Innovate for Impact: Siemens Design Challenge

Driving solutions for zero hunger and clean water

Clean Water Track

Problem Statement: Design a very low-cost, energy-efficient, scalable technology for desalinating brackish water

Design Objectives:

Seawater typically contains 35,000 ppm amount of salt per liter, while brackish water contains 500 to 10,000 ppm. Potable drinking water may contain ~200 ppm amount of salt per liter - above this level the taste change is noticeable. The proposed technologies or approaches should reduce the salinity to acceptable levels for the situation being considered, and be affordable - to both implement and operate - for the target community and the end user.

Background:

97.5% of water on the Earth contains a high concentration of salt, making it unsuitable for drinking or farming. By 2030, nearly 35% of the world will be living in water-stressed countries. Most water that is used for drinking and farming comes from low-salt or salt-free underground sources or surface water. However, due to increasing droughts and saltwater intrusion by rising sea levels brought upon by climate change, these are becoming more and more unreliable. Worldwide, engineers and scientists race to develop innovative methods to remove salt from water, however, current solutions are extremely energy-intensive and high-cost.

In this document you will find additional background information to provide foundational knowledge and introduce terminology for entrants to investigate further (Section 1). In this document you will find important aspects concerning design parameters you will need for the Learn & Plan phase (phase 1) and Design phase (phase 2) of the challenge.

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SECTION 1: BACKGROUND

1. Introduction

According to the 50 Breakthroughs report, one of the 50 most important science and technology breakthroughs needed to achieve the Sustainable Development Goals (SDGs) is developing a very low-cost, scalable technique for desalination brackish water.

The United Nations Sustainable Development Goal 6 Synthesis Report on Water and Sanitation expresses that desalination is “evolving into a viable alternative water source to combat water scarcity and water stress”, especially considering how water scarcity will be exacerbated by seawater intrusion in ground and surface waters, with rising sea levels, climate change and increased droughts. However, desalination is “costly and energy intensive, requiring significant investments in infrastructure.” This is where “advances in technology are needed to reduce cost and offer a logical solution for sustainable, long-term management as water demand grows in arid regions”; designs with the least damaging ecological impacts are called for. **Read more** about the challenges in water supply in the Grand Challenge 1 of Environmental Engineering for the 21st Century by the National Academies of Sciences, Engineering, and Medicine.

2. Current global state of seawater desalination

Currently, desalination projects have been increasing over the years in contrast to the increase of freshwater scarcity worldwide (Figure 1). Countries at the head of desalination technologies such as Israel are turning to the sea however the cost of desalination remains high in relation to alternatives. **Read more** about this MIT Technology review **here**.

3. Basic principles in desalination

Desalination is the process by which salt is removed from seawater and/or brackish water. The following is a list of basic terms commonly used and related to desalination and its technologies.

Glossary

- *Brackish water*: Water that has a higher salinity than freshwater but lower than seawater such as estuaries. Brackish water contains from 500 to 10,000 ppm of total dissolved solids (including salt) per liter.
- *Concentrate or brine*: is concentrated seawater or brackish water as a byproduct of the desalination processes. The volume of concentrate typically accounts for 1-50% of total source water used. The desired is less than 10%, but concentrate volume discharge can only be reduced depending on the initial source water type.
- *Seawater*: water from a sea or ocean containing around 35,000 ppm of salt per liter.
- *Drinking seawater* as a source of water can be deadly to humans because the human body (the kidneys) cannot process and eliminate the excess salt without diluting it, therefore leading to dehydration.

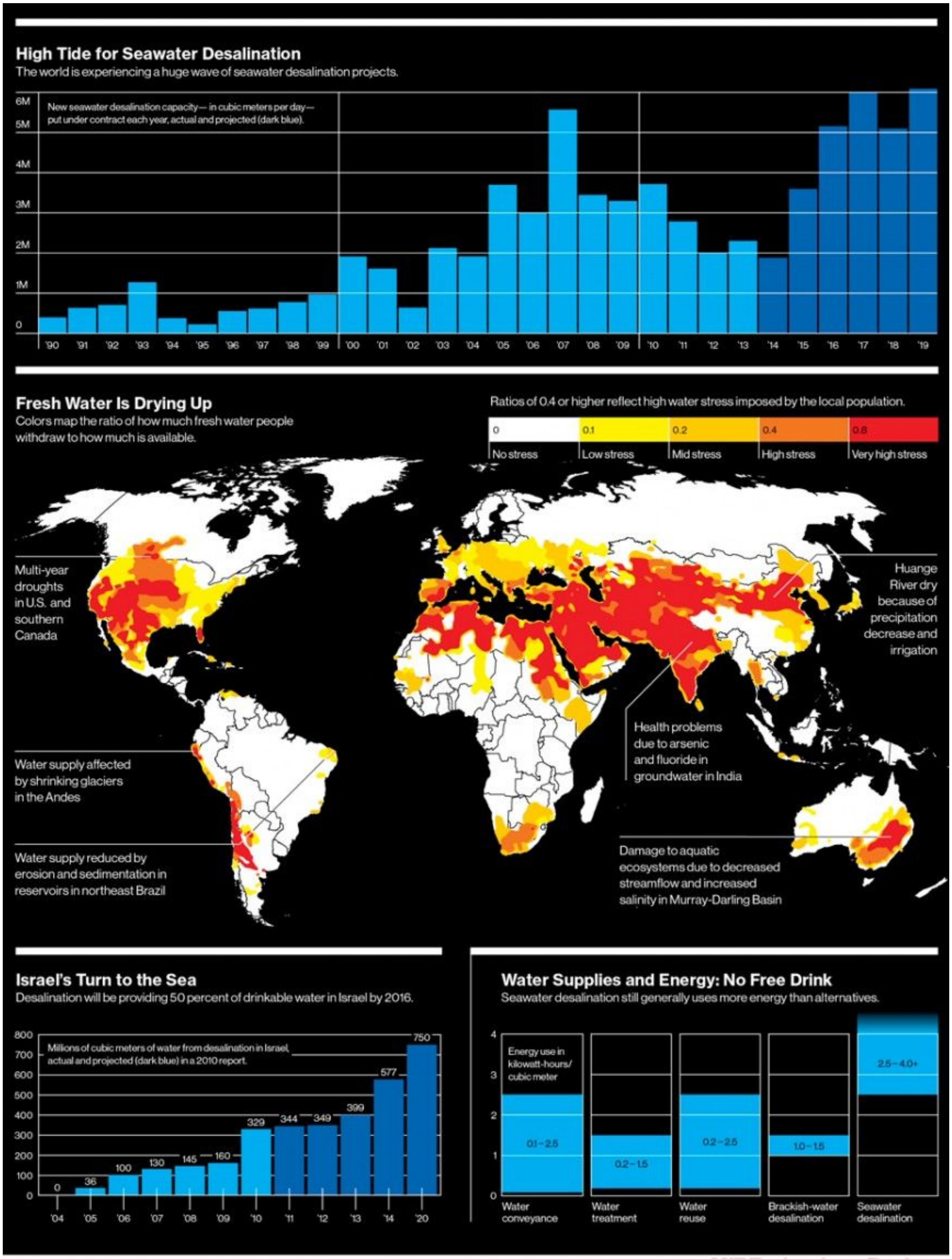


Figure 1. Current global state of seawater desalination.

