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# Desalination of Geothermal Water Using a Multistage Flash Distillation System and Solar Energy: A Case Study from Dholera, Gujarat

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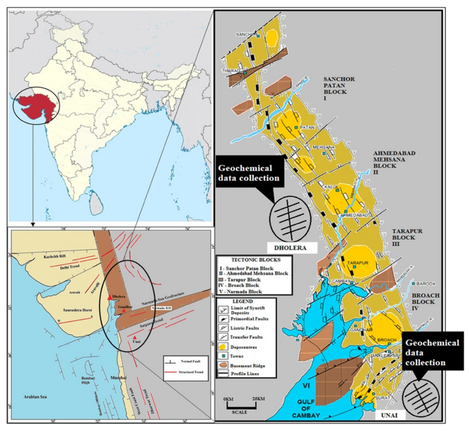
## BRIEF MOTIVATION

Dholera is a region with scarcity of fresh drinking water. As it is situated nearby the sea even the groundwater is saline in nature. The geothermal water is also at shallow depth at most of the places. Hence access to potable drinking water is difficult there. The objective of this research is to develop a green desalination system which can provide potable fresh drinking water.

## OBJECTIVE

- Develop a thermodynamic model for Multi- Stage Distillation system for geothermal water desalination
- Develop a thermodynamic model for solar evacuated tubes system as per the need of Multi- Stage Distillation system
- Simulate the production of heat from an evacuated tube solar collector with the geothermal Multi-Stage Distillation system for the generation of steam and salt separation
- Estimate the performance characteristics of the system, including total mass and salt balances, heat transfer unit rate equations, and energy balances for the brine heater

## STUDY AREA




| Parameters | Well-1 (Dholera) | Well-2 (Dholera) | Well-3 (Utthan) |
|---|---|---|---|
| Depth | 320m | 320m | 500m |
| Water temperature | 40°C | 45-50 °C | 40 °C |
| Water flow rate | 7 l/s | 7 l/s | 7 l/s |
| Data acquired | SP and Resistivity logs | Cutting data | |
| Tubular diameter | 8’ | 8’ | |
| Hole diameter | 18’ | 18’ | |

| Geothermal Water Samples | Utthan | Dholera 1 | Bhadiyad | Dholera 2 |
|---|---|---|---|---|
| pH | 7.05 | 7.22 | 7.32 | 7.25 |
| Na (mg/L) | 1139 | 1176 | 1156 | 1107 |
| K (mg/L) | 26.5 | 25.7 | 21 | 23.7 |
| Ca (mg/L) | 107 | 107 | 125 | 100 |
| Mg (mg/L) | 49 | 50 | 72 | 46 |
| $SiO_2$ (mg/L) | 12.32 | 16.85 | 9.98 | 12.79 |
| B (mg/L) | 3.88 | 3.76 | 4.44 | 4.8 |
| Cl (mg/L) | 2426 | 2510 | 2635 | 2476 |
| F (mg/L) | 0.21 | 0.17 | 0.22 | 1.16 |
| $SO_4$ (mg/L) | 30 | 13 | 56 | 16 |
| $HCO_3$ (mg/L) | 190 | 160 | 140 | 170 |
| As (mg/L) | 0.01 | 0.01 | 0.01 | 0.01 |
| Rb (mg/L) | 0.002 | 0.002 | 0.002 | 0.002 |
| Cs (mg/L) | 0.002 | 0.002 | 0.002 | 0.002 |
| Sr (mg/L) | 0.002 | 0.002 | 0.002 | 0.002 |
| Ba (mg/L) | 0.002 | 0.002 | 0.002 | 0.002 |
| Fe (mg/L) | 0.505 | 0.482 | 0.01 | 0.647 |
| Mn (mg/L) | 0.02 | 0.02 | 0.02 | 0.02 |
| Salinity (ppm) | 3968.2 | 4042.4 | 4205.4 | 3940.5 |
| Conductivity (µmhos/cm) | 6200 | 6400 | 6670 | 6190 |

## CONTACT

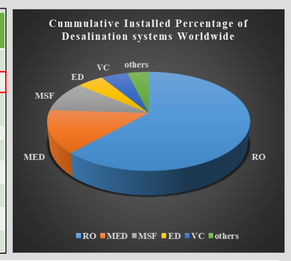
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## METHODOLOGY

