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Sistema sustentable para desalinización de agua

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Este proyecto fue realizado en colaboración con la
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QUEREMOS DEDICAR ESTE PROYECTO AL PUEBLO WAYUU EN LA GUAJIRA, PARA QUIENES FUE DESARROLLADO

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Este logro es suyo.

RESUMEN

Esta tesis es el resultado de una colaboración academica durante un semestre de intercambio estudiantil entre la Universidad Nacional Autónoma de México, la Universidad Högskolan I Skövde localizada en Skövde Suecia y la organización Ankarstiftelsen. La organizacion Ankarstiftelsen es una organización sin fines de lucro con la misión de satisfacer las necesidades básicas en comunidades marginadas y en vías de desarrollo. Uno de los principales problemas que busca solucionar es el acceso al agua potable en la región de La Guajira en Colombia. Esta colaboración tuvo como finalidad el desarrollo de una propuesta inicial para un sistema sustentable de desalinización para la obtención de agua potable para el cosumo humano a través del uso de energía solar con un costo de producción mínimo.

Debido a la naturaleza técnica del proyecto, el proceso de diseño requirió realizar durante cinco meses investigaciones y estudios sobre los principios de desalinización y sistemas de purificación de agua, así como revisar y analizar las condiciones actuales referentes a la colección y consumo de agua en La Guajira. A través de una selección de métodos de diseño, se desarrolló una primera propuesta de un producto coherente con el contexto y necesidades del mismo. Los cinco meses de trabajo en colaboración con la Universidad de Skövde, la organización Ankarstiftelsen y la comunidad indígena Wayuu en Colombia dieron como resultado un sistema sustentable de desalinización de agua salada para la generación de agua potable. Dicho sistema es una configuración simple y comprensible que integra materiales y procesos locales para fines funcionales a través de tres sistemas (Sistema de agua de entrada, Sistema de evaporación, Sistema de condensación) que trabajan al unísono para desalinizar el agua.
El agua obtenida se puede utilizar para el consumo humano debido a los bajos índices de salinidad, aunque para su calidad óptima y clasificación como agua potable se deben agregar ciertos nutrientes y minerales al agua resultante. Sin embargo, también se puede implementar para la limpieza de alimentos y utensilios, dado que el agua desalinizada puede mejorar la higiene de los procesos de cocción. Además, el uso del agua resultante para el baño personal o la limpieza de heridas pueden reducir el riesgo de infecciones y enfermedades. El proceso de diseño, sus limitantes y resultados presentados en Suecia pueden consultarse en el documento anexo de este reporte (página 75).

En busca de adecuarse a la misión de la UNAM, este documento presenta un replanteamiento de los resultados obtenidos en Suecia con la finalidad de realizar un aporte a nuestro país, México, tomando como referencia los materiales y recusos locales asi como las condiciones climaticas del pais.

INDICE

01

INTRODUCCION

El agua potable es una de las necesidades básicas indispensables de los seres humanos, sin embargo, de acuerdo con el reporte de la Organización Mundial de Salud en 2007, más de un billón de personas en el mundo carecen de acceso al agua limpia y bebible. En comunidades vulnerables o en vías de desarrollo como es La Guajira en Colombia e incluso en la region noroeste de México, el agua salada representa la única fuente de consumo para un gran porcentaje de la población. Esto implica altos riesgos para la salud ya que el consumo de agua salada es una de las principales causas de enfermedades agudas y crónicas en países tercermundistas.

Ciertamente, diversos procesos proveen alternativas para la purificación del agua, en donde los más eficientes se basan en el uso de energía eléctrica para acelerar el proceso de evaporacion, una explicacion y evalucion de los procesos de desalinizacion se puede consultar en el documento anexo pagina.23. Dichos procesos altamente tecnológicos, se vuelven inasequibles para las comunidades que más lo necesitan y al mismo tiempo implican una huella ecológica mayor dado que representan altos costos de producción y mantenimiento.

La región de La Guajira como varias regiones de México está mayoritariamente poblada por comunidades indígenas y de bajos recursos; por lo tanto, el desarrollo de un sistema de purificación de agua salada debe considerar sus condiciones de vida cotidiana y garantizar altos niveles de productividad manteniendo un costo accesible y asi poder ser implementado de manera eficiente en comunidades vulnerables. Existen diferentes productos y proyectos de desalinización solar que han sido probados en comunidades en desarrollo, ya que son una tecnología adecuada para lugares donde el suministro de energía eléctrica o el acceso a recursos convencionales es escaso.

Las costas de México así como en La Guajira, cuentan con una fuente abundante de agua salada; sin embargo, no puede utilizarse para el consumo humano debido a sus altos niveles de sales. Así mismo, la energía solar es un suministro cuantioso de energía en el país, que al aprovecharla mediante la implementación de un sistema de desalinización solar puede reducir significativamente el costo de obtención de agua para consumo humano. Adicionalmente, el uso de la energía solar implica una independencia de las fuentes de energía y garantiza el acceso al agua con un bajo impacto ambiental. Es por esto que acontinuacion se presenta el desarrollo de una propuesta del sistema de desalinizacion para dar solucion a la problematica antes descrita dentro del territorio mexicano.

Objetivos

En este documento el replanteamiento del resultado obtenido inicialmente en la tesis realizada en Suecia, será enfocado a una region en México, como la zona noroeste, y se tomarán como referencia para el proceso de diseño. El replanteamiento busca adaptar y mejorar la propuesta inicial a traves de la seleccion de materiales y procesos locales sin modificar aquellos aspectos técnicos en los que se basa el funcionamiento y eficiencia de la propuesta.

Este planteamiento surge con el propósito de mostrar un breve ejemplo de la capacidad adaptable de la propuesta de diseño inicial, la cual debido a la selección de componentes comerciales en su sistema de desalinización permite una modificación con la posibilidad a ser escalable y reproducido en distintos contextos siempre y cuando las condiciones climáticas sean favorables para la desalinización de agua y los factores que comprometen el funcionamiento y eficacia del sistema sigan presentes. Asimismo el cambio de contexto también permite la libertad de conceptualizar una propuesta más integrada con mayor variedad de materiales, procesos de produccion y un rango de costo menos limitado. Esto concede tolerancias a la propuesta inicial logrando un sistema cohesivo a través del replanteamiento de algunos de sus componentes.

Metodologia

El objetivo del proyecto se centra en la funcionalidad y eficiencia de un sistema, por lo que se requirió la implementación de métodos apropiados que ofrezcan estructura y permitan la creación de restricciones y criterios para la evaluación de conceptos. Se entiende por funcionalidad, la desalinizacion del agua sin alterar la composicion original del sistema de evaporación, mientras que por eficiencia se entiende el incremento teórico de producción de agua del sistema a comparacion del sistema diseñado en Suecia. Los criterios especificos de evaluación de eficiencia y funcionalidad del proyecto se pueden consultar en el documento anexo (capitulo 4).

Esquemáticamente, el proyecto se lleva a cabo como una iteracion dentro de las cuatro etapas del modelo descriptivo de procesos de diseño de Nigel Cross (2008). Una descripción detallada de las metodologías aplicadas en cada fase del desarrollo se puede consultar en el Anexo (capítulo 1.4). Esta iteracion representa una continuación de la metodología original del proyecto para explorar el contexto mexicano. La metodologia del poryecto original comprendio, como se puede observar en la Figura 1, herramientas como entrevistas, desarrollo de prototipos funcionales de mecanismos, tablas de especificacion y *Life Cycle Assesments* de los materiales seleccionados para evaluar su impacto ambiental.

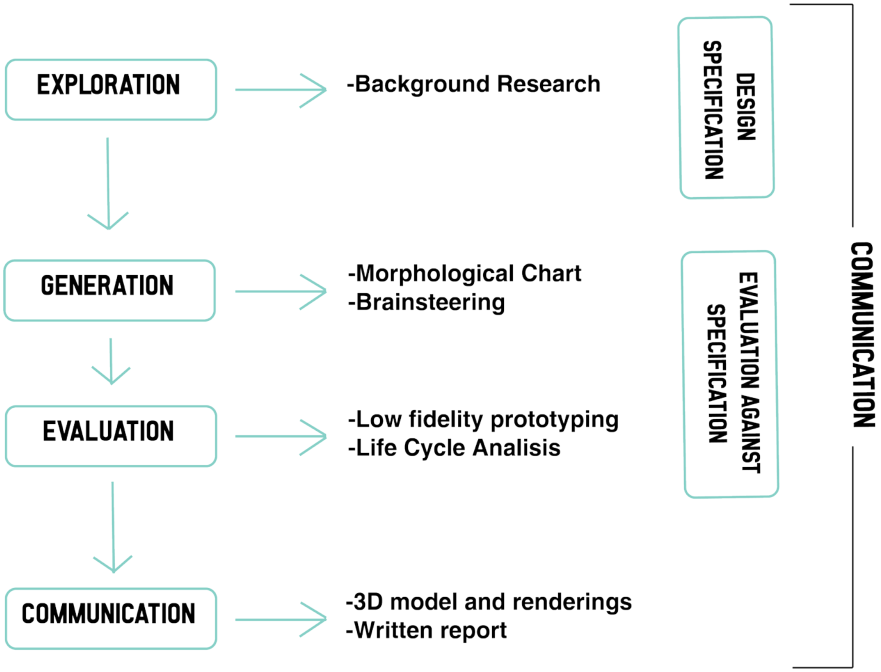


Figura 1. Diagrama de metodologia.

El seguimiento de la metodología parte de en una investigación breve para la identificación de una región con las condiciones climáticas que permitan el correcto funcionamiento del sistema técnico del desalinizador. Una vez recopilada la información necesaria de dicho entorno, sesiones de *brainsteering* guiarán la creación de posibles soluciones.

Brainsteering es un proceso de pensamiento guiado por parámetros establecidos para generar conceptos dentro de un contexto o problema con factores que restringen la generación de soluciones (Coyne y Coyne, 2011), como el que se aborda en este replanteamiento del proyecto. Las ideas resultantes fueron introducidas a una tabla morfológica para generar propuestas formales, las cuales se evaluaron según su adaptación al contexto y cumplimiento con los requerimientos de un sistema más integrado visualmente.

02

SINTESIS DE LA PROPUESTA INICIAL

La desalinización es un proceso para separar la sal y otros minerales, como son los cloruros, bicarbonatos, carbonatos, sulfatos, sodio, calcio, magnesio, entre otras (Feliú y Morcillo, 1982), del agua salina para que sea aceptable para el consumo humano. El principio se basa en separar los contenidos del agua en función de los diferentes puntos de ebullición (Ahsan et al., 2014). En este proceso, el agua se calienta en un ambiente cerrado para que alcance un punto de evaporación, la temperatura se mantiene durante largos períodos de tiempo para evaporar agua continuamente sin evaporar ningún otro contaminante en el agua. El vapor de agua se condensa y se recolecta como agua purificada.

Existen diferentes tipos de procesos de desalinización que aplican nuevas tecnologías para aumentar la eficiencia del proceso (Véase documento anexo capitulo 2), sin embargo, el método más popular sigue siendo la desalinización solar, la cual hace uso de la radiacion solar para elevar la temperatura del agua hasta alcanzar su evaporacion. Existe una extensa investigación y estudio por diferentes organizaciones, universidades e investigadores con respecto al uso de la desalinización en la producción de agua potable; un análisis de ellos y las conclusiones de sus parámetros puede consultarse en el documento Anexo (capítulo 2.3).

Después de la investigación y el análisis inicial de la desalinización solar, se identificaron los componentes básicos de los desalinizadores (Véase documento Anexo, capítulo 2.6) y se dio paso a la creación de subsistemas con el fin de comprender mejor cómo funciona el proceso de desalinización. El estudio también proporcionó información clave sobre las consideraciones para el incremento de la eficiencia y la construcción adecuada del sistema. Los subsistemas identificados son los siguientes.

Recoleccion de Calor

Consiste en la colección de rayos solares y el aumento de la radiación solar para ser transferidos al sistema de retención de calor. Su funcionamiento adecuado está condicionado por el tamaño del área de colección así como el uso óptimo de materiales resistentes a la exposición solar por largos periodos de tiempo.

Retencion de calor

Este sistema se enfoca en la absorción, retención y transferencia de calor al cuerpo de agua para aumentar la temperatura y permitir la evaporación. Este sistema requiere una observación especial de los coeficientes de transferencia de calor de los materiales para garantizar una alta eficiencia de todo el sistema.

Proceso de Condensacion

El condensador es un sistema destinado a reducir el tiempo de condensación del vapor de agua para aumentar la eficiencia del sistema. Un diseño adecuado debe considerar la capacidad de absorción de agua de los materiales, así como la diferencia de temperatura entre el recipiente de agua y el área de condensación. El diseño propuesto es una solución inicial para un sistema de desalinización para producción local. Dicho sistema está compuesto por tres sistemas diferentes, basados en los subsistemas explicados anteriormente, que trabajan en conjunto para desalinizar el agua y se describen a continuacion.

Sistema de llenado

Integra un conjunto de componentes que permiten el rellenado de la cámara de evaporación. Comienza con una manguera y una boquilla de tanque que se puede conectar a cualquier recipiente o fuente de agua. Este sistema integra una válvula flotante, la cual además de facilitar el rellenado automático de la cámara de evaporación, permitirá que el agua fluya hasta una cuarta parte del tubo, sellando la entrada de agua y el escape de vapor de agua. Los componentes del sistema pueden verse en la Figura 2.

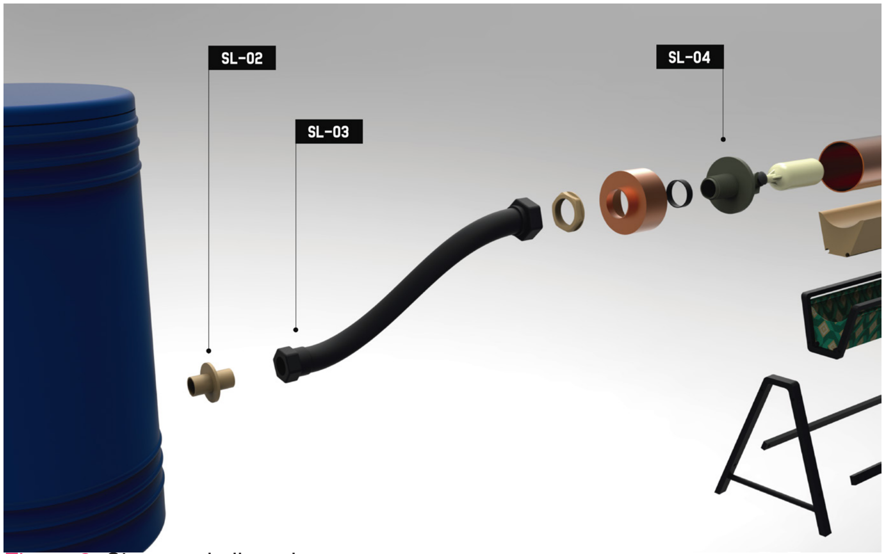


Figura 2. Sistema de llenado

Sistema de Evaporacion

Se compone de una cámara de evaporación, un sistema de aislamiento y una estructura soporte. Su principal objetivo funcional es la evaporación del agua salina mediante la implementación de un tubo de cobre. La superficie externa del tubo de cobre recibe la radiación solar y la transfiere al agua en su interior permitiendo la evaporación. Cuando el agua contenida se evapora, aumenta la presión dentro del tubo sellado, como resultado, el vapor comprimido se expulsa bajo presión a través de una manguera de conexión en el condensador siguiendo la teoría de la Compresión Mecánica de Vapor (Shankar, R. 2014). La implementación de este sistema de evaporación mejora la eficiencia térmica del proceso de desalinización, ya que evita que el vapor de agua se condense dentro de la cámara de evaporación.