Glossary continuation..

- *Distillation:* the action of purifying a liquid by a process of evaporation followed by condensation.
- *Fresh water*: any naturally occurring water except seawater and brackish water containing low salt concentration (less than 1,000 ppm).
- *Osmosis:* the spontaneous movement of water or other solvent molecules through a selectively permeable membrane into a region of higher solute concentration.
- *Permeate*: is the treated or product water containing a lower salinity than the source water after desalination (usually after passing through a membrane).
- *Reverse osmosis*: is a water purification process in which a solvent (ex. water) passes through a partially permeable membrane in the direction opposite to natural osmosis when subject to an applied pressure that overcomes osmotic pressure.
- *Water scarcity*: the lack of sufficient available water sources to meet demands either due to physical shortage, lack of adequate infrastructure or access due to failure of institutions to ensure a regular supply.
- *Water suitable for human consumption*: (safe drinking water): water that does not represent any significant risk to health over a lifetime of consumption and that meets standards on composition and quality related to physical, chemical and microbiological parameters; A physical parameters for safe water is total suspended solids which includes water containing around 200 ppm or less of salt per liter.

4. Desalination Prior Art:

The following illustrations, videos and diagrams aim to provide a foundational background of the desalination processes.

General stages in the desalination water treatment:

There are a variety of approaches and technologies to achieve salt removal from seawater or brackish water. All of them involve different processes starting from the water source supply to fresh water drinking production that can be separated into the following general stages:

1. Raw seawater/brackish water intake
2. Pre-treatment
3. Pumping (solar, wind powered or other..)
4. Desalination Treatment (Membrane or heat-based desalination)
5. Post-treatment
6. Fresh drinking water production
7. Waste Concentrate/Brine Treatment or disposal process

Read further into the key issues of each step on page 6 here or in chapter 4 State of Technology in Desalination by National Research Council

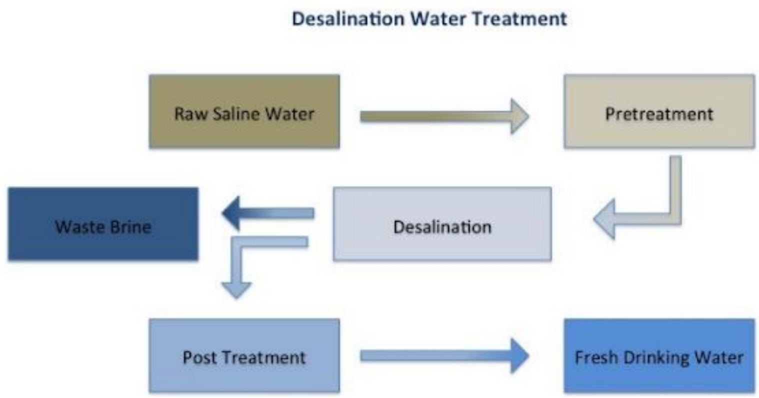


Figure 2. Flow diagram of the steps involved in desalination water treatment. Taken from *A Road Map for Small-scale Desalination (Oxfam 2018)*

Experts indicate that…

- The most **technically challenging** step in desalinating water is waste brine treatment and disposal, which is both costly and associated with negative environmental impacts.
- The most **expensive** stage in the desalination process depends on the type and location of facility: Coastal facilities using seawater will have a higher cost in energy or heat source required to generate pressure for reverse osmosis. Inland facilities will not have such a high energy cost as coastal because of the use of water source with less salt concentration but the cost of brine treatment and disposal will be high.

Types of desalination methods/approaches

There are many desalination methods or approaches which include **membrane-based** filtration methods such as reverse osmosis and **thermal-based** such as distillation. A combination of these methods, known as Hybrid Systems can also be found. According to the International Renewable Energy Agency (IRENA) technology brief, “the dominant desalination processes in use today are based on Reverse Osmosis (RO) and Multi Stage Flash (MSF) which constitute around 60.0% and 26.8% of the worldwide capacity, respectively”.

Membrane-based desalination

Membrane technologies include *Reverse osmosis* and *Electrodialysis*. **Find information** on membrane filtration in the HWTS knowledge base.

Reverse osmosis

Reverse osmosis is the main membrane-based method of desalination. It uses hydraulic pressure to drive water through a permeable membrane to remove dissolved minerals. **Watch here** [How Seawater Desalination Works] and [How Reverse Osmosis works in desalination].

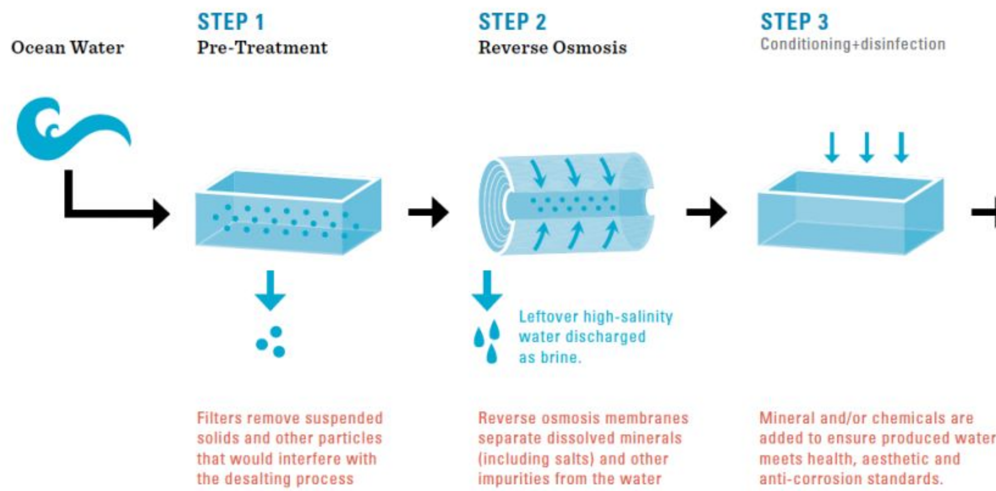


Figure 3. The desalination process. Taken from the [San Diego County Water Authority].

The next image shows an example of how reverse osmosis is performed on a large scale to generate municipal water from seawater.