### Selection of Energy Source and Desalination System

| RE Source | Particulars | RE Capacity of Gujarat (As on 31.3.2021) | Capacity expected by the year | | |
|---|---|---|---|---|---|
| | | | 2022 | 2025 | 2030 |
| Wind | Non-Park | 8,561.82 | 8,429 | 8,929 | **8,929** |
| Solar (Ground mounted) | Solar (Non-Park) | 3,425 | 4,021 | 5,021 | **6,021** |
| | Dholera Solar Park[a] | | 300 | 1,000 | **5,000[a]** |
| | Raghanesda Solar Park | | 600 | 700 | **700** |
| | Harshad Solar Park | | - | 500 | **500** |
| | Sub-station Scheme | | 500 | 2,000 | **2,500** |
| | Small Scale distributed solar | | 500 | 2,495 | **2,495** |
| Solar Rooftop | | 1,006 | 2,006 | 3,506 | **6,006** |
| Other RE | Biomass & Bagasse | 77.30 | 81 | 141 | **141** |
| | Mini Hydel | 82.69 | 74 | 74 | **74** |
| | MSW | - | 67 | 100 | **100** |
| | Khavda Hybrid RE Park[a] | - | - | 14,000 | **28,000** |
| | Off-shore wind | - | - | - | **1000** |
| Total | | 13,152 | 16,578 | 38,466 | **61,466** |

| Motion | Collector Type | Absorber Type | Concentration Ratio | Indicative Temperature range (°C) |
|---|---|---|---|---|
| Stationary | Flat Plate Collector (FPC) | Flat | 1 | 30-80 |
| | Evacuated Tube Collector (ETC) | Flat | 1 | 50-200 |
| | Compound parabolic Collector (CPC) | Tubular | 1-5 | 60-240 |
| Single- axis tracking | | | 5-15 | 60-300 |
| | Linear Fresnel Reflector (LFR) | Tubular | 10-40 | 60-250 |
| | Parabolic Trough Collector (PTC) | Tubular | 15-45 | 60-300 |
| | Cylindrical Trough Collector (CTC) | Tubular | 10-50 | 60-300 |
| Two- axis tracking | Parabolic Dish Reflector (PDR) | Point | 100-1000 | 100-500 |
| | Heliostat Field Collector (HFC) | Point | 100-1500 | 150-2000 |



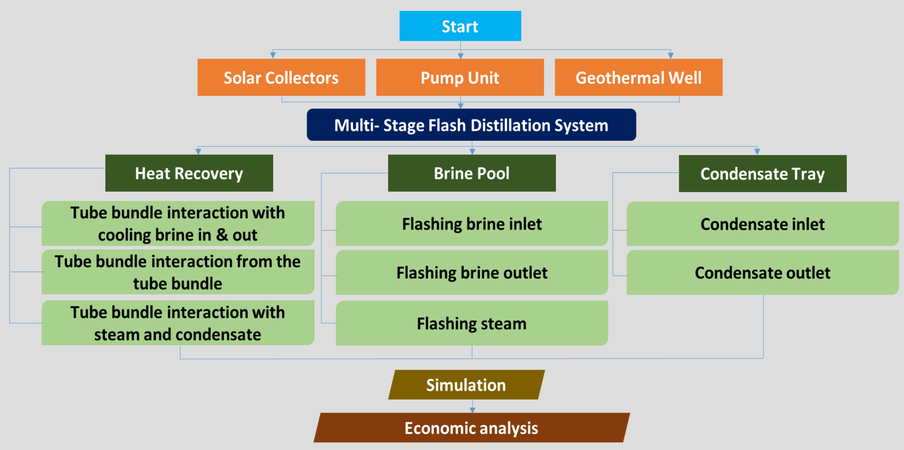

- At present the state´s total installed power generation capacity from renewable energy sources- solar, wind, hydro, biomass is about 13,152MW.
- The ground mounted solar has total installed capacity of around 4,000MW and solar- rooftop contributes about 1,006MW.