Además, para evitar la pérdida de calor en caso de viento o humedad en el ambiente, se integró un sistema de aislamiento, el cual consiste en el uso de arena sedimentaria y lana o algodón para retener el calor conducido a través del tubo de cobre, aumentando así la eficiencia de evaporación dentro del tubo.

Los componentes mencionados se mantienen unidos mediante una estructura metálica, que proporciona la estabilidad y la altura necesarias para transferir el vapor al condensador sin presentar el riesgo de que el agua se desborde en el tubo de evaporación. Los componentes de este sistema pueden verse en la Figura 3.

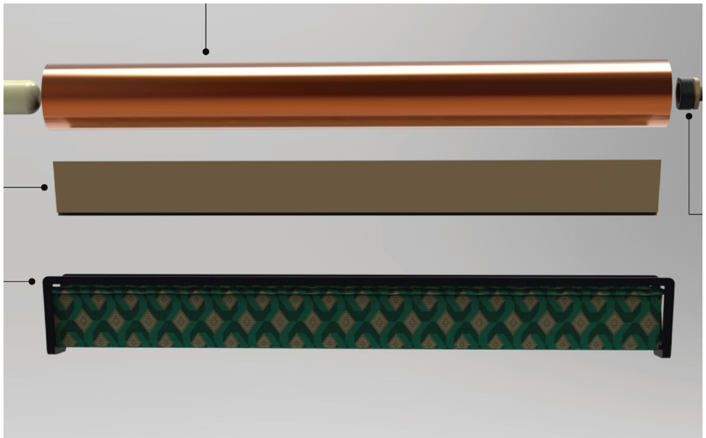


Figura 3. Sistema de evaporacion

Sistema de Condensacion

El vapor de agua producido en la cámara de evaporación, debido a la alta presión creada en el tubo de cobre, se mueve a través de un conector de gas hacia el contenedor final. Este movimiento se basa en el efecto del vapor comprimido y en su tendencia a trasladarse de áreas reducidas o de alta temperatura a áreas de menor presión y temperatura (Al-Juwayhel et al., 1997). El vapor generado en el tubo de cobre viaja a presión hacia un tanque de agua con mayor área y menor temperatura, permitiendo así la condensación a un ritmo más rápido. Para generar un menor temperatura en el contenedor final, se implementa un efecto *Pot-in-pot*, este efecto funciona con el principio de enfriamiento por evaporación, el cual a través del uso de un pequeño recipiente dentro de uno de mayor tamaño y mediante el uso de arcilla o raena humeda en el espacio naular, incentiva la transferencia de calor. Este sistema produce un efecto de enfriamiento dentro del contenedor interno (Date, 2012). La configuración de este sistema da como resultado un aumento de la eficiencia en la condensación y recolección de agua en el mismo recipiente, pero separado de la cámara de evaporación, evitando la pérdida de energía. En éste caso, el yeso fue seleccionado como material contenido en los espacios anulares debido a su bajo costo y baja temperatura. El sistema se representa en la Figura 4.

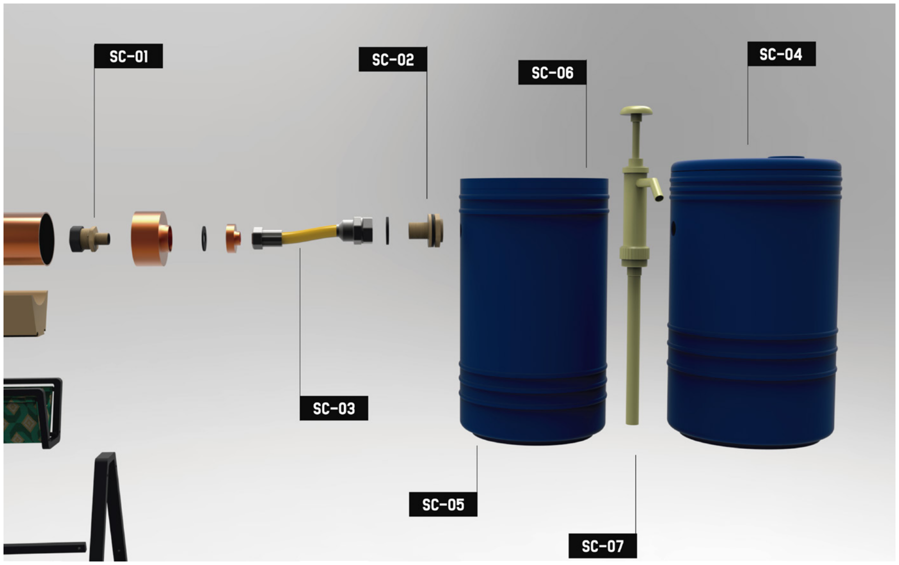


Figura 4. Sistema de Condensacion.

El diseño y la eficiencia del Sistema de desalinización propuesto es el resultado de la combinación adecuada de materiales, sus propiedades y geometría que propicien un proceso de desalinización más eficiente tomando en cuenta las condiciones climáticas de la localidad donde se implementa. La propuesta representa una solución rápida y viable para casos extremos y comunidades de bajos ingresos para obtener agua potable y ofrece la posibilidad de experimentar y perfeccionar el modelo a distintos contextos gracias al uso de componentes comerciales y procesos locales.

03

PARAMETROS DE DISENO

Las tecnologías que usan energía solar se pueden clasificar como pasivas o activas. Las tecnologías activas convierten la luz solar en electricidad como paneles solares, mientras que las técnicas pasivas utilizan materiales con propiedades térmicas y diseño para intensificar y retener la energía obtenida de los rayos directos del sol (Tiwari y Sahota, 2017), reduciendo así la necesidad de fuentes de energía alternativas.
Dado que las técnicas pasivas se basan solo en el uso adecuado de los materiales y la geometría para concentrar, aumentar y retener el calor obtenido de la exposición al sol, los componentes de la cámara de evaporación, así como el sistema de insulación no serán alterados en la adecuación de diseño. Sin embargo, el rendimiento del sistema de desalinización solar depende en gran medida de las condiciones climáticas en las que se implementa entre otros factores técnicos, tales como:

Radiacion solar y clima

La radiación solar es la cantidad de energía proveniente del sol, por unidad de área, que recibe todo punto por encima de la atmósfera terrestre, en cada instante de tiempo (Plasencia S. et al.,2007); esta cantidad de calor varía tanto espacial como temporalmente, de acuerdo a la posición de un punto en particular sobre la Tierra y de la posición de ésta respecto del Sol. Se puede obtener una estimación de la cantidad de radiación solar que se recibe en una localidad mediante la medición del número de horas de sol por día.
Este parámetro requiere la selección específica de regiones en el territorio mexicano que presenten características climáticas similares a aquellos presentes en la Guajira, Colombia. Entre los requerimientos climáticos están la exposición solar de ocho horas diarias, baja precipitación anual y acceso a fuentes de agua salina.

Cuerpo de agua

Para garantizar la máxima eficiencia de evaporación del cuerpo de agua dentro de la cámara de evaporación, esta no debe exceder los 2,5 cm de profundidad (Arunkumar, 2013).

Está claro que la eficacia del producto es el resultado de una combinación adecuada de geometría y materiales para garantizar la exposición a la radiación solar con el fin de recolectar y retener el calor, aun así existe la posibilidad de modificar aquellos componentes que no afectan directamente la eficiencia del sistema para lograr generar una propuesta de producto más integrada considerando una selección más amplia de materiales y procesos de producción.

04

LOCALIDAD

Debido a lo esencial de las condiciones climáticas para la eficiencia de un sistema de desalinización solar, la adecuación a un contexto mexicano debe enfocarse hacia aquellas zonas o regiones que presenten las características necesarias para la implementación de un desalinizador solar. Dado que las condiciones climáticas no caen dentro de los parámetros modificables de diseño, las regiones seleccionadas para esta adecuación deben caracterizarse por altas temperaturas con mínimo ocho horas de radiación solar y baja precipitación anual. De acuerdo al Instituto Nacional de Estadística y Geografía (INEGI, 2018) la zona que presenta temperaturas altas y baja precipitación es el noroeste del país como son Sonora, Baja California Norte, Baja California Sur y Sinaloa, los cuales cuentan con acceso a agua de mar del Oceano Pacifico y el Golfo de California, tal como se muestra en la Figura 5.

La zona pacífico del país, muestra una radiación solar estacional, lo que significa que tiene valores de calor bajos durante los meses de invierno debido al movimiento del sol además de valores bajos en los meses de mayor lluvia como son agosto y octubre (Noguera, 2002). En estos estados mencionados, la temperatura alta promedio es de 30 grados centígrados, alcanzando en ocasiones los 45 grados centigrados en los meses de verano. En promedio la precipitación anual en esta zona del país es de alrededor 200 mm lo cual representa lluvias escasas. Estas características son clave para permitir el uso de un desalinizador solar sin afectar la eficiencia estimada de este. Otra característica clave para seleccionar la zona de implementación es el acceso al agua potable, dada la naturaleza del proyecto, las zonas elegidas deberán presentar también problemáticas respecto al acceso a agua potable.

La Secretaria de Medio Ambiente y Recursos Naturales (SEMARNAT, 2016) indica que la oferta de agua dulce en la zona noroeste del país proviene en su mayoría de mantos acuíferos subterráneos los cuales están actualmente a la baja por la sobreexplotación, aunado a esto la contaminación proveniente de fábricas, vehículos y las prácticas en la agricultura han dañado las fuentes de agua dulce superficial. Estas circunstancias han resultado en la escasez de agua potable para al menos 12% de la población en las regiones noroestes del país. Es por esto que las poblaciones rurales con bajo acceso a agua potable en la región noroeste del país serán a las cuales se enfocará esta adecuación de diseño como una propuesta para resolver la escasez de acceso a este recurso.

Figura 5. Zona noroeste del Territrio Mexicano

05

AGUA SALINA Y CORROSION

El agua de mar se caracteriza por si salinidad, la cual varia entre 30 y 37% de sales anhidricas por kilogramo de agua de mar, lo cual le da una alta conductividad debido a sus características fisicoquímicas. Dentro de sus componentes cabe mencionar las sales disueltas, oxígeno y bióxido de carbono disueltos, y prácticamente todos los cationes y aniones que intervienen en la composición mineralógica normal del agua: cloruros, bicarbonatos, carbonatos, sulfatos, sodio, calcio, magnesio, entre otras (Feliú y Morcillo, 1982). En la Tabla 1 se pueden observar los componentes del agua de mar.

Tabla 1. Componentes del agua de mar (Feliú y Morcillo, 1982).

COMPUESTO	CONCENTRACIÓN GRAMOS/LITRO
Cloruro de sodio, NaCl	27.0
Cloruro de magnesio, MgCl2	3.2
Sulfato de magnesio, MgSO4	1.6
Sulfato de calcio, CaSO4	1.3
Sulfato de potasio, K2SO4	0.8
Cloruro de potasio, KCl	0.5
Carbonato de Calcio, CaCO3	0.1
Varios (bromuros, fosfatos)	0.5
TOTAL	35.0

Esta alta conductividad genera que los procesos de corrosion se efectuen en lapsos cortos de tiempo. La velocidad de corrosion media en agua de mar sin contemplar los niveles de contaminacion, es de .12 um/año Debido a la implementacion de cobre en la propuesta de este proyecto, es importante considerar que este metal, al igual que otros elementos, es facilmente oxidable en presencia de oxigeno o hirogenos como los presentes en agua de mar (Gonzalez Gonzalez, 2006). Afortunadamente existen mas de 400 aleaciones de cobre que se daptan a un gran numero de aplicaciones, el cobre y varias de sus aleaciones son utilizados en diversos ambientes como son las aguas de mar, donde están sometidos al ataque corrosivo, principalmente debido al alto contenido de iones de cloruro.

Algunas de las aleaciones de cobre incluyen el niquel, estas aleaciones, principalmente 90/10 y 70/30, son aplicadas en las areas mariticas y tuberias para agua de mar asi como en las plantas de desalinizacion debido a su excelente resistencia a la corrosion por agua de mar. (Garcia, Uruchurtu y Genesca, 1995). Implementa esta aleacion de cobre en el producto final, es necesario para garantizar un perdiodo de vida util mayor a seis meses, el cual se tendria si se mantiene el uso de un cobre tipo M, el cual no presenta las caracteristicas necesarias para soportar la constante exposicion al agua salada de mar.

06

OPORTUNIDAD DE MEJORA

Si bien el resultado de diseño inicial responde a las necesidades de un contexto específico, su alto nivel técnico y selección de componentes comerciales permite su modificación a diversos contextos sin necesidad de afectar negativamente la eficiencia estimada. La adaptación de los resultados obtenidos en el proyecto realizado en Suecia, presenta la posibilidad de aplicarse a un contexto mexicano, integrando materiales y procesos de producción disponibles en la región. Así mismo es posible mejorar la apariencia estética para incorporar todos los componentes en un producto más unificado visualmente. A continuación se presenta un listado de los componentes modificables y sus posibles mejoras.

Contenedores

El contexto original en la Guajira, Colombia presentaba una limitada disponibilidad de materiales, por lo que para los contenedores de agua, tanto inicial como final, se planteo el uso de tambos de plástico que las familias de la región reciben como donaciones. Para el replanteamiento del diseno se considera la posibilidad de diseñar la geometría de los contenedores en beneficio del sistema.

Camara de Evaporacion

La distribución equitativa de agua dentro del tubo asegura un ritmo de evaporación más rápido, aun así, existe la posibilidad de incrementar el ritmo de evaporación al separar el tramo de un metro de tubo de cobre en dos secciones de 50 centímetros. Esto representaría dos cuerpos de agua de menor volumen, lo cual en teoría reduciría el tiempo requerido para evaporar el agua incrementando así la eficiencia del sistema. Es importante considerar que el área de exposición solar no puede ser modificada dado que para producir dos litros de agua, que es el mínimo recomendado para el consumo por persona en un día, el dispositivo debe tener un mínimo de un metro cuadrado de área de recolección solar. Dicha área puede describirse como el área de la superficie del tubo de cobre que está expuesta directamente a los rayos del Sol.

Estructura Soporte

Al no tener restricciones de presupuesto y selección de materiales, la estructura soporte del sistema se puede modificar para ofrecer un producto más integrado. Esto permitira una manipulación de todos los componentes sin necesidad de desinstalarlo, generando asi un transporte mas eficiente del producto. Sin embargo se deben tener en consideracion las condiciones climaticas de la region noroeste del pais por lo cual el material no podra ser modificado.

La solución original, presentada en Suecia, es el resultado de una amplia y minuciosa investigación de usuario y contexto, y como tal responde a las condiciones de vida de los Wayuu. Es por eso que varios de sus componentes fueron seleccionados de aquellos ya pertenecientes a los usuarios, este replanteamiento de diseño permite la consideración de mejoras que además de ofrecer una imagen más unificada del producto, mejoren el funcionamiento y usabilidad del producto.