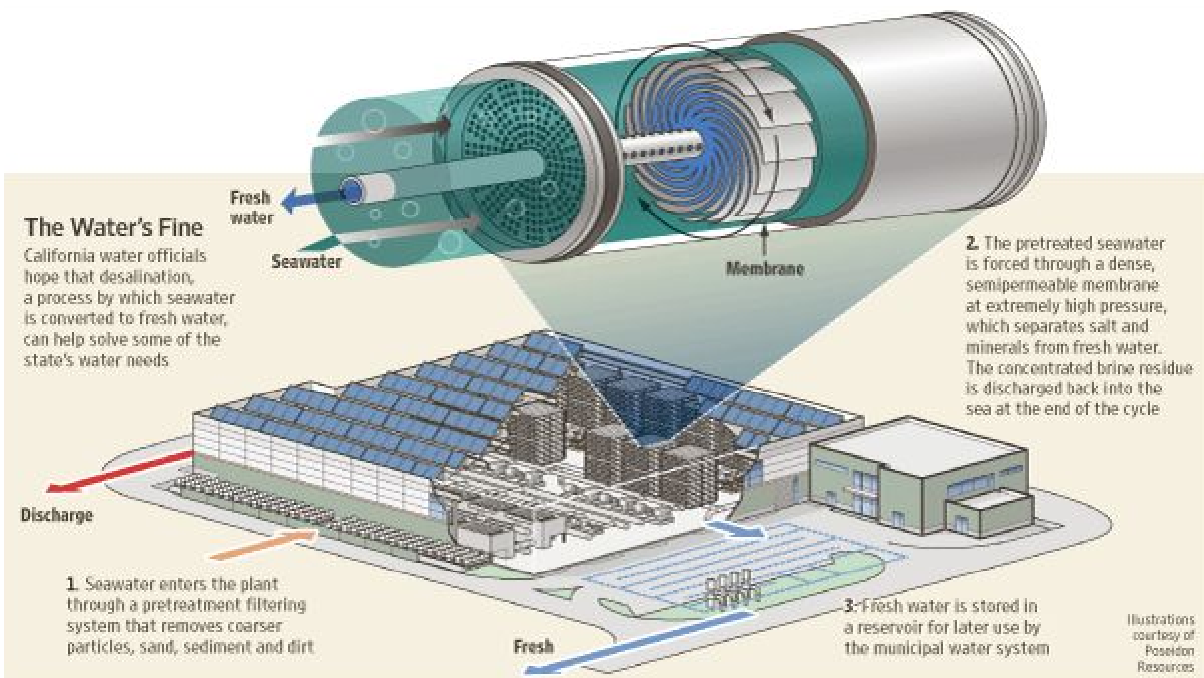


Figure 4. Reverse osmosis on a large scale projected for California State.

Read about the world's largest and cheapest reverse-osmosis desalination plant in Israel **here**.

Electrodialysis
Electrodialysis uses an applied electric potential difference to transport salt ions through a permeable membrane to remove dissolved minerals. **See an example** of the New Mexico State University in collaboration with the Brackish Groundwater National Desalination Research Facility **here**.

Thermal Based desalination
Thermal technologies for desalination use energy to evaporate water and condense it (distillation) to free it from salt. Most of these distillation technologies are used at large scale facilities in the Middle East where the energy is cost effective due to low oil costs.

Multistage-Flash (MSF) distillation is a multi-stage process that distills sea water by flashing a portion of the water into steam in multiple stages of what are essentially countercurrent heat exchangers, recovering most of the heat of vaporization. **Find out more here**.

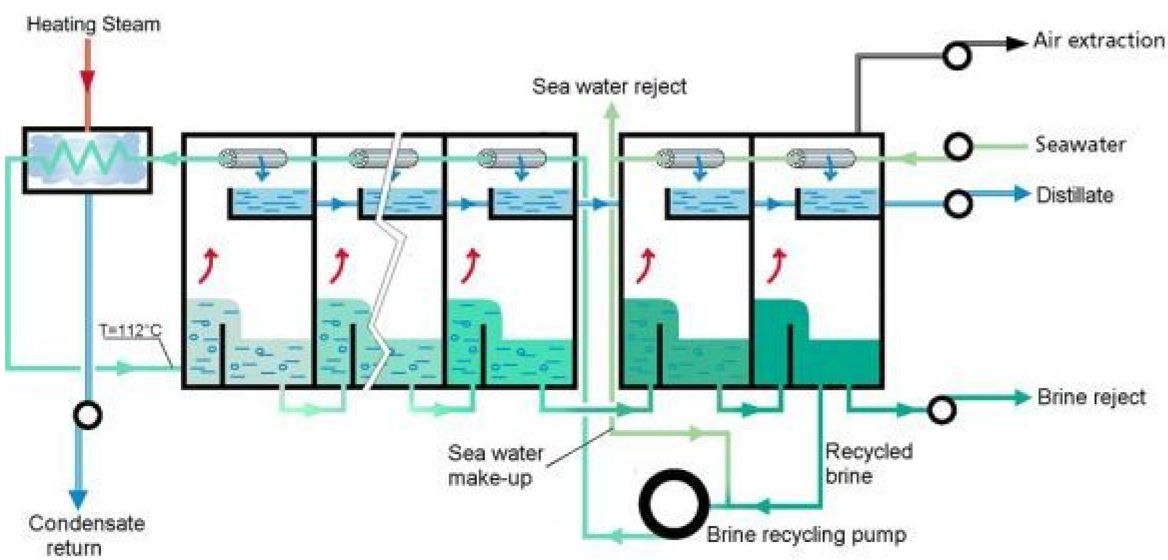


Figure 5. Multi-Stage Flash desalination process

Other distillation systems include **Multiple-Effect Distillation (MED), Vapor Compression Distillation (VCD)** and **Vacuum distillation (VD)** or a combination of them, These are based on this same common process but present variations that help improve overall efficiency and reduce energy use by allowing the feed-water to be processed without the need to supply additional heat for vaporization at each stage or using compression or vacuum. **Read more** about the different desalination methods and their characteristics view chapters 3 of the following Review by the World Bank. **Read more** about Multi Effect Distillation **here** and about Vapor Compression Distillation (VCD) **here.**

Other thermal based processes include **Freeze-thaw** and **Membrane distillation**. Freeze-thaw is a weather dependent process that uses freezing to remove fresh water from salt water. It is known to be feasible in cold climates yet it is not widely used. **Read an example here**.

Membrane distillation a specific thermally-driven type of desalination process in which separation is driven by phase change. Vapour pressure difference between two sides of a hydrophobic membrane presents a barrier for the liquid phase (e.g. seawater) but allows the vapor phase (e.g. water vapour) to pass through the membrane's pores. **Read more here.**
It has not yet reached commercial breakthrough on a large scale but is an attractive technology for solar-thermal decentralized desalination. **Read more here.** Other approaches to desalination can include but are not limited to forward Osmosis and hydrogel based desalination.
For more information on desalination materials, processes and related technologies check The International Journal on the Science and technology of Desalting and Water Purification.

Renewable energy powered desalination technologies

One of the most critical aspects of any desalination technique is the energy source. Membrane-based desalination technologies will require energy sources that can generate electricity for powering pumps, while thermal-based desalination will need energy sources that can generate the heat to drive the process. Alternative sources of energy such as solar, wind, wave or other energy sources have been explored alone but also in combination in hybrid systems and their use will depend on the desalination technology. The following figure shows reverse osmosis powered by a hybrid renewable energy system of solar-electrical and wind power.

