# Graphene Use in Wave Powered Desalination

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## Situation

As the world's population is predicted to increase (shown in figure 1), consumption of drinking water will increase [1]. However, the freshwater withdrawals have tripled over the last 50 years and this is predicted to increase even more in the future due to the increase in demand. More sources of water are needed and two methods of desalination – distillation and reverse osmosis – are being spoken about as viable alternatives.

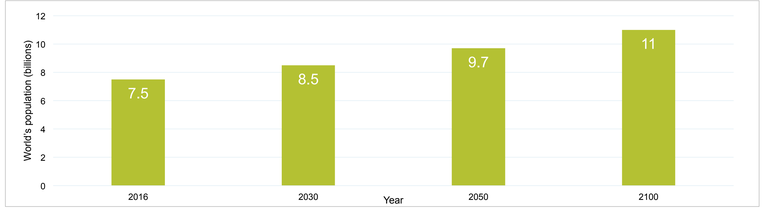


Figure 1: World's population prediction for the next 90 years [1].

## Problems

Current desalination methods – distillation and reverse osmosis – are extremely energy intensive such that:

1. The high costs prevent the industry from growing.
2. They emit large amounts of carbon dioxide, due to the fossil fuels being burnt to power the process.

## Solutions

A process to desalinate water more efficiently and with lower greenhouse gas emissions is proposed. This can be achieved by

1. Reducing costs:
   A. Using a graphene microfilter to desalinate water:
      - The desalination process (shown in figure 2) requires the water taken from the sea to undergo screening and filtration before reaching the microfilter.
      - Nanoporous graphene – a two dimensional sheet of graphene bombarded by oxygen molecules to create gaps in the surface – allows water molecules to pass but leaves behind salt particles (as seen in figure 2) [2].
      - The thin material helps increase the flux across the membrane.
      - It helps reduce costs by lowering the pressure required to push the seawater through the membrane.

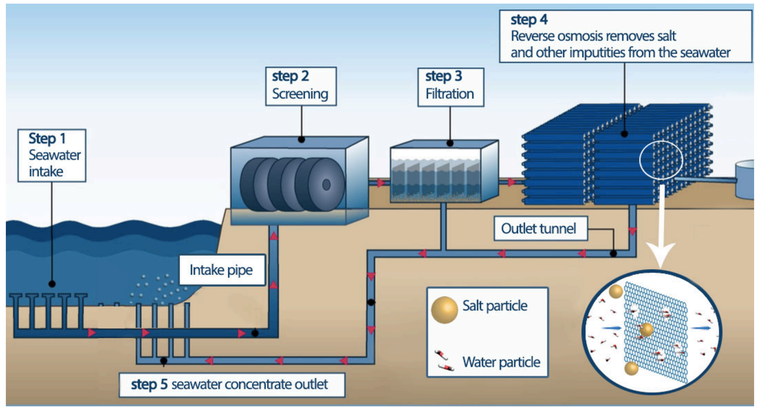


Figure 2: The Desalination Process [3].

B. Designing the pipes to minimize energy consumption:
   - Common pipe materials include PVC (polyvinyl chloride) and stainless steel.
   - Using PVC to manufacture the pipes will reduce the pressure lost by friction due to its low friction factor.
   - PVC also resists corrosion, reducing costs by ensuring pipes do not have to be changed often (as seen in Table 1).
   - As Table 1 shows, coating the PVC pipe with graphene will increase the strength of the pipe, ensuring it does not break under the high pressure of the soil.

Table 1: Comparison of the options for pipe materials

| Surface | Absolute Roughness-k (mm) | Compressive Strength (MPa) | Cost |
|---|---|---|---|
| PVC Pipes | 0.0015-0.007 | 55-89 | $0.33/m |
| Stainless Steel Pipes | 0.015 | 310 | $11.80/m |
| Graphene Coating | - | 1,600 | $1.50/kg |

C. Using graphene as a supercapacitor to store energy:
   - Storing the energy harnessed by waves will reduce energy waste.
   - Supercapacitors are superior to lithium batteries as they have a higher energy density (shown in table 2) and charge and discharge much faster.
   - According to equation 1 below, the thinness of the graphene (which increases surface area and reduces distance between the plate) will increase the energy stored in the supercapacitor.
   - The low electric resistivity of graphene will permit a large flow of charges.

Table 2: Comparison of supercapacitors and lithium-ion batteries [5]

| Function | Supercapacitor | Lithium-ion (general) |
|---|---|---|
| Charge time | 1-10 seconds | 10-60 minutes |
| Cycle life | 30,000 - 1000,000 hours | 500+ hours |
| Specific energy (Wh/kg) | 5 (typical)<br>1000 (graphene) | 120-240 |

$$C = \frac{\varepsilon A}{d}$$

Where:
C = capacitance
A = surface area
ε = Permittivity of dielectric
d = distance between plates

Equation 1: Capacitance equation [6]

2. Reducing greenhouse gas emissions:
   A. Powering the process using wave energy:
      - Using a renewable source of energy will help reduce the greenhouse gas emissions.
      - Wave power increases with increasing distance from the shore.
      - Harnessing wave energy using the oscillating water column system.
        - Air is compressed in the columns which turns a turbine.
        - Energy is transferred through an electrical cable.
        - The water flows naturally towards the desalination process.

## Evaluation

- This solution is only viable in coastal areas with strong winds to produce wave energy.
- The suction from the inlet pipe may damage the surrounding marine life.
- High quality graphene is expensive. The higher initial cost may prevent some firms from entering the market.

## References

[1] UN News. UN projects world population to reach 8.5 billion by 2030, driven by growth in developing countries, 2016. [Online]. Available: http://www.un.org/apps/news/story.asp?NewsID=51526#.V-O-0fB97IU. [Accessed: 22- Sep- 2016].

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