| Desalination system | Pros | Cons |
|---|---|---|
| Reverse Osmosis | • Simple operation and fast start-up<br>• High footprint/production capacity<br>• 30–60% recovery<br>• Removal of contaminants other than salts achieved | • Higher costs for chemical and membrane replacement<br>• Weak to feed water quality changes<br>• Adequate pre-treatment a necessity |
| Multi-stage flashing (MSF) | • Proven, reliable technology with long operating life<br>• Flashing rather than boiling reduces incidence of scaling<br>• Minimal pre-treatment of feed water required<br>• High-quality product water | • Huge capital investment required Energy-intensive process<br>• Larger footprint required<br>• Corrosion problems if materials of lesser quality used |
| Multi-effect desalination (MED) | • Minimal pre-treatment of feed water required<br>• Very reliable process with minimal requirements for operational staff Tolerates normal levels of suspended and biological matter | • High energy consumption<br>• High capital and operational cost |

### Key Thermodynamic Equations for MSF Design

| Parameters | Equations |
|---|---|
| Temperature difference in each stage | $\Delta T = \frac{T_{flash} - T_{brine}}{j}$ |
| Temperature at each stage | $T_1 = T_{brine} - \Delta T$<br>$T_{j+1} = T_j - \Delta T$ |
| Mass flowrate of distilled water at each stage | $\dot{m}_{distilled} = l_{heat} \times \dot{m}_{recoverable} \times (1 - l_{heat})^{j-1}$ |
| Mass flowrate of desalinated water | $\dot{X}_{flash}\dot{m}_{flash} = \dot{X}_{brine}\dot{m}_{brine}$ |
| Mass and Salt balance for distilled water | $\dot{X}_{distilled} = \frac{\left((x_{flash} - x_{brine}) \times \dot{m}_{flash}\right) + (x_{brine} \times \dot{m}_{distilled})}{\dot{m}_{distilled}}$ |
| Mass flowrate of desalinated water | $\dot{m}_{flash} = (\dot{m}_{brine} + \dot{m}_{distilled})$ |
| Heat transfer at each stage | $\dot{Q} = \dot{m}_{steam}\,(h_j + h_{j+1})$ |

### Simulation Flowchart

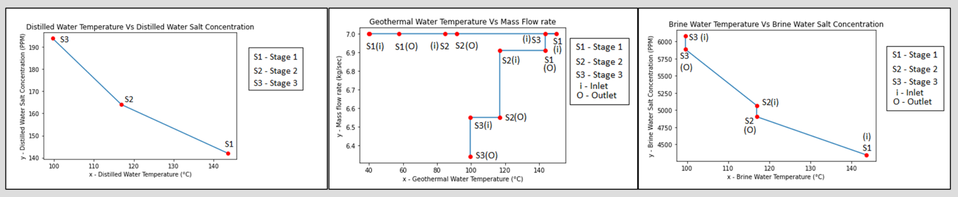



### Key Thermodynamic Equations for Solar ETC Design

| Parameters | Equations |
|---|---|
| Quantity of heat absorbed by evacuated tube collector | $Q_{absorbed} = A_{collector} \times l_{intensity} \times n_{optical}$ |
| Total area exposed to collector | $A_{collector} = \pi \times d \times l \times n$ |
| Heat loss to surrounding by solar collector | $Q_{loss} = A_{collector} \times F_{heat\ loss} \times (S_{collector} - U_{Loss}\,(T_{inner} - T_{average}))$ |
| Net heat gain by collector | $Q_{useful} = Q_{absorbed} - Q_{loss}$ |
| Heat absorbed by ETC | $H_{absorbed} = Q_{absorbed} + Q_{useful}$<br>$= (A_{collector} \times l_{intensity} \times n_{optical}) + A_{collector} \times F_{heat\ loss}$<br>$\times (S_{collector} - U_{Loss}\,(T_{inner} - T_{average}))$ |