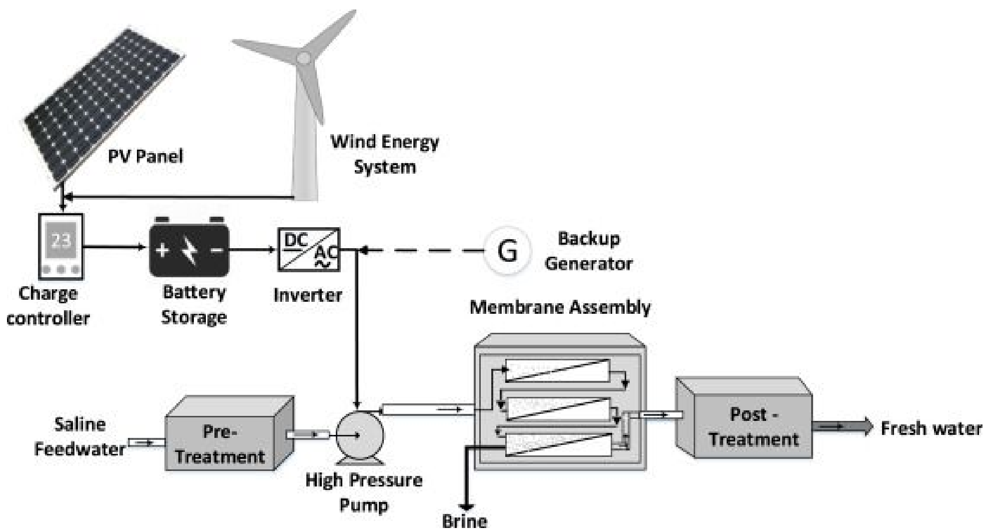


Figure 6. Water desalination using reverse osmosis powered by a hybrid renewable energy system. Taken from the Renewable and sustainable energy review journal.

Another example is solar powered reverse osmosis in Namibia. **See more examples** of renewable energy use in desalination techniques see **here**.

Examples of wave-powered plants that desalinate seawater using reverse osmosis are those in Perth and Garden Island, Australia.

While wind and wave energy are used to produce electricity and power membrane-based desalination, Solar energy can be Solar-electrical(or solar photovoltaic) and Solar-thermal which means it can also be used for thermal-based desalination to produce heat through solar concentration. The following images show examples of solar powered membrane and Multi-Effect distillation.

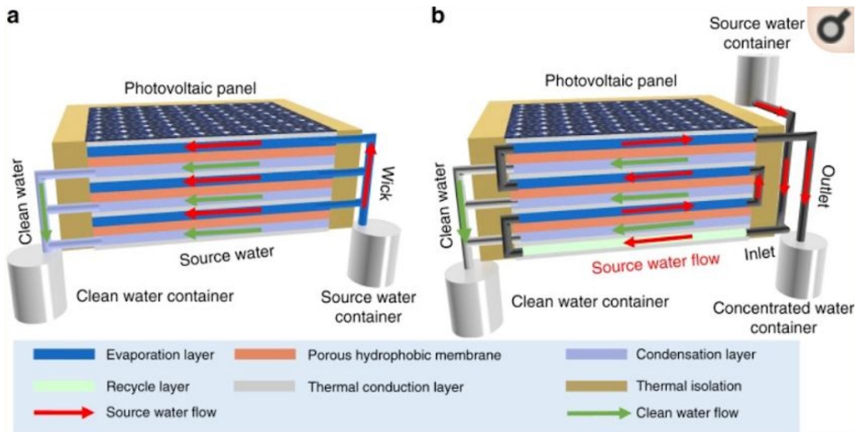


Figure 7. Illustration of an integrated photovoltaic-membrane distillation (PV-MD) device (a dead-end mode, b cross-flow mode). **Read more here.**

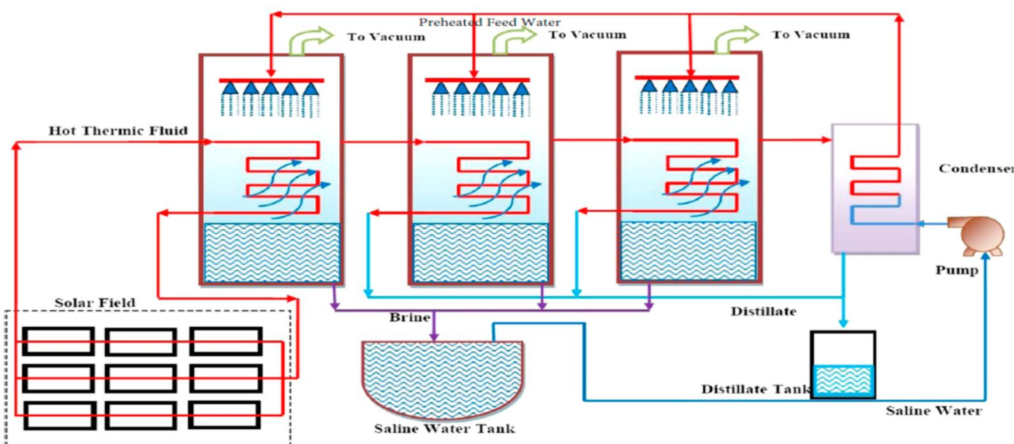


Figure 8. Solar powered Multi-Effect Distillation. **Read more here.**

Learn more in the Technology brief on Water Desalination Using Renewable Energy here. And a review on the Recent Developments in Solar Thermal Desalination Technologies, here.

Solar distillation

Solar distillation uses solar energy to evaporate salt or brackish water and collect its condensate for fresh water drinking. To illustrate the principle, this video shows one commercial implementation. **Read more** about Distillation approaches based on solar energy here.

Distillation processes are often used for small scale - such as households - and can be made from local materials, with no moving parts.