07

GENERACION DE CONCEPTO

Con la información recopilada sobre la región seleccionada en México y la identificación de posibles mejoras, se crearon tablas morfológicas para desarrollar conceptos de posibles adaptaciones, seguidas por el diseño a detalle de ciertos elementos del producto. La Tabla 2 muestra una tabla morfológica con un listado de las áreas de mejora y sus posibles replanteamientos considerando aun algunas soluciones originales de la propuesta inicial que por las condiciones climáticas y de contexto pueden ser replicadas en México.

Tabla 2. Tabla morfologica para generacion de concepto

POSICIÓN DE CONTENEDORES	MATERIAL DE CONTENEDORES	MATERIAL DE INSULACIÓN	SISTEMA DE ENFRIAMIENTO
Horizontal	Plástico	Arena	Doble Pared
Vertical	Vidrio	Textil	*Pot in Pot*
Diagonal	Cerámica	Ambos	Combinación de ambos a partir de la cerámica

Las posibles soluciones se ligaron para generar diferentes conceptos teniendo en cuenta la region de noroeste de México y las oportunidades de mejora anteriormente mencionadas. Las propuestas resultantes deben ser evaluadas según su aportación al funcionamiento del sistema sin afectar la lista de especificaciones y requerimientos funcionales, la cual puede ser consultada en el documento Anexo (capitulo 8).

Dadas las condiciones climáticas de la zona noroeste del pais, la selección de materiales debe enfocarse a quellos que resistan largos períodos de exposición al sol o a otros factores ambientales como la lluvia, el viento y la humedad. Estas condiciones también determinan con qué frecuencia deben de reemplazarse los componentes del sistema para mantener su correcto funcionamiento. A continuación se hace una descripción sobre las propuestas generadas y su evaluación basada en los conocimientos previos de la investigación original así como el cumplimiento de las áreas de mejora.

La primera propuesta,vease Figura 6, consiste en la colocación inclinada de los contenedores de agua. Esta orientación busca facilitar la toma de agua hacia el tubo de cobre, mediante la inclinacion del contenedor inicial, esta posicion tambien permite el mayor aprovechamiento del agua dentro del contenedor. Así mismo la entrada de vapor hacia el contenedor final puede ser a una mayor altura permitiendo el aprovechamiento de la capacidad de llenado del contenedor.

La base se modificó a un conjunto tubular de soporte que permitirá la integración del sistema original de insulacion en la parte media junto con el tubo de cobre. Sin embargo esta propuesta se descartó, ya que una disposición diagonal de los contenedores significa que quedaría cierta cantidad de agua sin aprovecharse en las esquinas inferiores. Así mismo la disposición de la base y sistema de insulación aún carecen de una integración que le dé una apariencia más unificada al sistema.

La segunda propuesta (Figura 7) mantiene la disposición vertical de los contenedores pero localiza las conexiones hacia el tubo de cobre a una altura menor en el caso del contenedor inicial y a una mayor para el contenedor final. Al colocar la conexión inicial más cercana a la base del contenedor, a diferencia de la solución original, no requiere que el contenedor esté a su máxima capacidad para llenar el tubo de cobre. Así mismo la conexión final al colocarse a una altura mayor permite el aprovechamiento del volumen total del contenedor para la colección de agua desalinizada. Esta disposición también consta de una base tubular metálica que rodea a los contenedores, abrazando las conexiones y los tubos de cobre en un sistema más integrado. A su vez las medidaes se reducen para permitir una manipulación más fluida para su traslado o cambio de orientación al no requerir ser desensamblado. Esta propuesta a través de lluvia de ideas enfocadas a la integración de los sistemas dentro de la disposición de la base generó una iteración de diseno, la cual se puede observar en la Figura 8.

La propuesta resultante de esta primera iteración considera descartar el textil como principal contenedor de arena y lo sustituye por uno de madera ensamblado a través de tornillos a la estructura tubular, la cual para logarar una mayor insulacion se planteo cubrir con materiales de insulacion como son el textil de 100% algodón o lana, la hoja de maíz, hoja de palma, entre otros. Una parte fundamental de esta etapa del replanteamiento es la selección de material de los contenedores, la tabla morfológica plantea la posibilidad de emplear tres materiales distintos aunque después de consideraciones de producción, específicamente del contenedor final, solo la cerámica resulta un material viable por se de baja produccion y por sus cualidades para aplicaciones en sistemas de enfriamiento. Esto se debe a la necesidad de crear un contenedor con menor temperatura para acelerar el proceso de condensación del vapor. La solución original emplea un sistema basado en la propuesta de refrigeración *Pot in Pot* (Véase documento Anexo, capítulo 7.2.3) lo cual es difícilmente replicable en vidrio por los procesos complejos de producción y su translucidez que permitiría la afectación del estado del agua por la exposición solar. El plástico igualmente queda descartado debido a la posibilidad de explorar materiales de menor impacto ambiental y de producción local en la región del territorio mexicano. La cerámica como material de producción para ambos contenedores permite la creación de una doble pared, este diseño permite la conservación de una temperatura menor dentro de los contenedores al no permitir la conducción de calor de la pared externa hacia la interna y sin la necesidad de un material en el espacio anular.

Al analizar la propuesta a profundidad, resulta posible explotar el uso de la cerámica como material de los contenedores para facilitar e integrar aún más las conexiones de entrada de agua y salida de vapor. Como aspecto negativo dichos contenedores, debido a su altura, afectan al área de colección solar ya que generan sombra sobre los tubos de cobre, impidiendo que los rayos solares sean reflejados directamente hacia los

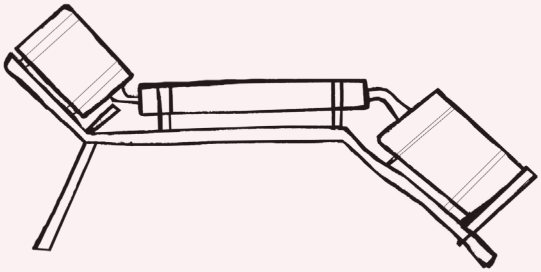


Figura 6. Boceto de concepto 1.

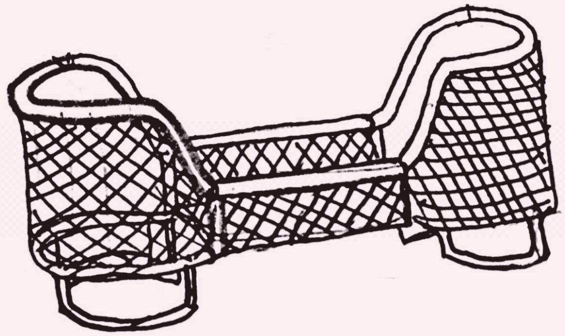


Figura 7. Boceto de concepto 2.

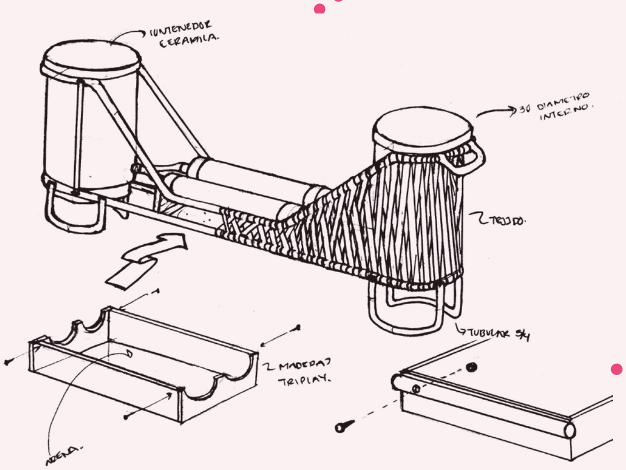


Figura 8. Boceto de concepto 3.

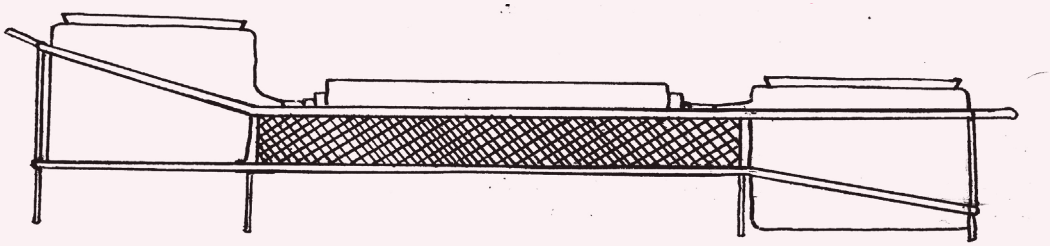


Figura 9. Boceto de concepto final.

tubos. Aunque la orientación del sistema respecto al sol es clave para la eficiencia del sistema, se puede mejorar la exposición al reducir la altura de los contenedores. Aunado a esto, el uso de madera no es adecuado pues ésta no es resistente a las condiciones climaticas de la región, además el tejido alrededor de la estructura resulta un tanto redundante ya que el único segmento del sistema que requiere de insulación es la cámara de evaporación. Se realizaron modificaciones con mejoras que se pueden observar en la Figura 9.

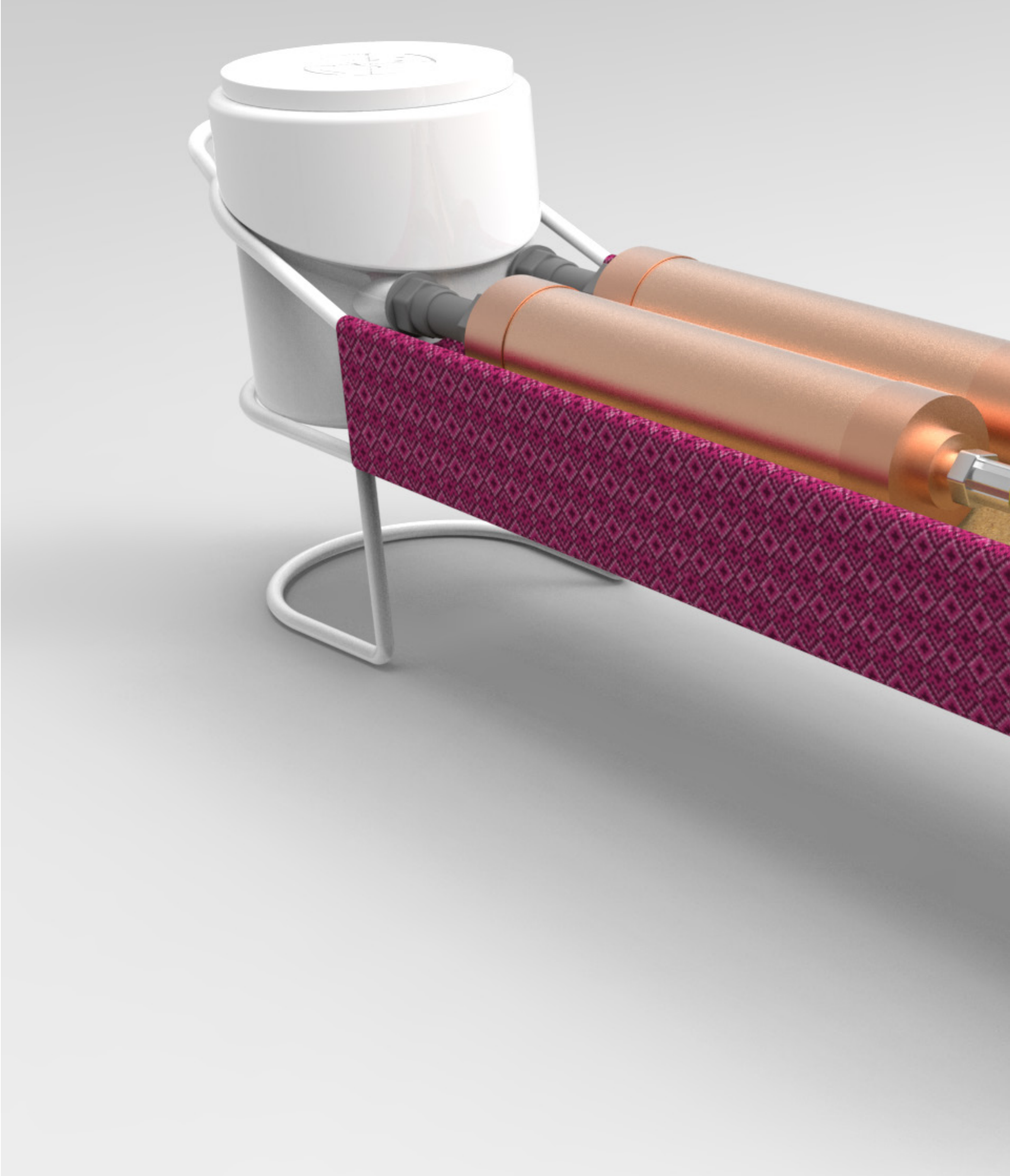
Esta propuesta contempla contenedores de cerámica de doble pared a una altura poco sobresaliente al tubo de cobre para permitir la mayor exposición solar posible. Como se mencionó anteriormente, la orientación juega un papel importante en la eficiencia del sistema por lo que se propone el grabado de indicaciones de orientación en la superficie de exposición de los tubos de cobre. Esto facilita el correcto posicionamiento en su lugar de uso y por ende un mejor funcionamiento. La geometría de los contenedores presenta protuberancias que se conectan al tubo de cobre, ofreciendo así una mayor estabilidad de las conexiones. Dichos contenedores cuentan con tapas de corcho sintético debido a su impermeabilidad a líquidos y gases así mismo por sus propiedades de aislación térmica y las cuales en su cara superior cuentan con iconografía grabada que permite la identificación de calidad del agua dentro de ellos.

El uso de corcho sintético en lugar de natural se empleó para evitar la generación de hongos que se encuentra en el corcho natural y el cual es imposible de detectar y erradicar hasta evaluar los alimentos o productos alimenticios que entran en contacto con él. Además de esto, el corcho sintético presenta varias otras ventajas como la facilidad de controlar sus acabados, es menos probable a presentar grietas ni genera polvo y pueden ser usados como tapaderas reusables, como las requeridas para este proyecto. Los tapones fabricados con corcho sintético presentan mayor consistencia y uniformidad, lo cual permite una menor entrada de aire al interior de la botella, aunado a esto, a diferencia del corcho tradicional, los tapones sintéticos no necesitan de humedad para permanecer expandidos y así sellar los contenedores en los cuales se implementan.

La reducción de altura de los contenedores de agua genera como efecto una simplificación de la estructura tubular soporte, aligerando la apariencia, además se integra de nuevo el uso de un textil de algodón o lana para contener arena, enfocado en la parte central del sistema donde se requiere el sistema de insulación. La aplicación de un tejido textil o de cualquier otro tipo de material con propiedades de insulacion, solo a la sección media del sistema además de reducir costos de producción, permite la apreciación de la cerámica.

