## SOLAR EVAPORATOR – SCIENCE & TECHNOLOGY

NEWS: Researchers at **IIT Bombay,** developed a new **graphene-based Dual-Sided Superhydrophobic Laser-Induced Graphene (DSLIG) evaporator.**

- This innovation offers a consistent, efficient, and scalable **desalination solution** by mimicking the **lotus leaf effect**, and integrating **dual-mode heating (solar + electric)**.

### WHAT'S IN THE NEWS?

**Interfacial Solar Evaporation**

- It is a **water purification technique** where only the surface layer of water is heated using a **floating solar evaporator** that absorbs sunlight directly.
- This method avoids heating the entire volume of water, thereby **minimizing energy consumption** and improving overall efficiency.
- **Localized surface heating** makes it ideal for **off-grid desalination applications**, especially in remote or resource-scarce regions.
- Due to the **reduced energy loss**, this technique achieves **higher thermal efficiency** than conventional bulk heating methods.

**Lotus Leaf Effect**

- The **Lotus Leaf Effect** refers to the natural **superhydrophobic (extremely water-repellent)** property observed in lotus leaves.
- This effect causes water droplets to **roll off the surface**, carrying away dirt and contaminants — leading to **self-cleaning behavior**.
- It is now widely replicated in engineered materials for **anti-wetting, self-cleaning, and corrosion-resistant technologies**.

**Joule Heating (Resistive or Ohmic Heating)**

- Joule Heating is the process of **converting electrical energy into heat energy** when an electric current flows through a **resistive material**.
- This principle is used as a **backup heating mechanism** in desalination technologies, especially when **solar radiation is insufficient**.

**Challenges in Solar Desalination Technologies**

- **Intermittent Solar Energy**: Variations due to weather, time of day, and cloud cover lead to **unpredictable heating performance**.
- **Material Limitations**: Some materials used in solar evaporators have **low solar absorption**, which affects thermal efficiency.

- **Salt Crystallization**: Salt deposits can form on the surface of evaporators, **blocking water contact** and **reducing system effectiveness** over time.

**About DSLIG Evaporator Technology**

- **DSLIG** stands for **Dual-Sided Superhydrophobic Laser-Induced Graphene** evaporator.
- It is a hybrid desalination technology that uses **interfacial solar heating** with **Joule heating backup**, ensuring operation even in poor sunlight.

**Key Components:**

1. **PVDF (Polyvinylidene Fluoride)**: Offers **superhydrophobicity on both sides**, mimicking the lotus leaf effect.
2. **PES (Polyether Sulfone)**: Provides **mechanical durability** and **flexibility**, making the evaporator long-lasting and robust.
3. **Laser-Induced Graphene (LIG)**: Created by laser engraving on PVDF to form a **graphene surface layer** for enhanced **solar absorption and heat conversion**.

**Working Mechanism of DSLIG**

- **Solar Heating Mode**: The evaporator **absorbs solar radiation** and heats only the thin surface layer of water for **efficient evaporation**.
- **Joule Heating Mode**: During cloudy or low-light conditions, **electrical heating** takes over to **maintain continuous operation**.
- **Superhydrophobic Surfaces**: Both sides repel salt and water, **preventing salt buildup**, thus extending the **lifecycle and efficiency** of the device.

**Benefits of DSLIG Technology**

| Feature | Advantage |
|---|---|
| **Dual Heating** | Works in all weather conditions with **solar and electric modes**. |
| **Superhydrophobicity** | Prevents **salt fouling and water blockage**, improving performance. |
| **Eco-Friendly** | Made from **low-toxicity, recyclable materials** with minimal carbon footprint. |
| **Versatile** | Suitable for **high-salinity brine** and **industrial wastewater treatment**. |

| Feature | Advantage |
|---|---|
| **Scalable Design** | Units can be **stacked or networked** to increase water output. |
| **Cost-Effective** | Uses **affordable and durable polymers** (PVDF and PES) for wider deployment. |

**Desalination Technologies: Classification**

Desalination systems are broadly classified into **two categories**:

**A. Thermal Desalination Techniques**

- These methods involve **heating saline water** to produce vapor and then **condensing it into freshwater**, mimicking the **natural water cycle**.

| Method | Description | Suitability / Advantage |
|---|---|---|
| **Multi-Stage Flash (MSF)** | Seawater is rapidly evaporated in multiple stages under decreasing pressure. | Common in **oil-rich Gulf nations** with surplus thermal energy. |
| **Multiple Effect Distillation (MED)** | Steam from one chamber is used to heat the next stage in a cascading manner. | **More energy-efficient** than MSF, operates at **lower temperatures**. |
| **Vapour Compression (VC)** | Mechanical or thermal compressors recycle vapor for heat recovery. | Compact and **portable**, ideal for **small-scale desalination**. |

**B. Membrane-Based Desalination Techniques**

- These processes involve **forcing water through semi-permeable membranes** to filter out **salts and impurities**, often using pressure or electric potential.

| Method | Description | Advantages / Suitability |
|---|---|---|
| **Reverse Osmosis (RO)** | High-pressure system that lets only water molecules pass through the membrane. | Most **widely used globally**; known for **energy efficiency**. |
| **Electrodialysis (ED)** | Uses an electric field to separate ions via **ion-selective membranes**. | Best for **brackish water**, suitable where **salinity is moderate**. |
| **Nanofiltration (NF)** | Similar to RO but with **larger pores**; removes divalent ions and organics. | **Lower energy consumption**, good for **water softening**. |

Source: https://www.thehindu.com/sci-tech/science/iit-bombay-scientists-develop-lotus-leaf-like-solar-evaporators-for-salt-water-treatment/article69457561.ece