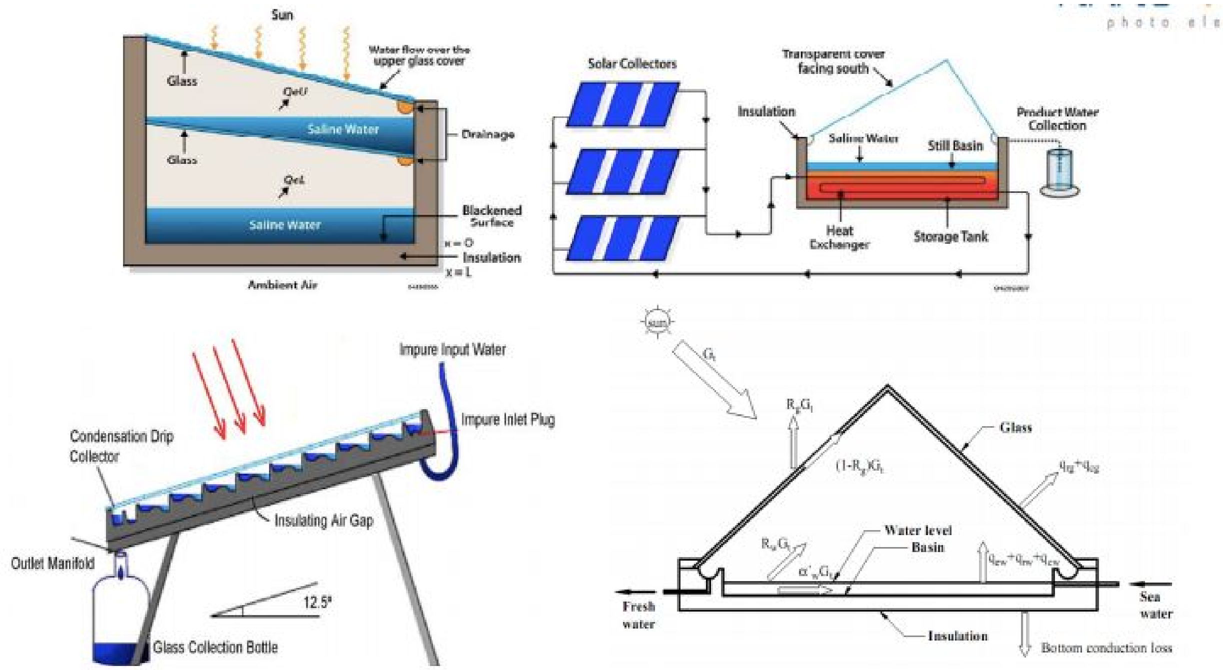


Figure 9. Schematic diagrams of a simple solar still.

5. Factors in desalination strategies

Many factors are involved in determining the efficiency and long term sustainability of desalination approaches: brackish water salinity, total solids concentration and temperature, energy consumption, local energy costs, desalination process sub-products, end-user water requirements, scale of application (e.g. household, irrigated farms or urban water), and environmental policies amongst others. **Read more** about factors affecting the cost of different desalination technologies view chapters 4 to 7 of the following Review by the World Bank. Read examples of other factors on page 2 of the U.S. Coordinated Strategic Plan to Advance Desalination for Enhanced Water security.

6. Desalination approaches: Comparison

Each different kind of approach to desalination has its advantages and disadvantages, regarding energy source, energy efficiency, cost, scalability etc. For example, the advantage of electrical over thermal energy sources depends greatly on the location of the installation and local cost of different energy sources. Another example is modularity which is an important consideration for scalability. Membranes are generally considered scalable because increasing capacity means adding additional membrane modules - and doesn't require changing what's already there, while thermal-based assemblies might require. See in figure 10 a comparison of different desalination technologies and in figure 11 a comparison between renewable water desalination. **Read more** in chapter 5 of the following Review by the World Bank. **Find here** a general comparative analysis of desalination technologies and a comparative cost analysis of different desalination technologies in Chapter 6 The benefits and costs of desalination in Desalination by the National Research Council.

Conventional Water Desalination					
Energy input	Fossil Energy (heat and/or electricity)				
Output	Fresh water				
Technology Variants	Thermal Processes			Membrane Separation Processes	
	MSF	MED	VC (MVC)	RO	ED
Energy input	Heat & electrical	Heat & electrical	Heat & electrical (mechanical power)	Electrical	Electrical
Feed water	More than 60% seawater (SW) plus brackish water (BW); Some high-salinity seawater may need pre-treatments for membrane separation				Mostly brackish water
Energy use	80.6 kWhe/m^3 (290 kJ/kg equivalent) plus 2.5-3.5 kWhe/m^3	80.6 kWhe/m^3 (290 kJ/kg equivalent) plus 1.5-2.5 kWhe/m^3	na	0 kJt /kg 3.5-5.0 kWhe/m^3	0 kJt /kg 1.5-4.0 kWhe/m^3
Typical total energy use	5 kWh/m^3	2.75 kWh/m^3	na	2.5 kWh/m^3	2.75 kWh/m^3
Operation temperature, °C	90-110	70	na	room temp.	room temp.
Plant lifetime, yr	na	na	na	na	na
Capacity factor, %	na	na	na	na	na
Market share, %	27	8	na	60	4
Global capacity (2011), m^3/day	72 million m^3/day (about 65 million m^3/day in operation) over about 15,000 plants				
Average plant capacity, m^3/day	4,000-5,000				
Largest plant capacity, m^3/day	800,000				
Major producers	MENA (Saudi Arabia), United States, China. About 38% of the global capacity (2,800 plants) in MENA				
Emissions	Emissions are associated with the primary energy used to power desalination plants				
Waste	Brine (high-salinity waste water)				

Desalination Costs	Typical current international values for new installed capacity (2010 USD)
Capital cost per unit of capacity	\$800 -\$1,500/m^3/day. Large variations depending on local labor cost, interest rates and technology
O&M cost per year	1.5-2.5 % of the investment cost per year
Fresh water production cost	USD 1-2/m^3 (USD 0.5/m^3 for large size plants), largely depending on energy cost and plant location
Projected Market Growth	
global desalination capacity	+ 9% per year between 2010 and 2016 (54% in MENA reaching 110 million m^3/d by 2030)
Investment	USD 88 billion between 2010 and 2016
Major producers/users	Saudi Arabia, UAE, US, China, rural remote areas and islands in the rest of world

Figure 10. Key data and Figures table for Desalination technology variants. Multistage-Flash distillation (MSF), Multi Effect distillation (MED), Vapor compression (VC),Reverse Osmosis (RO) and Electrodialysis (ED). **Read more in the Technology brief on Water Desalination Using Renewable Energy** here.

Renewable Water Desalination								
Technology Variants	**Solar stills**	**Solar MED**	**Solar Membrane Distillation**	**Solar CSP/MED**	**PV/RO**	**PV/ED**	**Wind/RO**	**Wind/MVC**
Development status	Applic.	Applic. / R&D	R&D	R&D	Applic./ R&D	R&D	Applic./ R&D	Basic R&D
Energy input, $kWhe/m^3+kJt/kg$	Solar passive	1.5 +100	0 +<200	1.5-2.0 + 60-70	0.5-1.5 BW 4.0-5.0 SW + 0	3.0-4.0 BW + 0	0.5-1.5 BW 4.0-5.0 SW + 0	11-14 SW + 0
Typical current capacity, m^3/day	0.1	1-100	0.1-10	>5,000	<100	<100	50-2,000	<100
Market share of renewable desalination	<1% of the global desalination capacity (62% based on RO, 43% powered by PV)							
Production cost, USD/m^3	1.3-6.5	2.6-6.5	10.4-19.5	2.3-2.9	6.5-9.1 BW 11.7-15.6 SW	10.4-11.7	3.9-6.5 BW 6.5-9.1SW	5.2-7.8

Figure 11. Renewable water desalination. **Read more in the Technology brief on Water Desalination Using Renewable Energy here.**

7. Innovation snapshot:

Recent innovations that have had the biggest impact on lowering the cost of desalination are illustrated by the following are examples from the E4C's SOlutions Library:

The WTC 500 RO System is a modular water purification system which produces drinking water at a rate of 550 L/hr from natural water sources.