08

PRESENTACION DESCRIPTIVA



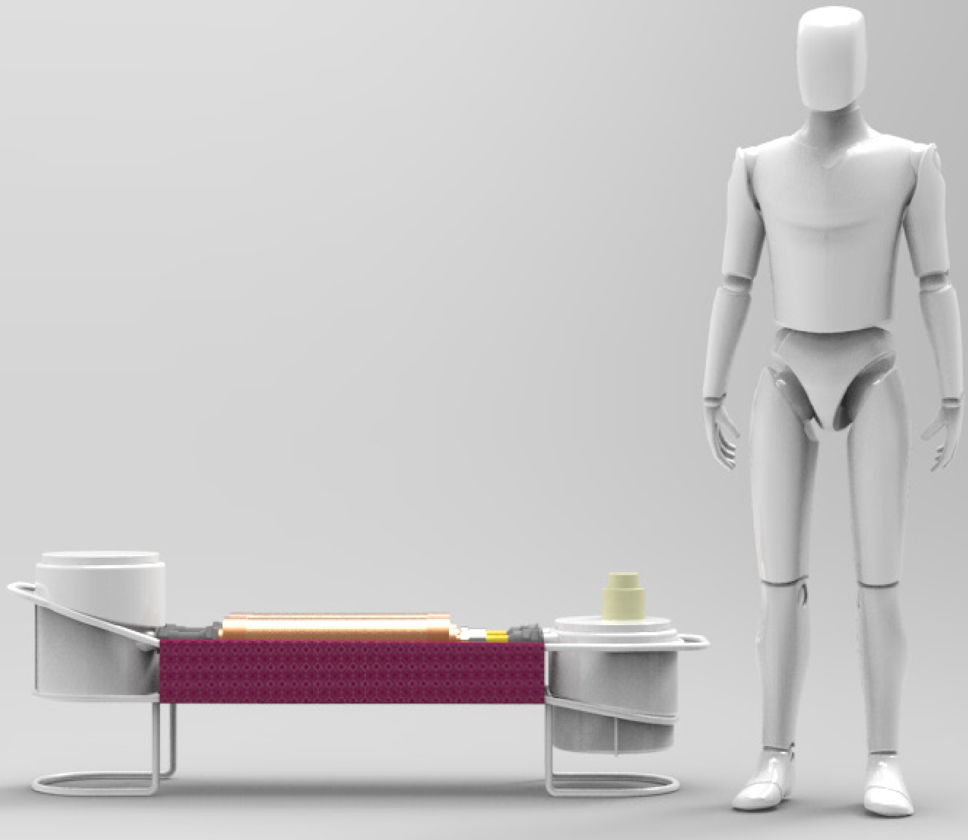


Figura 10. Producto con escala humana.

La propuesta de concepto final, mostrada en la Figura 10 representa una aproximación a la región noroeste de México. Su propósito funcional es la desalinización del agua proveniente de la costa Pacífico para ofrecer una fuente de agua bebible en casos donde el acceso al agua potable es escaso o inexistente. Al basarse en los resultados obtenidos del proyecto desarrollado en Suecia, la propuesta conceptual mantiene el objetivo de implementar materiales y procesos de producción locales en aquellos componentes que fueron modificados.

Como se mencionó previamente, esta propuesta de concepto mantiene los mismos componentes técnicos inicialmente propuestos y solo representa una variación en apariencia y algunos materiales dada la libertad de diseño en este replanteamiento y la mayor oferta de materiales y procesos en la región seleccionada. La Figura 11 muestra un explosivo de las partes que componen a este concepto y las medidas generales pueden observarse en la Figura 12.

El desalinizador propuesto se encuentra dividido en tres subsistemas, la explicación descriptiva de la propuesta se fundamenta en estas divisiones y contempla la nomenclatura de las partes, su material y proceso de producción.

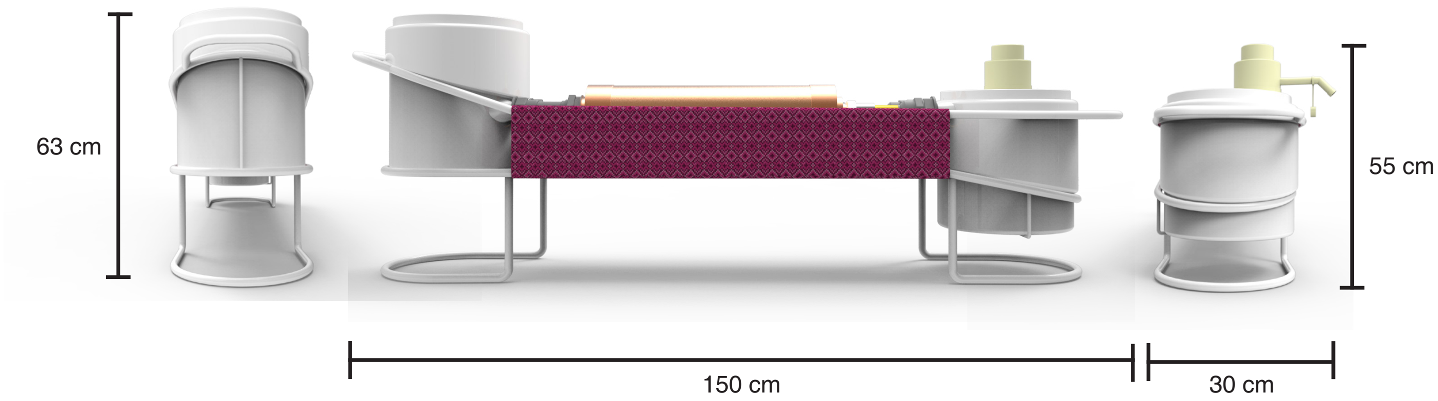
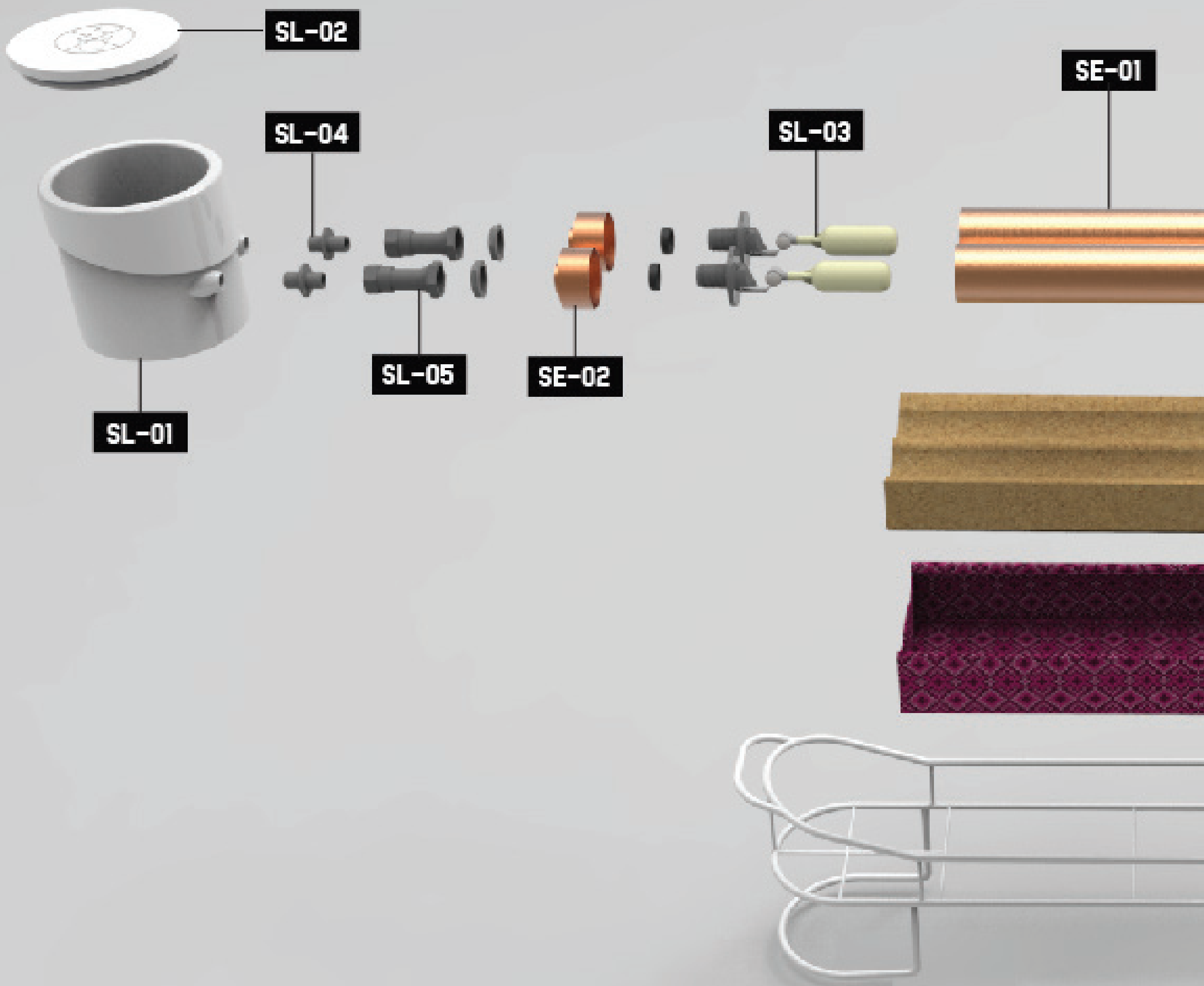


Figura 12. Medidas generales.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SL-04
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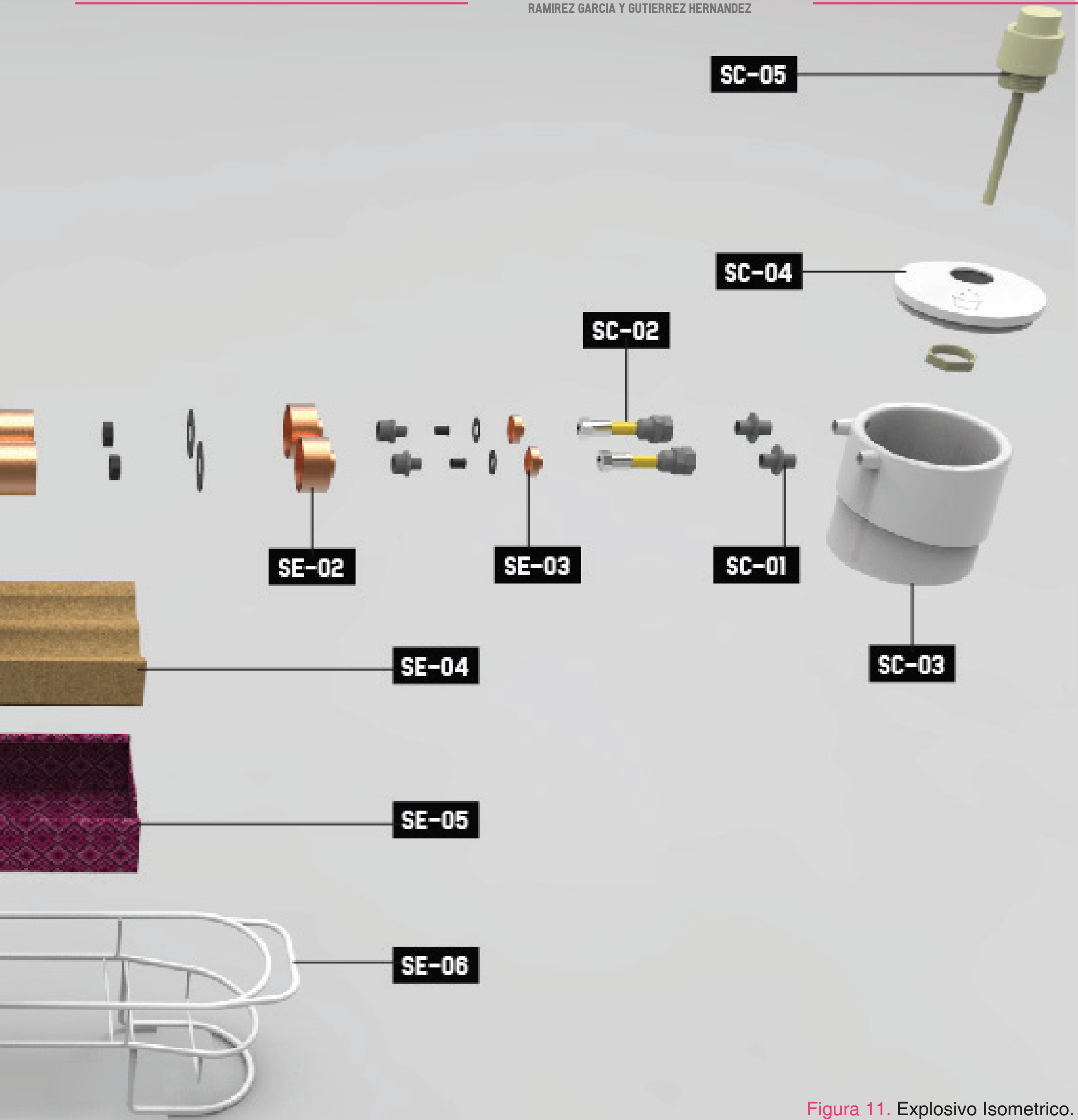


Figura 11. Explosivo Isometrico.

Sistema de llenado

El sistema de llenado comienza con un contenedor cerámico de doble pared con capacidad de 20 litros. Este se conecta a través de manguera y conector de tanque al tubo de cobre, esta colección incluye empaques para prevenir fugas de agua. El contenedor inicial cuenta con un símbolo distintivo grabado en su tapa superior para comunicar que el agua contenida en él no es apta para consumo humano (Véase Figura 13).

Figura 13. Grabado en tapa.

Dentro de este sistema también se encuentra una válvula de flote que permite el llenado automático del tubo de cobre a la altura requerida de dos centimetros y medio para una eficiente evaporación del cuerpo de agua dentro del tubo. La Tabla 3 describe cada componente de este sistema.

Tabla 3. Componentes del sistema de llenado

COMPONENTE	CÓDIGO	CANTIDAD	MATERIAL	PROCESO
Contenedor inicial	SL-01	1	Cerámica	Moldeo por vaciado
Tapa	SL-02	1	Cerámica	Moldeo por vaciado
Valvula de flote	SL-03	2	Plástico PVC	Pieza comercial
Adaptador de tanque	SL-04	2	Plástico PVC	Pieza comercial
Adaptador de tanque	SL-05	2	Plástico ABS y Polietileno	Pieza comercial

Sistema de evaporación

Este sistema como se observa en la Ilustracion 13, se compone de una cámara de evaporación, un sistema de aislamiento y una estructura de soporte; los componentes especificados se muestran en la Tabla 4. El principal objetivo funcional de este sistema es la evaporación del agua salina haciendo uso de la alta conductividad térmica de los materiales seleccionados y su exposición a la radiación solar. La radiación exterior será recibida por la cara exterior del tubo de cobre, y posteriormente se transferirá el calor al agua del interior para permitir su evaporación.

Tabla 4. Componentes del sistema de evaporación

COMPONENTE	CÓDIGO	CANTIDAD	MATERIAL	PROCESO
Tubo de cobre	SE-01	2	Cobre Niquel 90/10	Pieza comercial
Reductor de cobre 4”-2”	SE-02	4	Cobre Niquel 90/10	Pieza comercial
Reductor de cobre 2”-1/2”	SE-03	4	Cobre Niquel 90/10	Pieza comercial
Arena sedimentaria	SE-04	10 Kg.	Arena Sedimentaria	Materia prima
Textil	SE-05	1	100% Algodón	Tejido a mano
Base	SE-06	1	Tubo 3/4” Acero A36	Pieza comercial cortada, doblada y soldada a mano

Para evitar la pérdida de calor en caso de viento o humedad en el medio ambiente, el uso de arena sedimentaria y un tejido de materiales térmicos retiene el calor conducido a través del tubo de cobre y aumenta la tasa de evaporación dentro del tubo. Este aislamiento consiste en un contenedor tejido, ya sea de algodón o lana, el cual además de sus propiedades térmicas, retendrá la arena sedimentaria. La información técnica sobre las propiedades térmicas de los materiales mencionados se puede consultar el documento Anexo (capítulo 6.2).