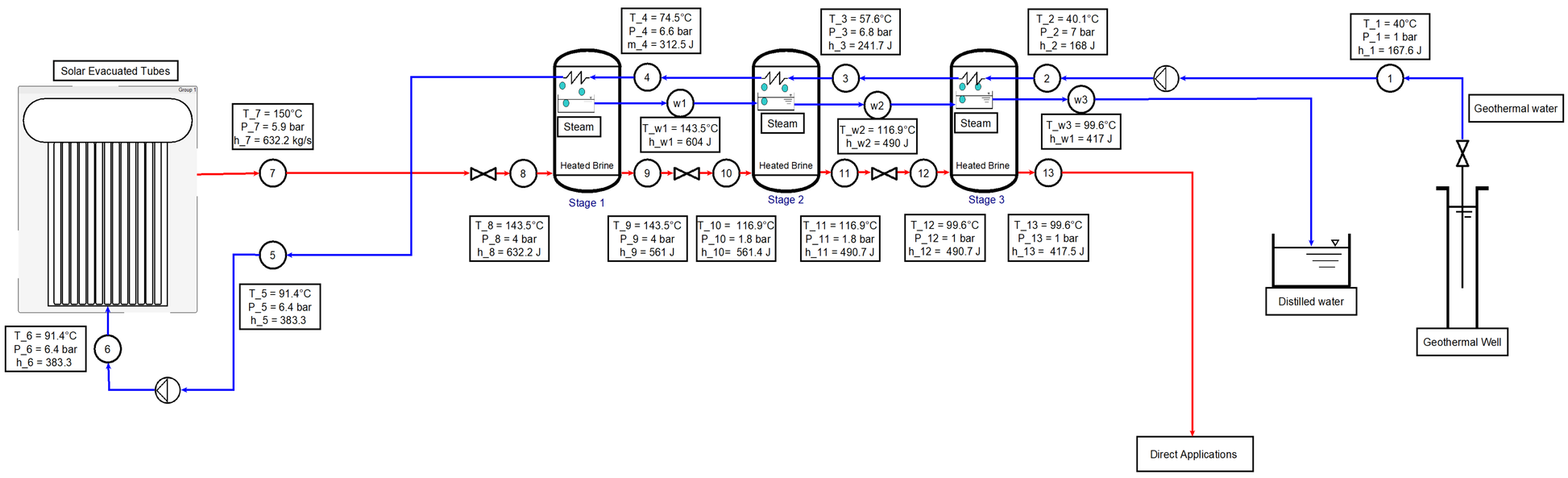
## OUTCOMES

| Fluid Type | Step No. | Temperature (°C) | Pressure (Bar) | Heat (kJ/kg) | Mass (kg/sec) | Quality (kJ) | Salt Concentration (PPM) |
|---|---|---|---|---|---|---|---|
| Geothermal | 1 | 40 | 1.0 | 167.6 | 7.0 | - | 4205 |
| Geothermal | 2 | 40.1 | 7.0 | 168.5 | 7.0 | - | 4205 |
| Geothermal | 3 | 57.6 | 6.8 | 241.7 | 7.0 | - | 4205 |
| Geothermal | 4 | 84.5 | 6.6 | 355.7 | 7.0 | - | 4205 |
| Geothermal | 5 | 91.4 | 6.4 | 383.3 | 7.0 | - | 4205 |
| Geothermal | 6 | 91.4 | 6.4 | 383.3 | 7.0 | - | 4205 |
| Geothermal | 7 | 150.0 | 5.9 | 632.2 | 7.0 | -1.0 | 4205 |
| Geothermal | 8 | 143.5 | 4.0 | 632.2 | 7.0 | 0.0129 | 4205 |
| Geothermal + Heated Brine | 9 | 143.5 | 4.0 | 604.7 | 6.91 | 0.0 | 4347 |
| Geothermal + Heated Brine | 10 | 116.9 | 1.8 | 604.7 | 6.91 | 0.0515 | 4905 |
| Geothermal + Heated Brine | 11 | 116.9 | 1.8 | 490.7 | 6.55 | 0.0 | 5069 |
| Geothermal + Heated Brine | 12 | 99.6 | 1.0 | 490.7 | 6.55 | 0.0324 | 5886 |
| Geothermal + Heated Brine | 13 | 99.6 | 1.0 | 417.5 | 6.34 | 0.0 | 6080 |
| Distilled Water | w1 | 143.6 | - | 604.65 | 0.09 | 193.17 | 142 |
| Distilled Water | w2 | 116.9 | - | 490.7 | 0.45 | 797.69 | 164 |
| Distilled Water | w3 | 99.60 | - | 417.5 | 0.66 | 512.37 | 194 |