The Katadyn Survivor 06 is handheld membrane filter designed to desalinate water in emergency situations.

[Desolenator](#) uses thermal and electrical energy to remove salt from water, powered by solar PV.

Biomimicry. Desalination processes in nature

Nature's time-tested patterns and strategies can be emulated in an approach to seek sustainable solutions to human challenges (known as biomimicry). Some examples of desalination in nature are: **Seabirds, Marine iguanas and sea turtles, Mangrove trees, Willow trees and reeds. See here** an example of Seawater Desalination and Biomimicry in Singapore

8. Disproportionately impacted communities

Communities that would benefit disproportionately from localized desalination include people living in desertic coastal areas or islands with no freshwater resources. Such is the case of rural communities in Guajira, Colombia, who live in the desert, face the need of having a more reliable and constant access to water for drinking, crops and livestock breeding. Inhabitants of carribean islands such as Aruba or of the pacific such as Kiribati that have sought the surrounding ocean and desalination technologies to ensure water safe for drinking.

9. Sustainable Desalination Considerations

Standards and Regulations pertaining the desalination process

Challenges for deployment of desalination technologies include access to policies regarding location and land rights, discharge streams and the quality (salinity) requirements of the product water depending on its application (for example, household, irrigated farm or urban water utility).

In the United States, there is the Coordinated Strategic Plan to Advance Desalination for Enhanced Water Security that responds to the 2016 Water Infrastructure Improvements for the Nation (WIIN) Act (Public Law 114-322, § 9(b)). Find more here. Water guidelines include the NSF standards for water treatment systems as well as those set by the U.S. Environmental Protection Agency (ISEPA) for drinking and waste waters. U.S. federal and state-level regulations related to desalination can be found here. International guidelines include the European Union and the World Health Organization (WHO) drinking water regulations and standards. Read an example of Desalination guidelines development for drinking water here.

Costs related to regulation compliance will depend largely on the type of desalination technology and vary depending on land rights and usage, discharge and product water requirements.

Environmental regulations related to the desalination process

Environmental and ecological impacts of desalination facilities. Modern reverse-osmosis desalination plants take in large volumes of seawater and discharge highly concentrated brine back into the sea. A 2018 United Nations study reports almost 16,000 desalination plants operating currently in 177 countries, producing toxic brine which is usually dumped in the sea, risking contaminating food chains if left untreated. Desalination technology consequences include impacts to marine life from seawater intakes, disruption of marine ecosystems from concentrate discharge, the energy intensity of the desalination process, and the potential degradation of water quality. Also other ecosystem impacts depending on site specific circumstances and local environmental conditions that may change over time, thereby requiring careful monitoring and management. This is why desalination technologies and facilities can not only aim to reduce water scarcity but must not cause more damaging ecological impacts therefore must comply with Federal, State and Local environmental regulations (Taken from the U.S. NTSC 2019 Report).

Environmental regulations. Environmental regulations for desalination technologies will be related to brine discharge concentrations and treatment procedures before returning to the sea or being pumped back into deep inland water pockets. Standards and regulations will also depend on specific location policies and the type of technology. An example of this in the United States is the practices and regulations for membrane concentrate disposal. Some International efforts that desalination technology will need to take into account include the Global Programme of Action for the Protection of the Marine Environment from Land-based Activities and the Resolution on the protection of the marine environment from land-based activities by the United Nations.

Case Studies

1. Best practices for siting and developing desalination projects in California developed by the National Oceanic Atmospheric Administration. Find out more here.
2. Concentrate Management Toolbox and selected Case studies developed by the U.S. Department of the Interior Bureau of Reclamation, designed to compare concentrate management technologies based on the needs of the end user. Access the toolbox here.

Read more about environmental regulatory issues of desalination in Chapter 7: Implementation Issues in Desalination by the National Research Council. To read about sustainable management of desalination plant concentrate click here.

User/Customer considerations of Desalination technology implementation

A variety of issues when implementing any desalination technology must be taken into consideration including customer needs, public/user acceptance and perception of the technology, strategy or facility, the source water used, location and environmental effects of the technology as well as the user provision model (product/service supply/ purchase model), cost for users, beneficiary purchasing-capacity and ability to operate and maintain the technology over time. Read more about implementation issues of desalination facilities in Chapter 7: Implementation Issues in Desalination by the National Research Council. Find out more about what affects public acceptance of recycled and desalinated water here.. Read a case study on perceptions and Acceptance of Desalinated Seawater for Irrigationin Southeast Spain here.

10. Business and Market Considerations

Desalination across the world

A variety of companies around the globe are involved in desalination and most of them participate in the **Global Water Awards** grants the "Desalination Company of the year" award.

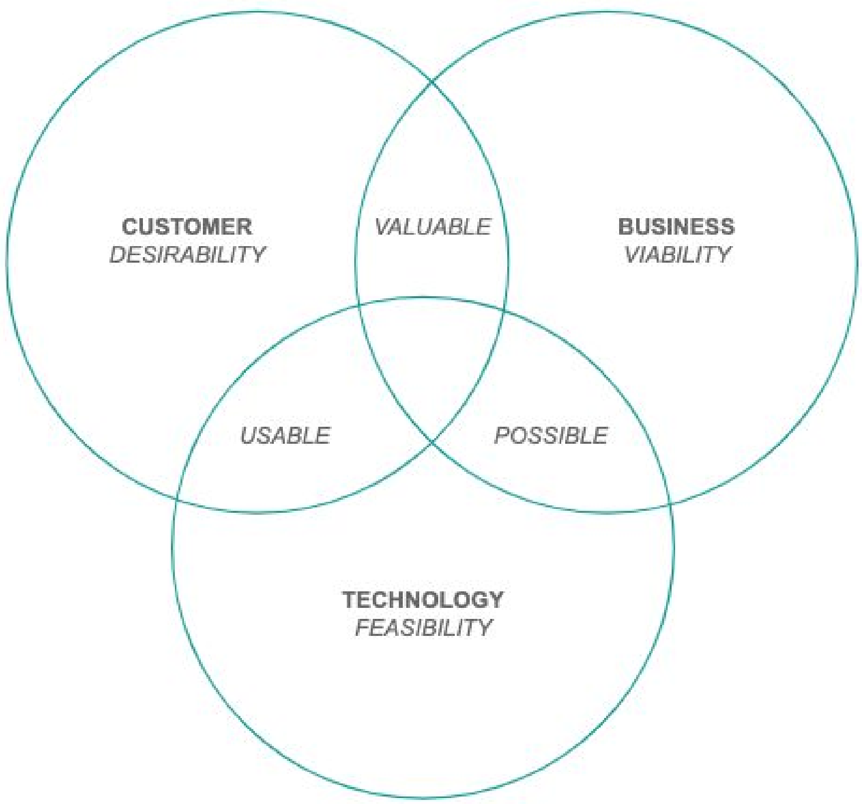
Possible Funding/cost models for desalination technologies