La arena sedimentaria, como se indicó anteriormente, tiene un bajo coeficiente de transferencia de calor, que permite la retención del calor transferido a través del tubo de cobre durante largos períodos, lo que reduce la pérdida de energía. La cantidad de arena utilizada se obtiene calculando el área del contenedor del tejido de punto. Los componentes mencionados se mantienen unidos por una estructura que proporciona estabilidad además de unir a todos los componentes de la propuesta en un artefacto integrado. Dicha base esta fabricada en tubular de Acero A36, una una aleación de acero al carbono de propósito general (American Society for Testing and Materials) con acabado en pintura electrostática.

Sistema de condensación

Este subsistema comprende la condensación del vapor de agua y la recolección del agua desalinizada resultante. El vapor de agua que se produce en la cámara de evaporación, debido a la alta presión creada en el tubo de cobre, se mueve a través de un conector de gas al contenedor final. Dicho contenedor tiene una capacidad de 15 litros y está fabricado con cerámica, ya que este material es aislante térmico. El efecto de disipación de calor o baja conductividad térmica de la cerámica se debe a la ausencia de electrones de conducción en su composición (Retana Fernandez, 2016). Aunque el producto se puede producir con cualquier material cerámico, se propone en específico los polvos vidrio cerámicos, como el pyroceramico, dado que son excelentes aislantes térmicos diseñados en los 50s durante la carrera espacial para absorber con seguridad las enormes fluctuaciones de temperatura en la sección delantera de los cohetes.

Además el contenedor final está fabricado con una doble pared para evitar que el agua de salida se evapore debido a la exposición a altas temperaturas y la radiación solar. Esta doble pared permite una menor temperatura dentro del contenedor a comparación del tubo de cobre, permitiendo la condensación del vapor a un ritmo más rápido.

La tapa superior del contenedor final cuenta con un grabado, como se muestra en la Figura 14, para comunicar que el agua contenida en él es para consumo humano, esto es para evitar la confusión de llenado del contenedor final con agua salina, así como el consumo de agua dañina por parte de los usuarios.

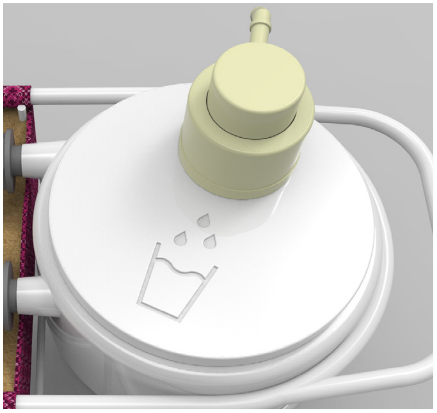


Figura 14. Grabado en tapa.

Esta configuración produce un efecto de enfriamiento dentro del contenedor interno. El agua resultante se recoge en el contenedor interno de condensación, lo que permite al usuario recuperarla por medio de una bomba manual en la parte superior del contenedor final, como se observa en la Figura 15. Los componentes de este sistema se describen en la Tabla 5.

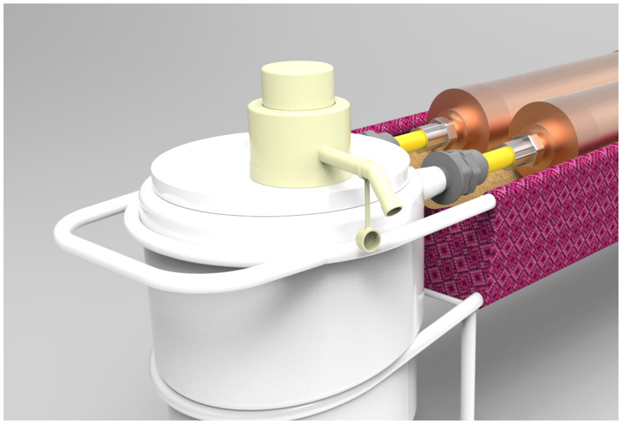


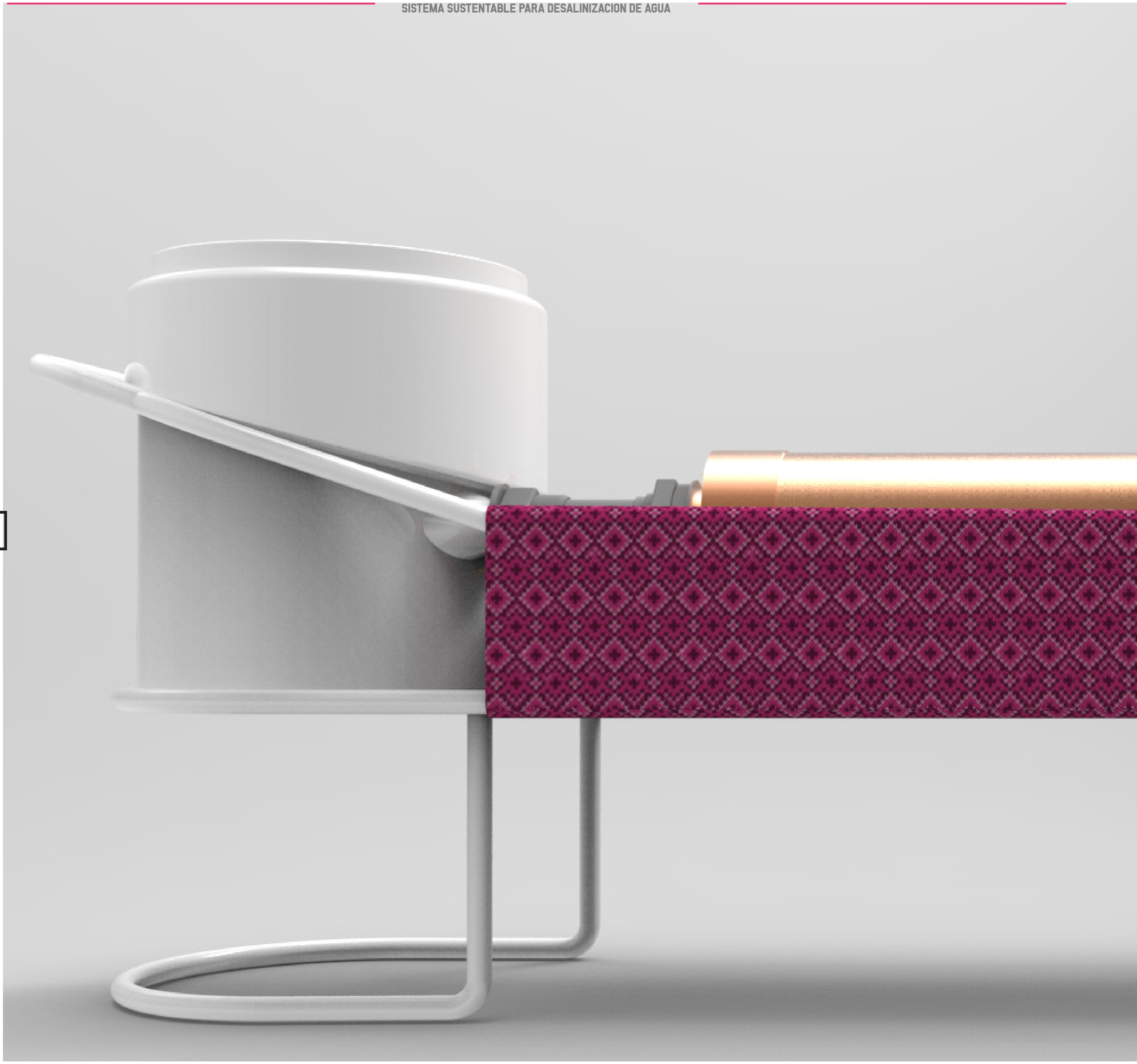
Figura 15. Bomba manual.

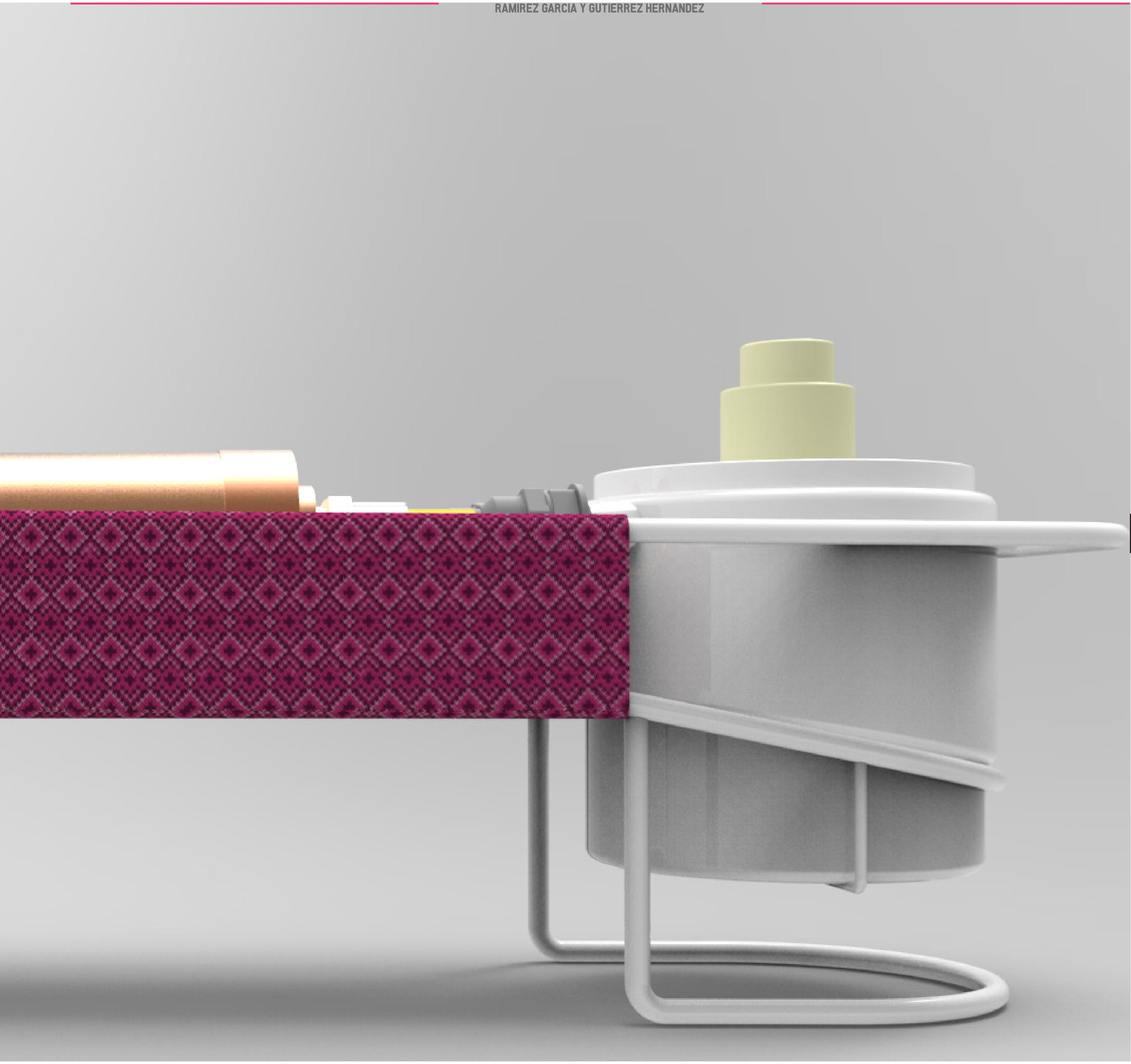
Tabla 5. Componentes del sistema de condensación

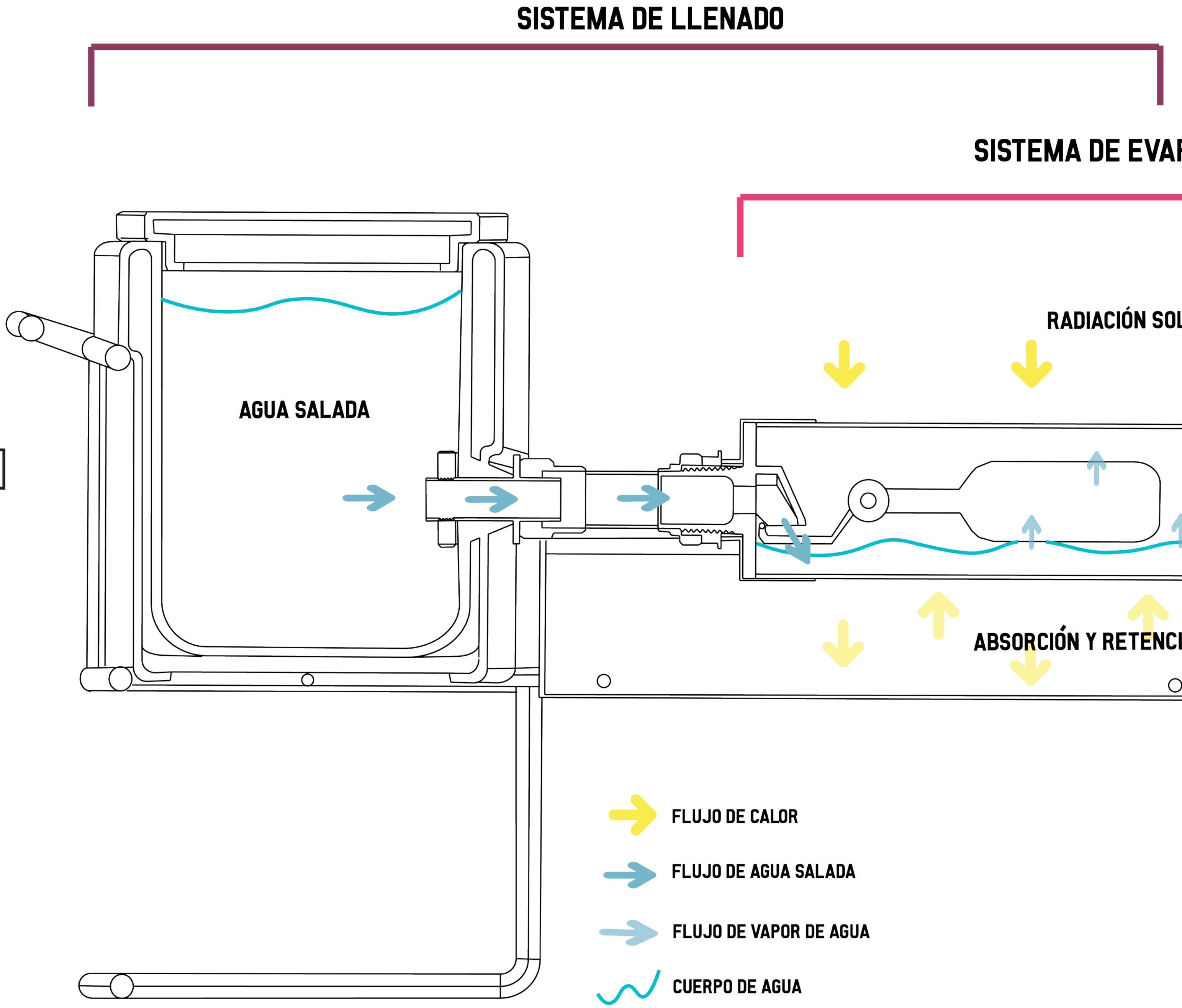
COMPONENTE	CÓDIGO	CANTIDAD	MATERIAL	PROCESO
Adaptador de Tanque	SC-01	2	Plástico PVC	Pieza comercial
Manguera	SC-02	2	Plástico PVC	Pieza comercial
Contenedor final	SC-03	1	Cerámica	Moldeo por vaciado
Tapa	SC-04	1	Cerámica	Moldeo por vaciado
Bomba manual 1/2"	SC-05	1	Plástico PVC	Pieza comercial