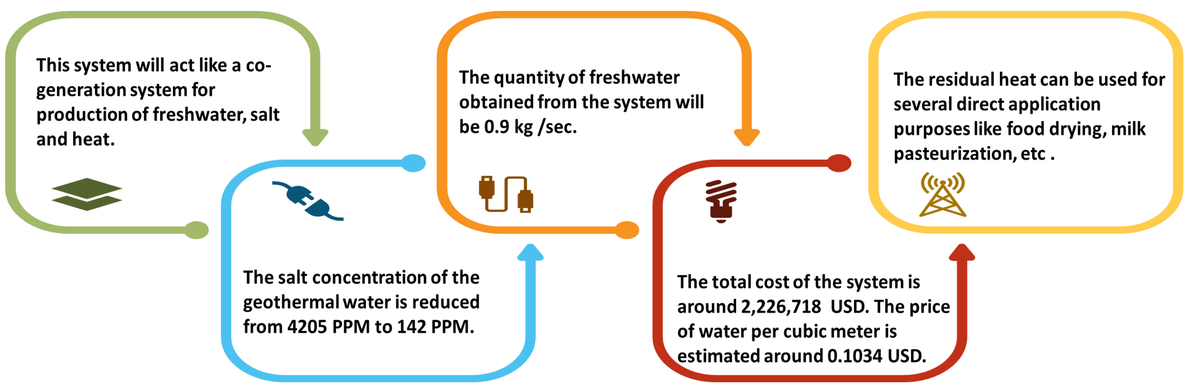



| Parameters | Equations |
|---|---|
| Annual Investment | $Annual\ investment = CAPEX \times \frac{i \times (1+i)^{n1}}{(1+i)^{n1}-1}$ |
| Hourly CAPEX | $hourly - CAPEX = \frac{Total\ annual\ investment}{365 \times 24 \times 0.9}$ |
| Hourly OPEX | $hourly - OPEX = Steam + Electricity$ |
| Unit Product cost | $Unit\ Product\ cost, \frac{\$}{m^3} = \frac{hourlyc_CAPEX + hourly_OPEX}{hourly_Product}$ |

| Particulars | Cost in $ | Cost in $/m3 |
|---|---|---|
| Evaporator | 1,040,551.00 | |
| Pumps | 118,026.00 | 0.0068 |
| Piping and valves | 188,939.00 | 0.0109 |
| Filters | 249,015.00 | 0.0144 |
| Others, building | 258,803.00 | 0.0150 |
| Evacuated Tubes | 1225 | |
| Engineering design | 131,455.00 | 0.0076 |
| Financial | 164,319.00 | 0.0095 |
| ***Subtotal*** | ***2,152,333.00*** | ***0.0643*** |
| **OPEX** | | |
| **Particulars** | **Cost in $/ year** | **Cost in $/m3** |
| Labour | 21,909.00 | 0.0115 |
| Maintenance | 16,431.00 | 0.0087 |
| Replacement of parts | 1,305.00 | 0.0007 |
| Electricity | 34,740.00 | 0.0183 |
| ***Subtotal*** | ***74,385.00*** | ***0.0392*** |
| ***Total*** | ***2,226,718.00*** | ***0.1034*** |




## CONCLUSION




## BIBLIOGRAPHY/ REFERENCES

1. Yadav, K., and Sircar, A., 2019: Integrated 2D joint inversion models of gravity, magnetic, and MT for geothermal potentials: a case study from Gujarat, India. *Model. Earth Syst. Environ.* 5, 963–983. . Available at: https://doi.org/10.1007/s40808-019-00582-2
2. Yadav, K., Sircar, A., Jani, D., Bist, N., Nirantare, A., Mali, N. and Singh, S., 2021: “Geochemical characterization of geothermal spring waters occurring in Gujarat, India”, *International Journal of Energy and Water Resources*, 5, 391-404. Available at: https://doi.org/10.1007/s42108-020-00111-3
3. Sircar, A., Yadav, K., Bist, N. and Oza, H., 2022, “Geochemical characterization of geothermal spring waters occurring in southern part of Gujarat and West Coast Geothermal Province of Maharashtra, India.” Sustain. Water Resour. Manag. 8, 7. https://doi.org/10.1007/s40899-021-00597-7
4. Yadav K., Sircar A. and Yadav A., 2022, “Geothermal Energy: Utilization, Technology and Financing”, Taylor and Francis; ISBN 9781032069470

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