This involves considering issues such as capital and operational costs, project delivery methods and traditional desalination plants financing of desalination technologies, as well as cost and adaptability by the user. More about this can be found in detail in Chapter 7: Implementation Issues of Desalination by the National Research Council. Also, read about desalination project financing and delivery and implications on cost and factors to take in consideration when choosing desalination in chapters 7 and 9 of the following Review by the World Bank**.**

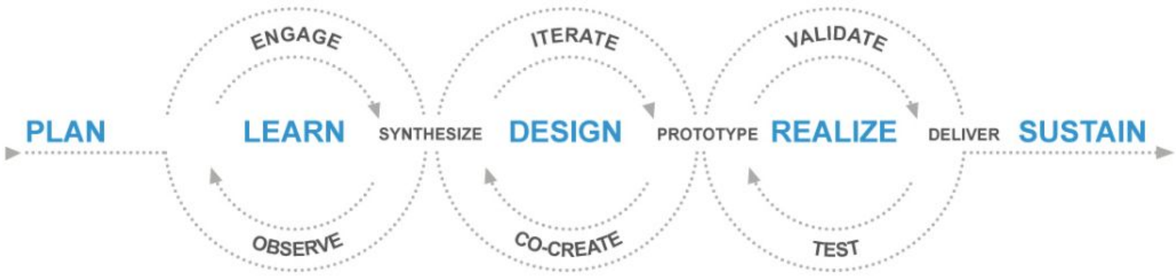
SECTION 2: DESIGN PARAMETERS

1. AN INNOVATIVE APPROACH

A **human centered design approach** to solving problems in underserved communities must take into account the gaps that presently exist between the principal domains that impact most situations - those centered on the *customer*, the *business*, and the *technology*. Without addressing each of these, and the ways that they interact, we risk presenting a solution which does not adequately address all of the issues, and thus will likely not be adopted by the population in a sustainable manner. It probably won't succeed. The Design Objectives below are meant as a guide, to be used to help make sure that key aspects of the water challenge are being taken into consideration. As you progress in the challenge process, use these as one way to make sure that your proposal stays focused on what is *possible*, what is *usable*, and what is *valuable*. To learn more with E4C's Introduction to Human Centered Design for Engineers webinar see here.



The Solutions Development process developed by E4C (shown below) illustrates the path towards sustainable solutions based on lessons learned from the field. This process is non-linear, in the real world, lines between phases often blur.



Learn more about the Solutions Development Process in E4C's [Introduction to Engineering for Global Development] course.

In order to help you address all of the relevant customer, business, and technology issues you should be thinking about the following questions. While you are not expected to know answers to all of the questions at the start, it can be helpful to answer as many as possible, knowing that your answers may change as you continue to research, design, and prototype throughout the challenge.

2. CHALLENGE DESIGN PARAMETERS

Throughout the Siemens Design Challenge, you will need to provide answers to the following design parameters for your product development for all the three phases from the Learn & Plan to the Realize & Sustain and development. Note: you will find specific design parameters required for each phase described in the 'Design parameters - per challenge phase' section. Please refer to those particularly when you are in that phase of the challenge.

Customer/User:

1. *Identify your target customer and determine if they are also your end user.*
2. *List your user's needs and decide what is not being met with current solutions.*
3. *Understand the context/environment in which your product will be used. Make note of how your product will have to perform under specific conditions.*
4. *Identify what your users water source will be (seawater or brackish water). Estimate the level of salinity you will be working with.*
5. *Determine your user's water needs per day. Define an appropriate capacity for your system.*
6. *Discuss how they currently solve their problem (either through market driven solutions or innovative workarounds)*

7. *Define how they make purchasing decisions and what may inhibit them from purchasing a new product.*
8. *Establish what price point is affordable for your customer. Estimate a willingness to pay based on other products they may own or purchase and market standards.*
9. *Determine what an acceptable operating cost would be for your user.*
10. *Determine if your user has the wherewithal (tools, money, expertise) to maintain your product.*
11. *Identify ways to design around ease of maintenance.*
12. *Identify how and where replacement parts will be available for routine maintenance.*
13. *Define how desalinated water will be used and whether there are specific properties needed.*
14. *Define how your user could safely dispose of concentrated brine.*

Technology:

15. *Research prior art. Identify standards or other benchmarks that have been set by competitors.*
16. *Identify your preferred water collection modality and scale (personal, household, community, large-scale etc).*
17. *Identify ways to distribute clean water.*
18. *Research regulatory standards and define how they might impact your design and development process.*
19. *Determine key technologies that you might integrate into your design.*
20. *Consider and/or estimate your design's energy consumption (kWh/L) and what that will require in terms of hardware.*
21. *Determine how the level of salinity will impact your product's efficiency (Is there a maximum salinity level at which it will function?)*
22. *Determine what material properties are required. Does your user require durability, weight management, longevity manufacturing?*
23. *Describe how your product will be manufactured. Identify what processes you will use and provide justification in terms of sustainability, cost, quality.*
24. *Identify which components could be manufactured locally and which should be outsourced. Internalize how that will impact overall cost, quality and sustainability.*
25. *Decide which technologies you will need to develop yourself and which can be assembled from off the shelf components.*
26. *Identify contaminants that should also be removed by your technology based on your user's region or location and how that will affect your overall design. Can it be used in conjunction with other treatment technologies?*
27. *What is the estimated lifetime of your technology?(In years, literes, etc.). Address how your design will prevent purified water from recontamination.*

28. Are there any drawbacks/challenges to your tech, and if so how have you started to plan to overcome them?

Business and/or Implementation:

29. Provide a list of other products/solutions that you will be competing with. Identify competitor products and their key features.
30. Determine how you will measure impact for the end user.
31. Identify where in the value chain the proposed technology fits. Determine how it will integrate in an existing system.
32. Identify how you would calculate (or estimate) your product's global climate impact. Impact could be measured by energy usage, emissions reduction, or water and land usage compared to the current solution in your target market.
33. Should you take this concept to market, identify where you lack expertise and how you might close those gaps.
34. Research regulatory requirements that may impact the design or distribution of your final product.
35. If your design requires chemical consumables, how will you safely procure and discard them after use.