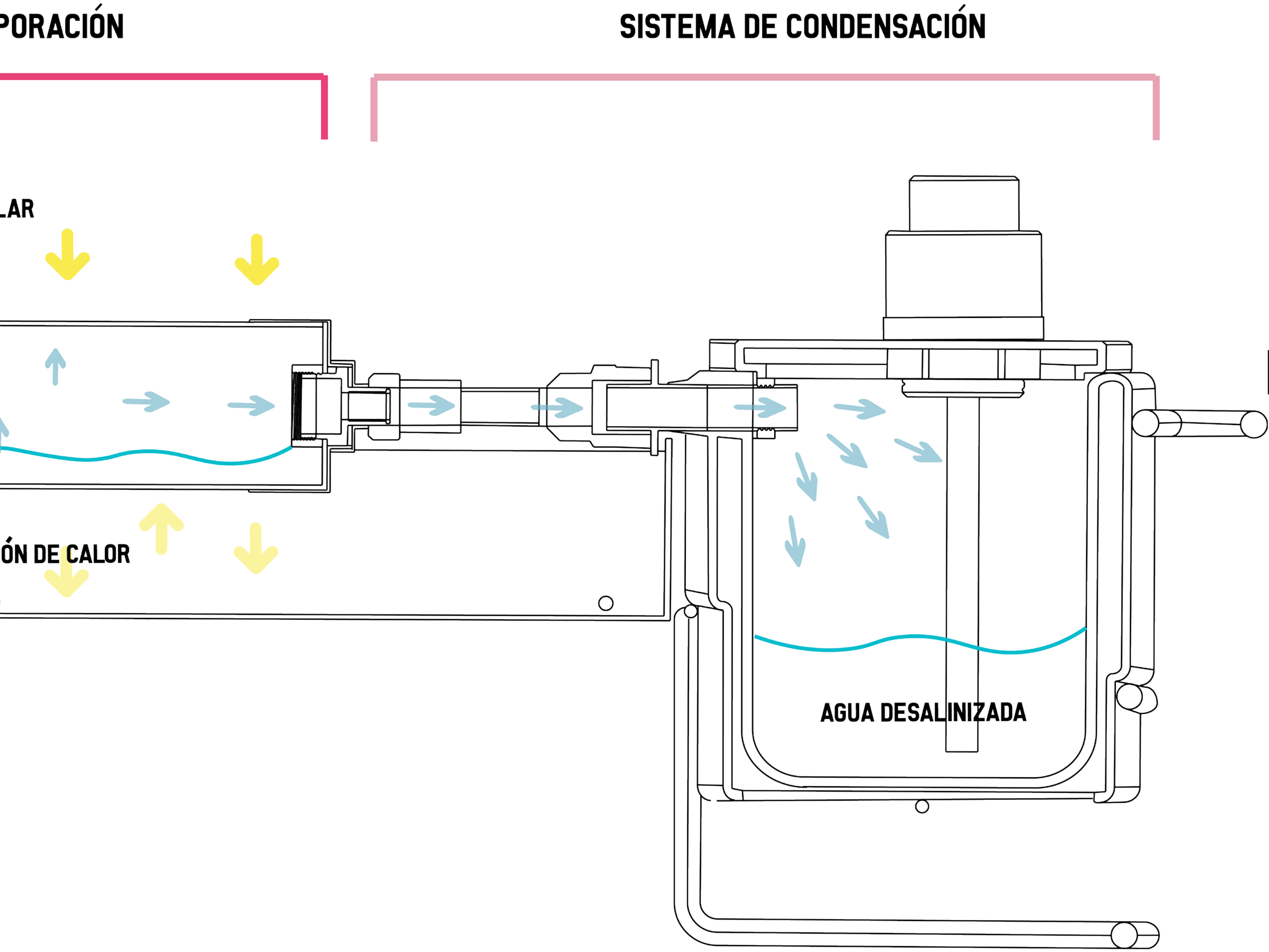
Aunque el funcionamiento es esencialmente el mismo que el de la propuesta inicial desarrollada en Suecia, el siguiente esquema muestra gráficamente el trayecto del agua salada a travez del sistema para ser desalinizada y recolectada por el usuario.

ESQUEMA DE FUNCIONAMIENTO

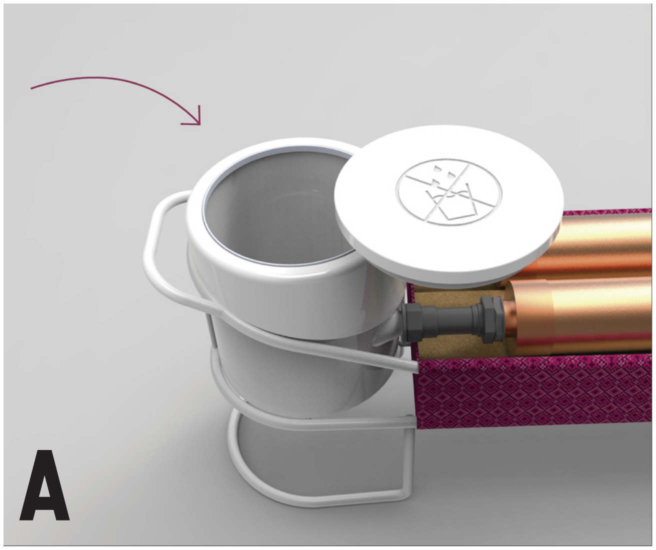




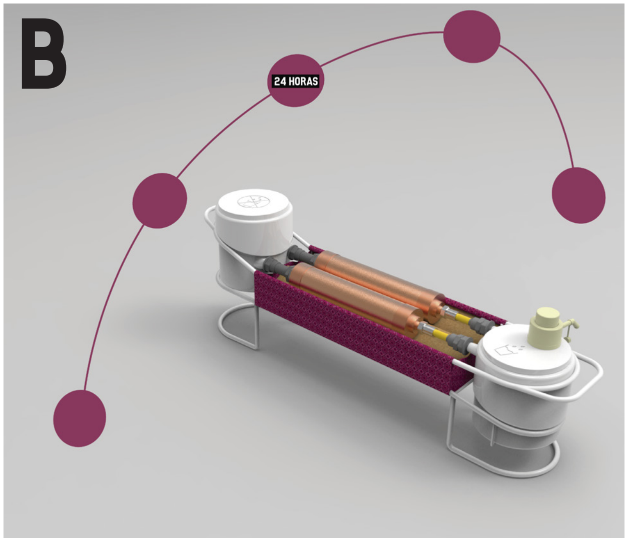

SISTEMA DE LLENADO
SISTEMA DE EVAI
RADIACIÓN SOL
AGUA SALADA
ABSORCIÓN Y RETENCI
FLUJO DE CALOR
FLUJO DE AGUA SALADA
FLUJO DE VAPOR DE AGUA
CUERPO DE AGUA


PORACIÓN
SISTEMA DE CONDENSACIÓN
LAR
ÓN DE CALOR
AGUA DESALINIZADA

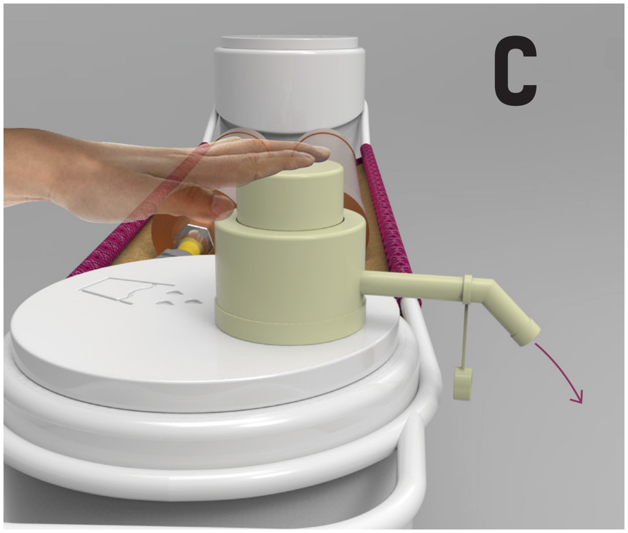
SECUENCIA DE USO



Como se puede observar en el diagrama A superior, para activar el funiconamiento del sistema es necesario llenar el contenedor inicial. El usuario se guia por emdio del grabado en las tapas de los contenedores para localizar aquel en el que debe ser introducida el agua salina. Se retira la tapa de ceramica para poder introducir agua salada y se coloca la tapa de nuevo a presión para sellar el contenedor.



Al llenar el contenedor el agua ingresa automaticamente a los tubos de cobre y se detiene a la profundidad indicada gracias a una bomba de flote en el interior de los tubos. Una vez expuesto al sol, el proceso de evaporización dentro de los tubos comienza y se dejan transcurrir 24 horas, como se muestra en la figura B, para permitir la máxima producción de agua para consumo humano. Aunque no es necesario esperar dicho periodo ya que la evaporación y condensación es constante en el sistema. La bomba de flote permite un funcionamiento automático del sistema aunque se require un constante relleno del contenedor inicial por parte del usuario.



Para acceder al agua desalinizada en el contenedor final se puede presionar la bomba manual como se muestra en la figura C. La seleccion de esta bomba es debido a la facilidad de accionamiento, bombea el agua al ser presionada en su parte superior y la forma del grifo permite al usuario colocar cualquier tpo de contenedor para llenar con el agua desalinizada.

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ANALISIS DE IMPACTO AMBIENTAL

Al considerar el impacto ambiental de un producto es necesario contemplar los materiales de cada componente, el proceso de fabricación y el consumo o uso de este a lo largo del proceso de diseño. La evaluación del uso de los materiales y su vida útil puede reducir significativamente el impacto negativo que tiene en el medio ambiente (Klöpffer, 1997). La Evaluación del Ciclo de Vida (ECV) es un análisis de las entradas y salidas de un producto a lo largo de su ciclo de vida, considerando los impactos ambientales y el uso potencial después de su eliminación (ISO, 2006). Esta evaluación es relevante para este replanteamiento de diseno ya que representa uno de los requerimientos iniciales del proyecto. Así mismo, permite la visualización de la relación entre los componentes, sus materiales y su función específica a lo largo de la cadena de producción.

El análisis de ciclo de vida toma en consideración todas las fases de la vida útil de un producto, como la extracción de materias primas, los procesos de fabricación, empaque, distribución, vida útil del producto y su deshecho. A continuación las Figuras 16 a 26 muestran gráficamente la Evaluación de Ciclo de Vida (ECV) para cada material de los componentes del sistema de desalinización propuesto.

Algunos de los materiales seleccionados tienen un impacto significativo en el medio ambiente, medidos por emision de carbon y su posibilidad de reuso despues de ser deshechado, como los adhesivos epóxicos. Sin embargo, su selección no puede ser sustituida ya que representan elementos clave en el objetivo del rendimiento del sistema. Asi mismo, la implementación de procesos y materiales locales reduce significativamente el impacto ambiental durante sus procesos de producción y distribución ya que no requieren de embalaje para su translado al sitio de uso. El aspecto mas importante de esta evaluacion recae en el uso de la radiación solar como única fuente de energía para el funconamiento de la propuesta, pues su implementación no genera emisiones de carbón durante su vida útil.

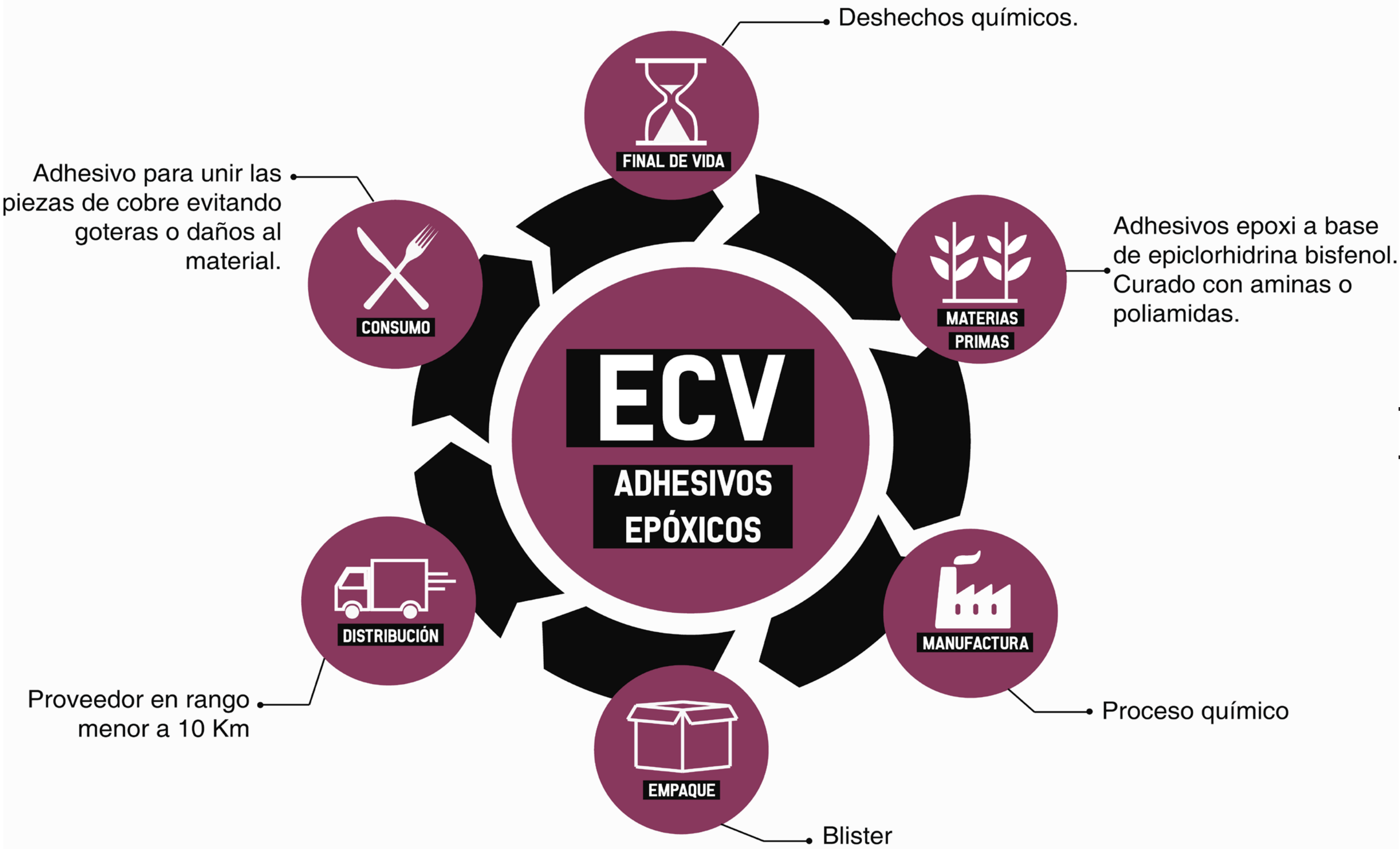

Figura 16. ECV adhesivos epóxicos.

