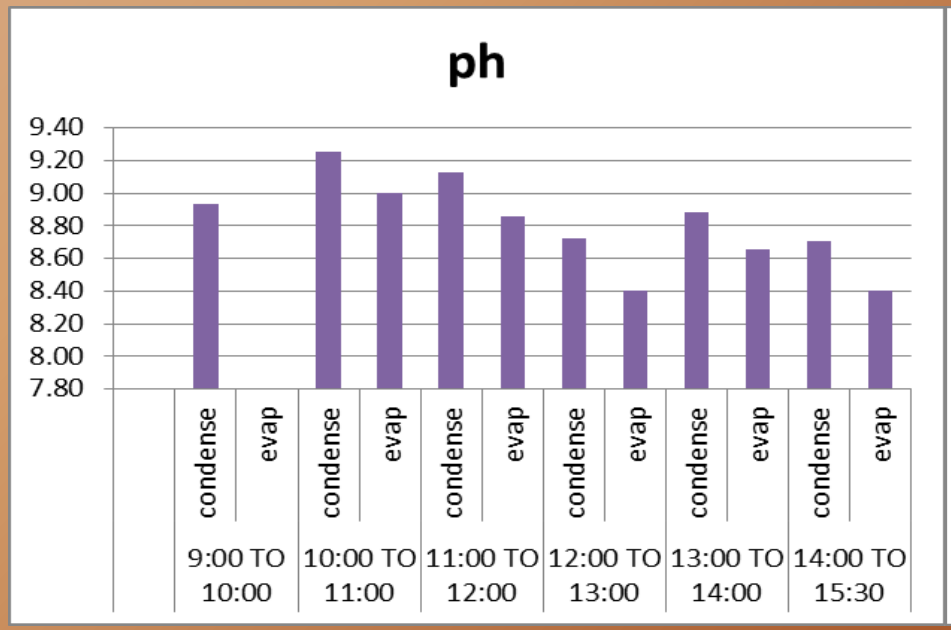
- 65% of the daily production produced from 11:00 to 14:00.
- evaporation tank temperature is still above 60 ℃ up to 16:00, sharp drop in the production rate after 14:00.
- average production rate of 6.31ml/min for a typical winter's day
- compares favourably with the 3.07ml/min recorded by Hatwig (2013)

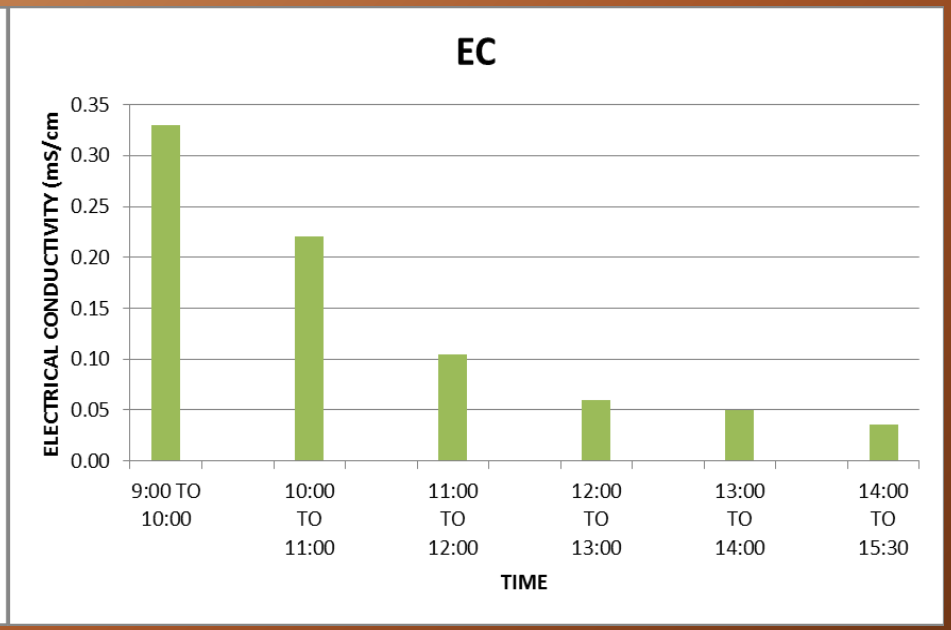




Preliminary results and discussion

- current experimental setup was for ordinary tap water,
- water quality increased from 0.33 mS/cm to 0.04mS/cm during the day,
- best quality water being produced in late afternoon.
- ph varied between 8.40 and 9.20 throughout the day.





Conclusions

- The production rate of the pilot solar desalination plant is comparable to other small scale desalination plants
- Preliminary results show increase in water quality of distillate
- The pilot plant shows very limited signs for environmental degradation

Future work

- Evaluation of production rate with modifications : water depth, increased surface area
- Application to highly saline water sources
- Development of an economic evaluation model


Questions
Thank you very much for your time