3. PHASE SPECIFIC DESIGN PARAMETERS AND DELIVERABLES

LEARN & PLAN PHASE (Phase 1)

DESIGN PARAMETERS

For the Plan and Learn phase of the design challenge, you will need to provide answers to the following design parameters:

Customer/User:

1. ***Identify your target customer and determine if they are also your end user.***
2. ***List your user's needs and decide what is not being met with current solutions.***
3. ***Understand the context/environment in which your product will be used. Make note of how your product will have to perform under specific conditions.***
4. ***Identify what your users water source will be (seawater or brackish water). Estimate the level of salinity you will be working with.***

Technology:

1. ***Research prior art. Identify standards or other benchmarks that have been set by competitors.***
2. ***Identify your preferred water collection modality and scale (personal, household, community, large-scale etc).***
3. ***Identify ways to distribute clean water.***
4. ***Research regulatory standards and define how they might impact your design and development process.***
5. ***Determine key technologies that you might integrate into your design.***

Business and/or Implementation:

1. ***Provide a list of other products/solutions that you will be competing with. Identify competitor products and their key features.***

Phase 1 Deliverables: Problem Definition and Proposed Concept Before jumping into developing a solution, it is critical that you outline the exact problem you are trying to solve with the users needs, wants and constraints in mind. This will help you frame, and in the end justify, the reasoning behind your design decisions. Based on your user research and the design parameters you've identified above, contextualize the problem you are intending to solve from the perspective of your user.

Problem Definition:

What is the problem you are intending to solve?

Example Problem statement: *La Guajira is the department with the lowest water coverage amongst rural areas in Colombia (only 4% of its rural population have access to potable water). Due to its deserted landscapes, communities such as the Wayuu indigenous clans get their water from 'Jagueys', ponds that form from rainwater in the rainy season however these have contamination problems due to animals; when 'Jagueys' are dried out during the drought season, communities use wells to access groundwater but this water is mostly brackish. Treated water can be purchased in plastic bags or from water tanks for drinking, crops and livestock but is extremely expensive because it must be brought from long distances (a cost representing sometimes more than half of these people's monthly wages) and yet, in some cases can still taste slightly salty. A few inverse-osmosis water treatment plants have been established in some areas but have had many challenges and have quickly stopped functioning due to operational costs but also because of the lack of maintenance, qualified personnel and successful management.*

Concept Development:

Draft an initial solution concept. Note that you will refine this concept over the course of the challenge. Solutions should address one of the two challenges posted. At the Plan and Learn phase, concepts may be explorative, but should start to answer the following questions:

1. *What is the problem you are intending to solve?*
2. *How is that problem currently being addressed? (Provide a list of other products/solutions that you will be competing with)*
3. *How is your idea different from an Engineering or Human Centered Design standpoint?*
4. *Who is your target user? Describe them and the context that your technology would be used in. What are their current unmet needs or how might your product improve their quality of life?*
5. *Describe your product architecture in 5 sentences. What is the technology at play? What is the relative size of the product? What are the main components and how are they assembled? What are the 3 main features and benefits that this solution provides? What are the potential challenges (design and development) you think you will face?*

In subsequent phases of this challenge, you will need to answer the questions below: What materials is your product made of? What manufacturing processes will you use to develop each of your products components? What are the potential challenges in design and development you predict you will face? Sketch how you currently envision your product assembly. Focus on conveying concepts of assembly, part count and functionality.

DESIGN PHASE (Phase 2)

DESIGN PARAMETERS

For the Design phase, you will begin to design a product concept around the insights you gained during the Plan and Learning phase. The following questions outlined are things to consider when heading into design and development:

Customer/User:

1. ***List your user's needs and decide what is not being met with current solutions.***
    1. ***What products currently exist in the market that solve the same problem?***
    2. ***Identify any product attributes you will have to integrate in your design (ie. will your design have to be modular, transportable, durable, lightweight, aesthetically appealing, etc.)?***
2. ***Understand the context/environment in which your product will be used. Make note of how your product will have to perform under specific conditions.***
3. ***Determine your user's water needs per day. Define an appropriate capacity for your system.***
4. ***Discuss how they currently solve their problem (either through market driven solutions or innovative workarounds)***
5. ***Establish what price point is affordable for your customer. Estimate a willingness to pay based on other products they may own or purchase and market standards.***
    1. ***What features do they offer and what is the perceived value of those features?***
    2. ***How will this cost benefit analysis of competitive features impact your design?***
6. ***Determine if your user has the wherewithal (tools, money, expertise) to maintain your product.***
7. ***Identify ways to design around ease of maintenance.***
    1. ***What features improve your products usability and ease of maintenance?***
8. ***Identify how and where replacement parts will be available for routine maintenance.***

Technology:

9. ***Identify your preferred water collection modality and scale (personal, household, community, large-scale etc).***
    1. ***Create a sketch that illustrates general product architecture.***
10. ***Consider and/or estimate your design's energy consumption (kWh/L) and what that will require in terms of hardware.***
    1. ***How will this required hardware impact your overall design?***
    2. ***Create a schematic diagram of how your product will function.***

11. ***Determine what material properties are required. Does your user require durability, weight management, longevity manufacturing?***
12. ***Identify which components could be manufactured locally and which should be outsourced. Internalize how that will impact overall cost, quality and sustainability.***
13. ***Decide which technologies you will need to develop yourself and which can be assembled from off the shelf components.***
    1. ***Are there components that may fail or need to be replaced more frequently? Are off the shelf components suitable for these parts?***

Business and/or Implementation:

14. ***Provide a list of other products/solutions that you will be competing with. Identify competitor products and their key features.***
15. ***Identify where in the value chain the proposed technology fits. Determine how it will integrate in an existing system.***
    1. ***Identify existing processes or routines you will need to consider in your design. Can your design standalone, or do you need to integrate with existing infrastructure?***
    2. ***How will this integration affect certain design decisions?***
16. ***Research regulatory requirements that may impact the design or distribution of your final product.***

Phase 2 Deliverables: Concept Visualization and Design Rationale

Now that you've identified a problem that is not currently being addressed in the market, or a current solution in need of improvement, it is critical that you place your user's needs at the core of your design process. Based on the user research you conducted and the design parameters you've identified above, prioritize the product attributes that most closely respond to your user's needs and develop a product architecture that addresses or responds to those needs. Your answers to the questions above will help define the design parameters you will have to work within. Having solid answers, or even assumptions at times, will help you justify your design decisions and weigh tradeoffs when beginning to refine and realize your solution.

Throughout Phase 2, you will move from schematic diagrams and 2D sketches, to 3D modeling and higher fidelity visualizations. The objective in Phase 2 is to take what we learned from our user and turn those insights into actionable design criteria. For instance, if we learned that our user will transport our product to and from work everyday so that it isn't stolen, we know that weight and durability will be important product attributes. Declaring 'lightweight' and 'rugged' as being important design criteria, means that material choice or manufacturing processes may be important considerations. Depending on our user's disposable income, we will have to weigh which materials and manufacturing processes will be the most appropriate for balancing, weight, durability and price. By starting with our user and defining design constraints around their needs, we can feel confident that we will develop a solution that will be desirable, valuable, and usable.

With a clear set of design criteria and a product concept in place, you will use the tutorials made available for you on how to use Solid Edge to model your product, visualize the relationship between parts and assemblies and create basic renderings to illustrate the different attributes of your product.

Finally, you will submit a three to five minute video presentation on your product concept and explain what design criteria you identified that drove your design decisions.