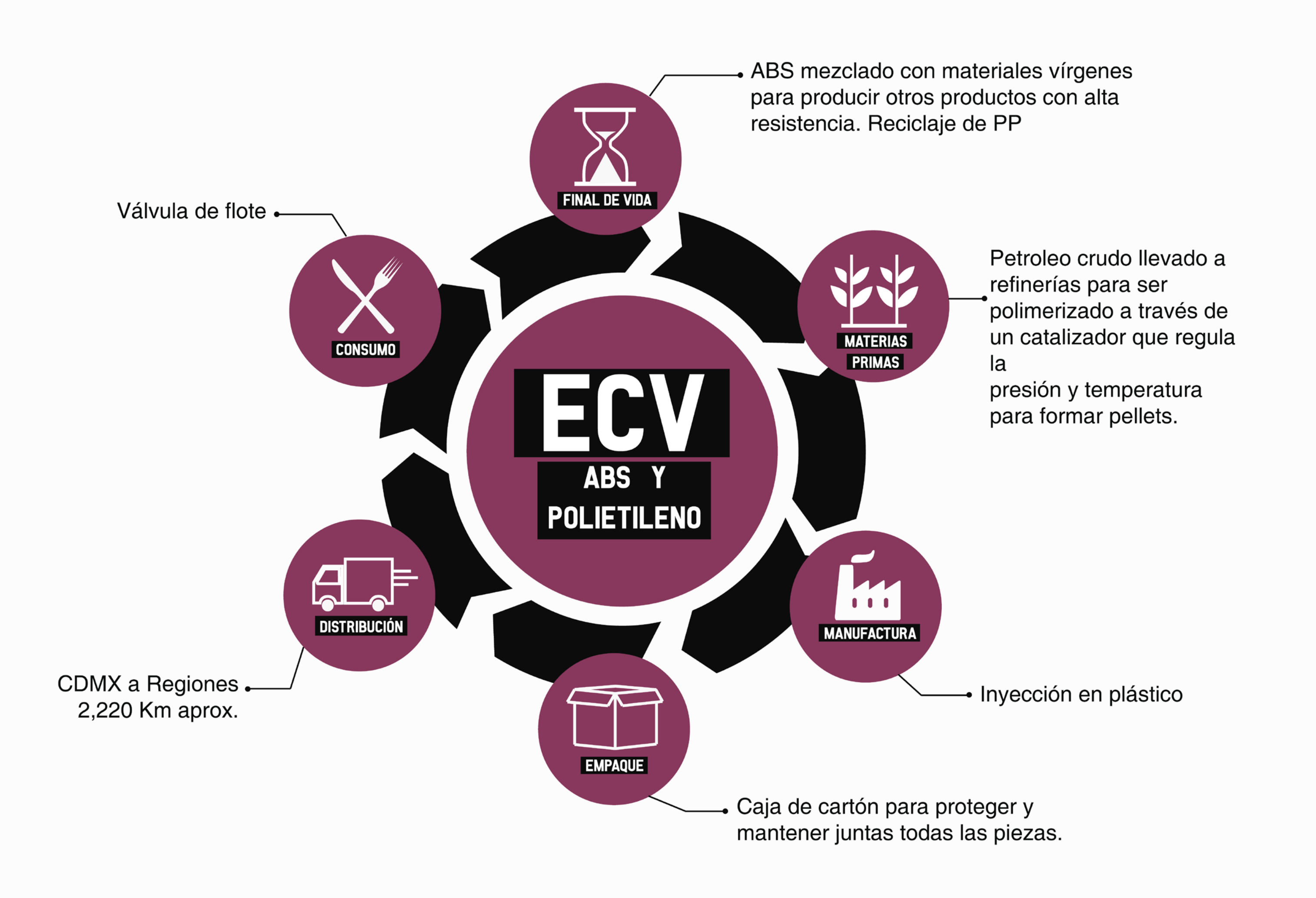

Figura 17. ECV Plástico ABS y Polietileno.

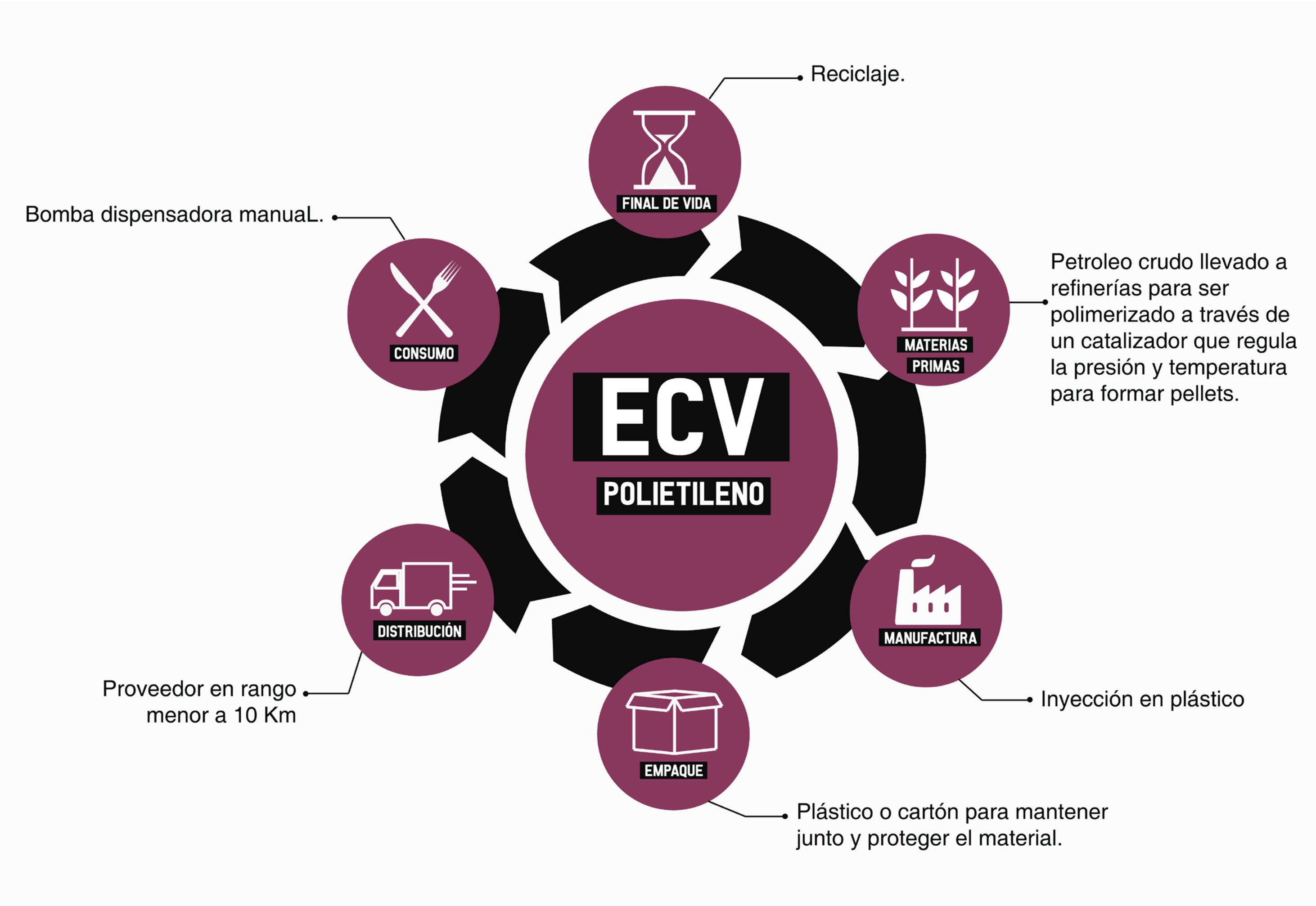

Figura 18. ECV Plástico Polietileno.

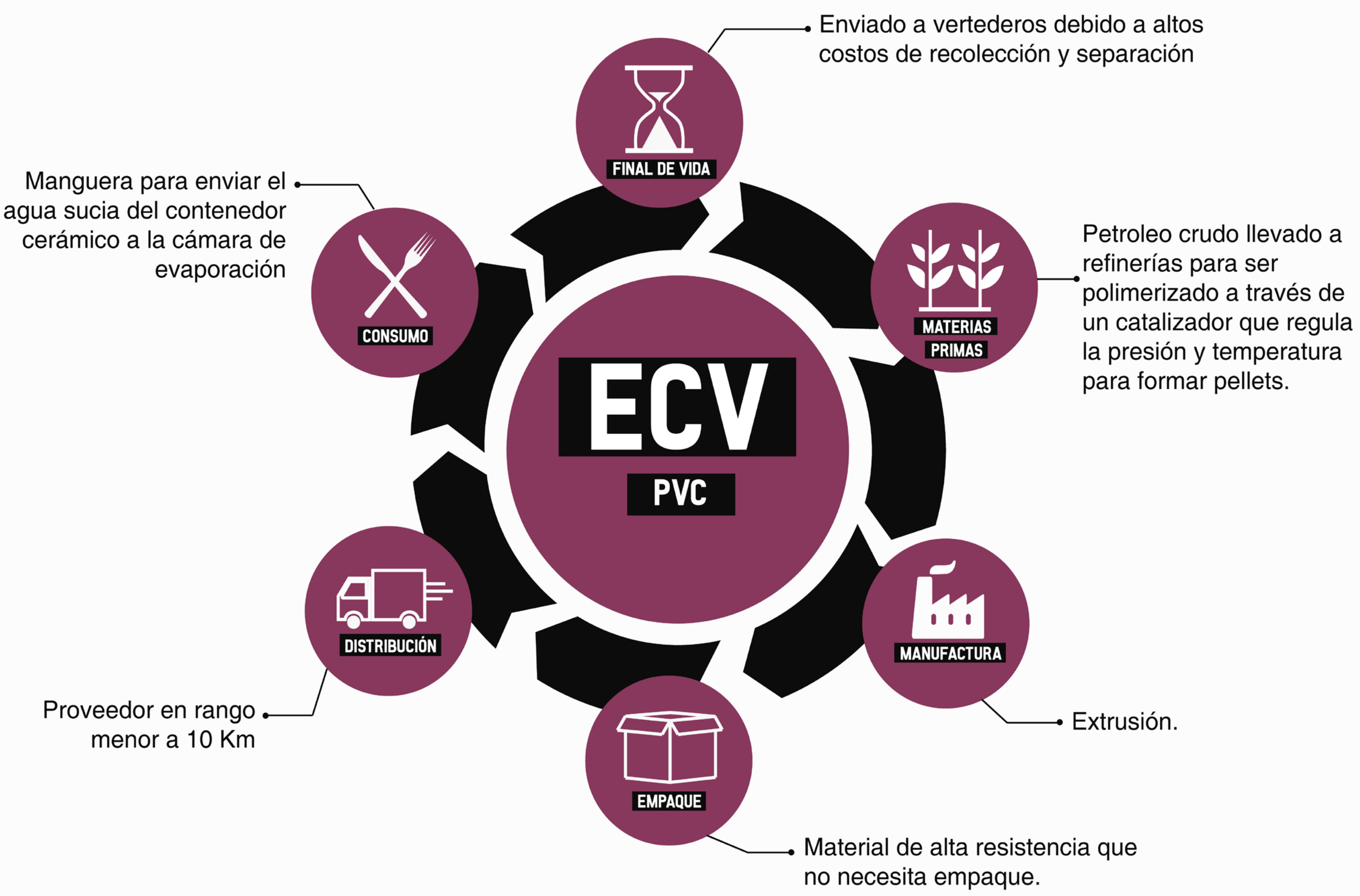

Figura 19. ECV Plástico Cloruro de Polivinilo.

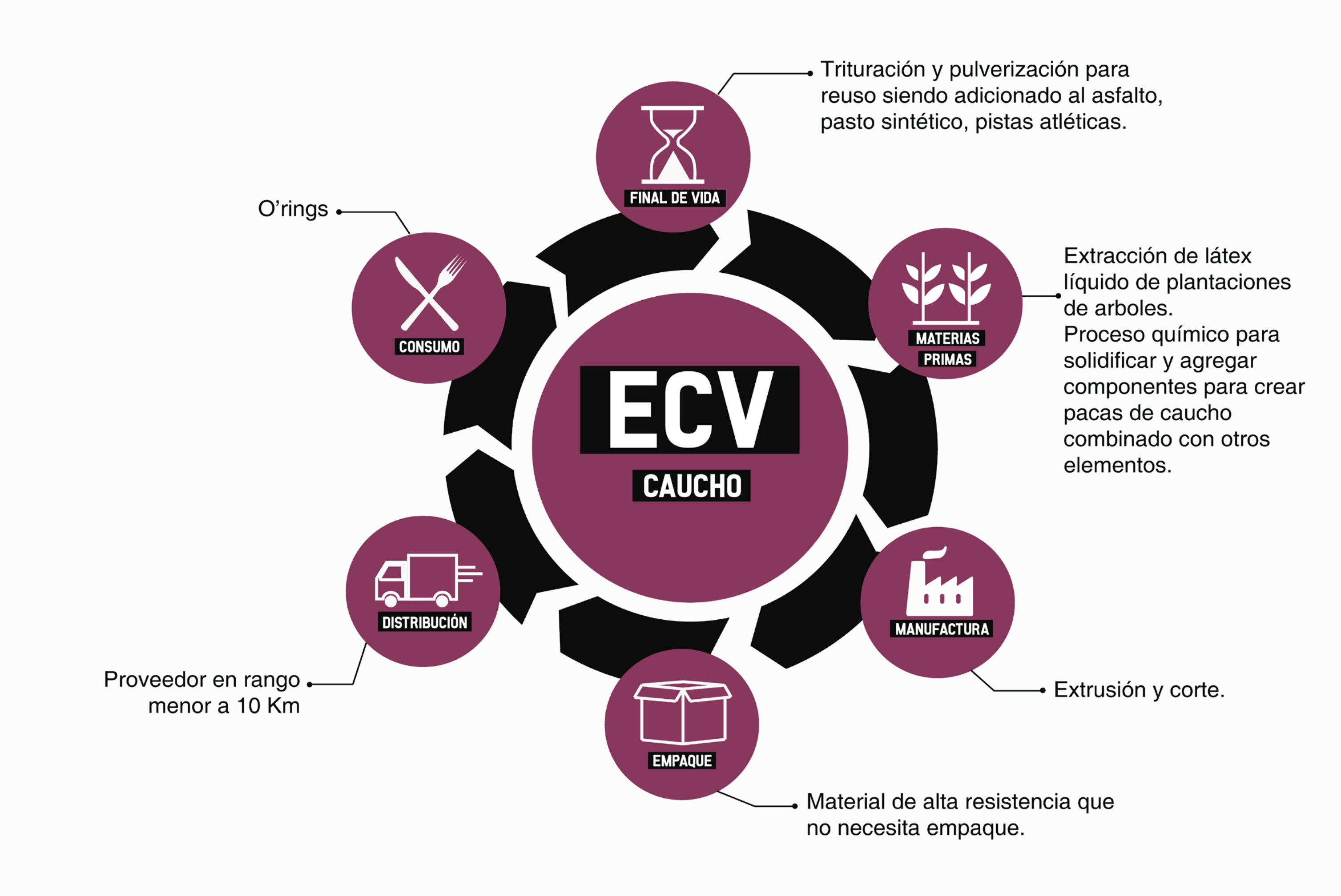

Figura 20. ECV Caucho.

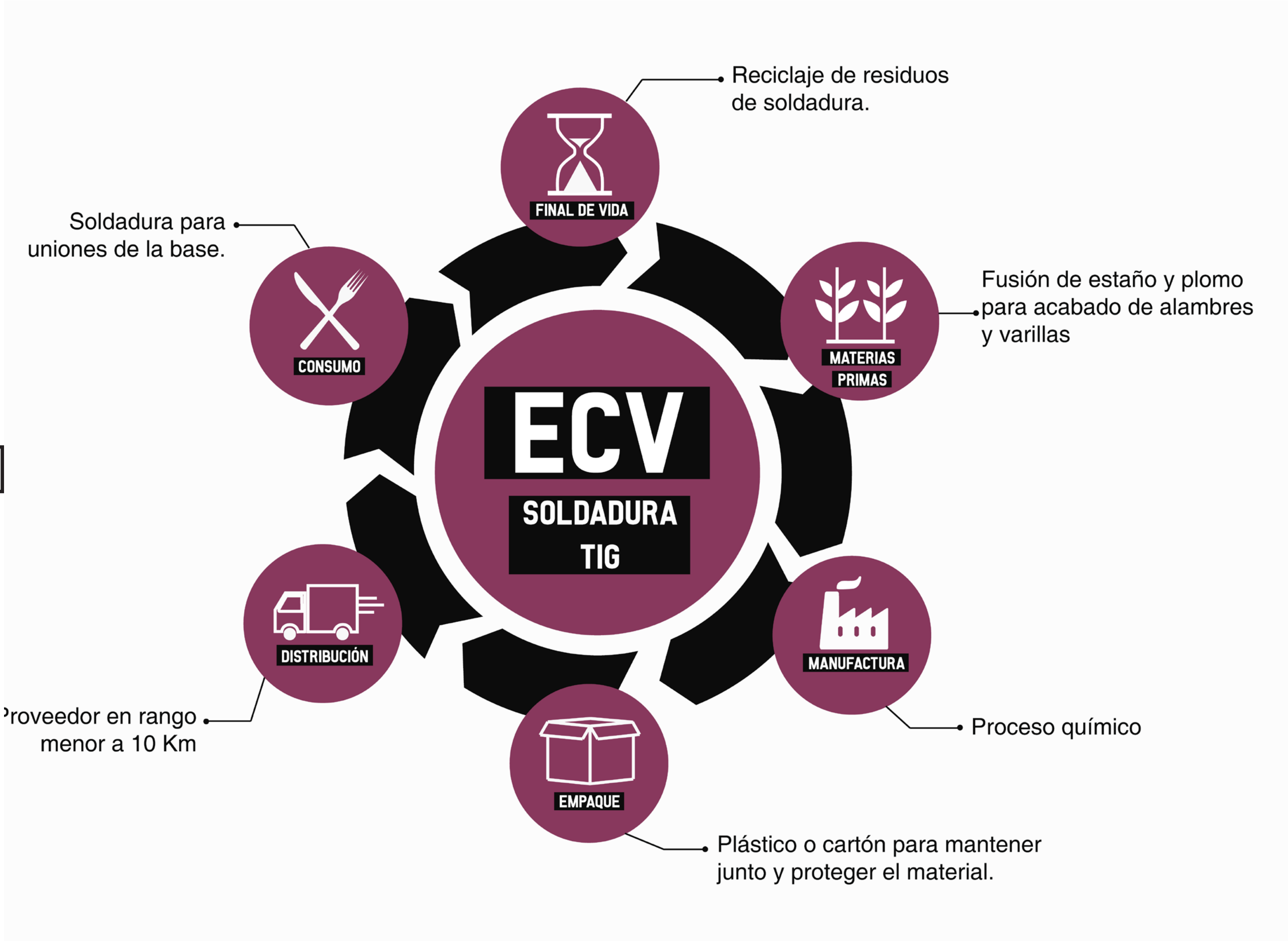

Figura 22. ECV Soldadura TIG.

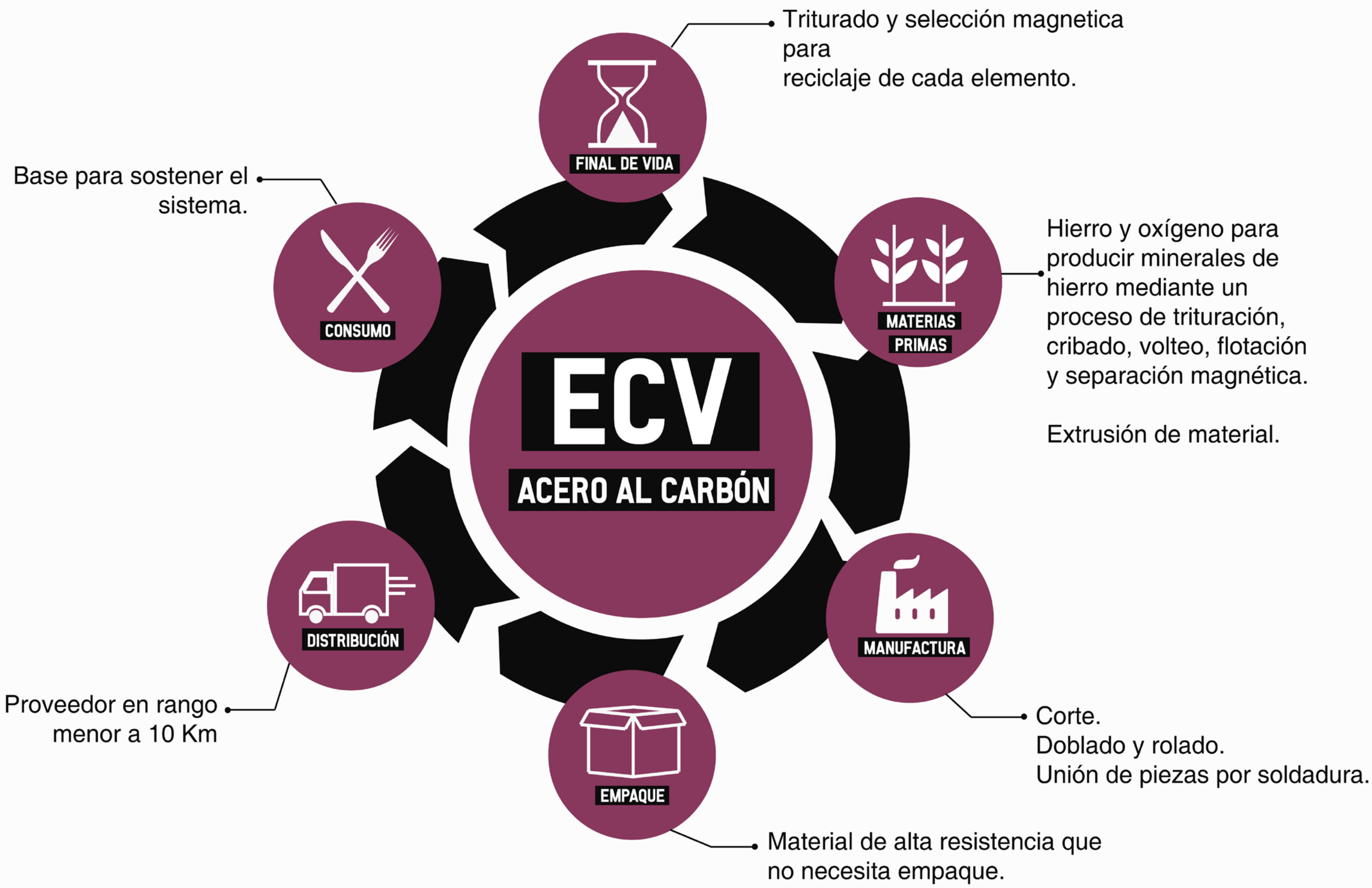

Figura 21. ECV Acero al Carbón.

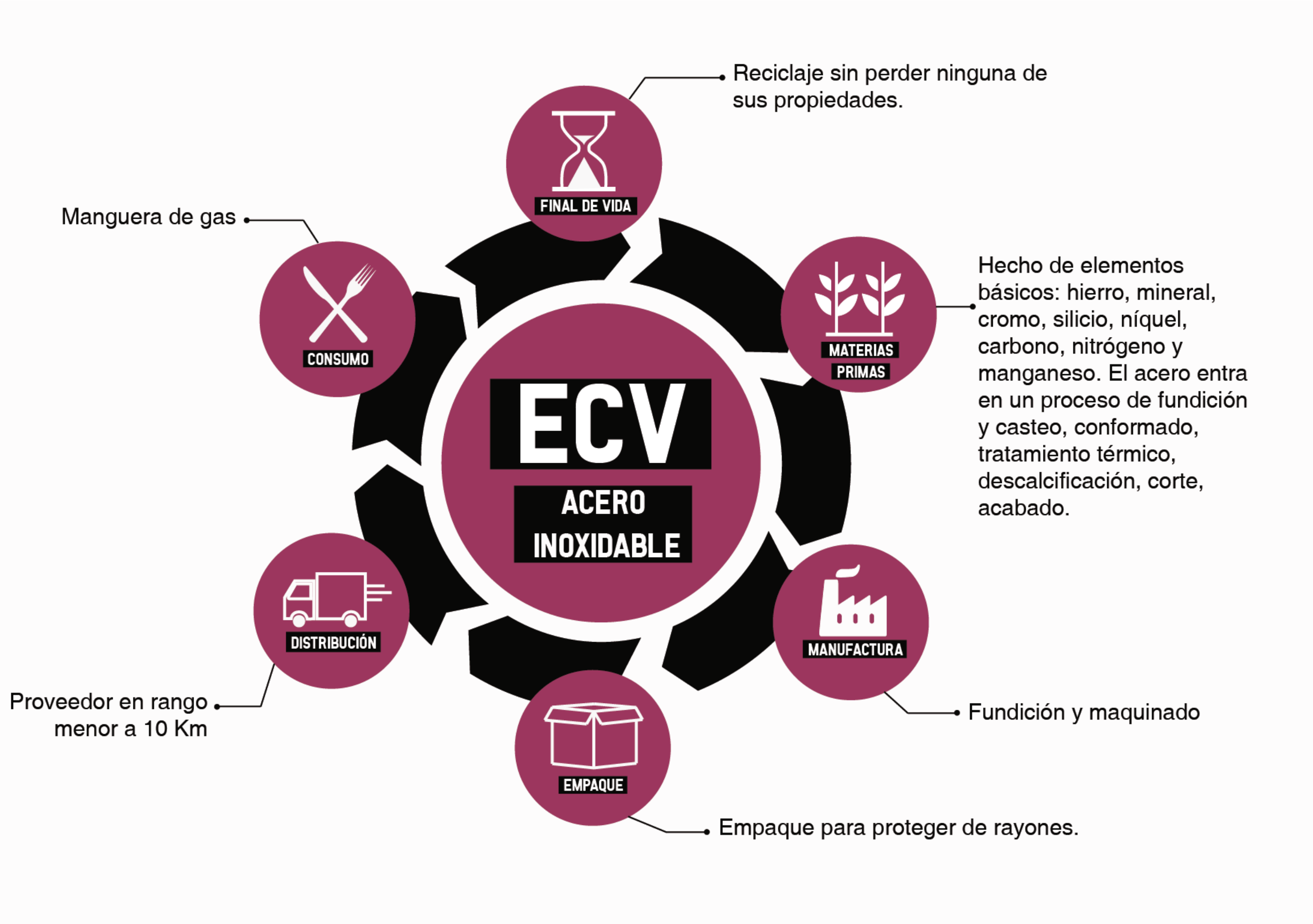

Figura 23. ECV Acero Inoxidable.

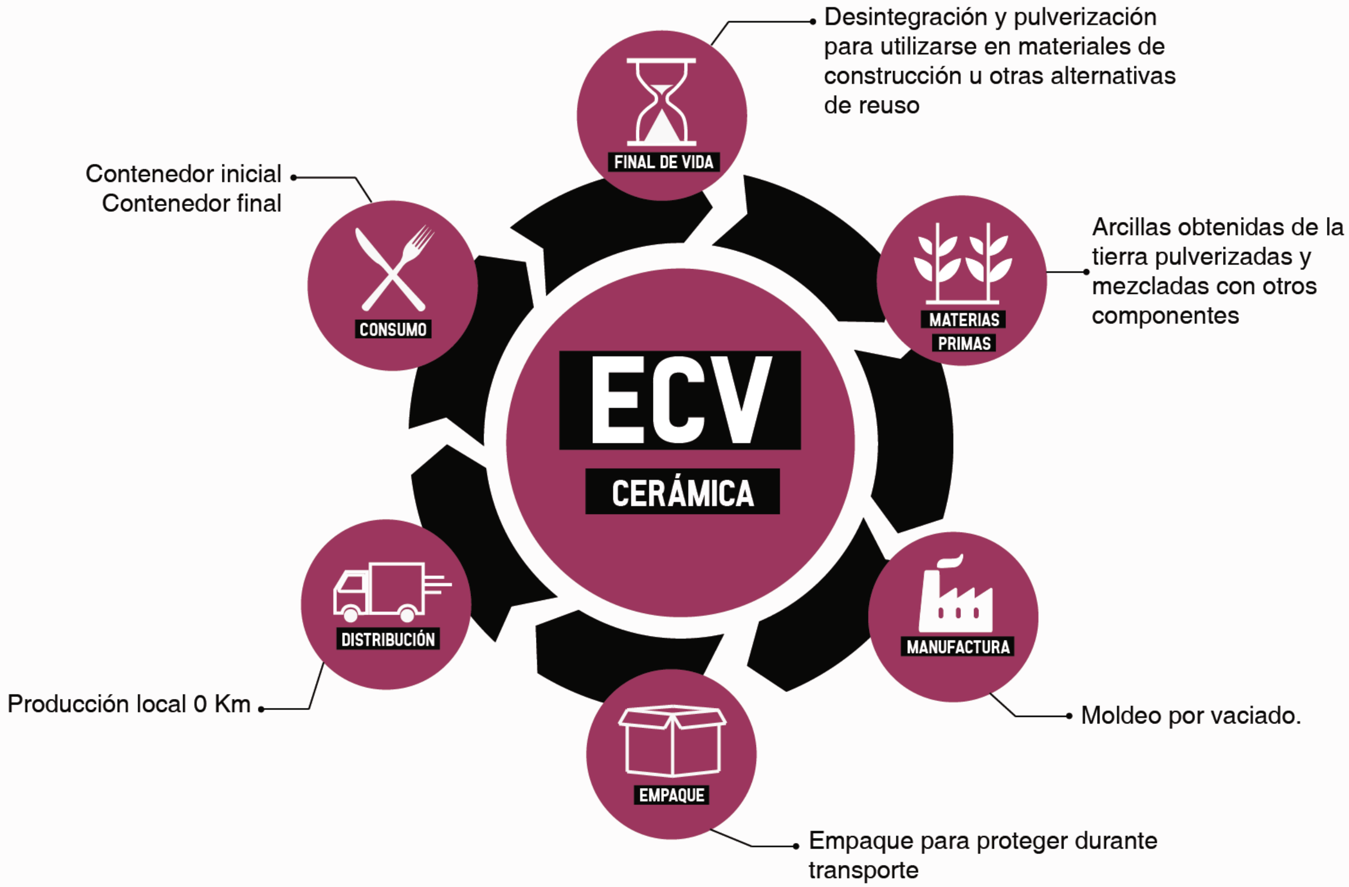

Figura 24. ECV Cerámica.

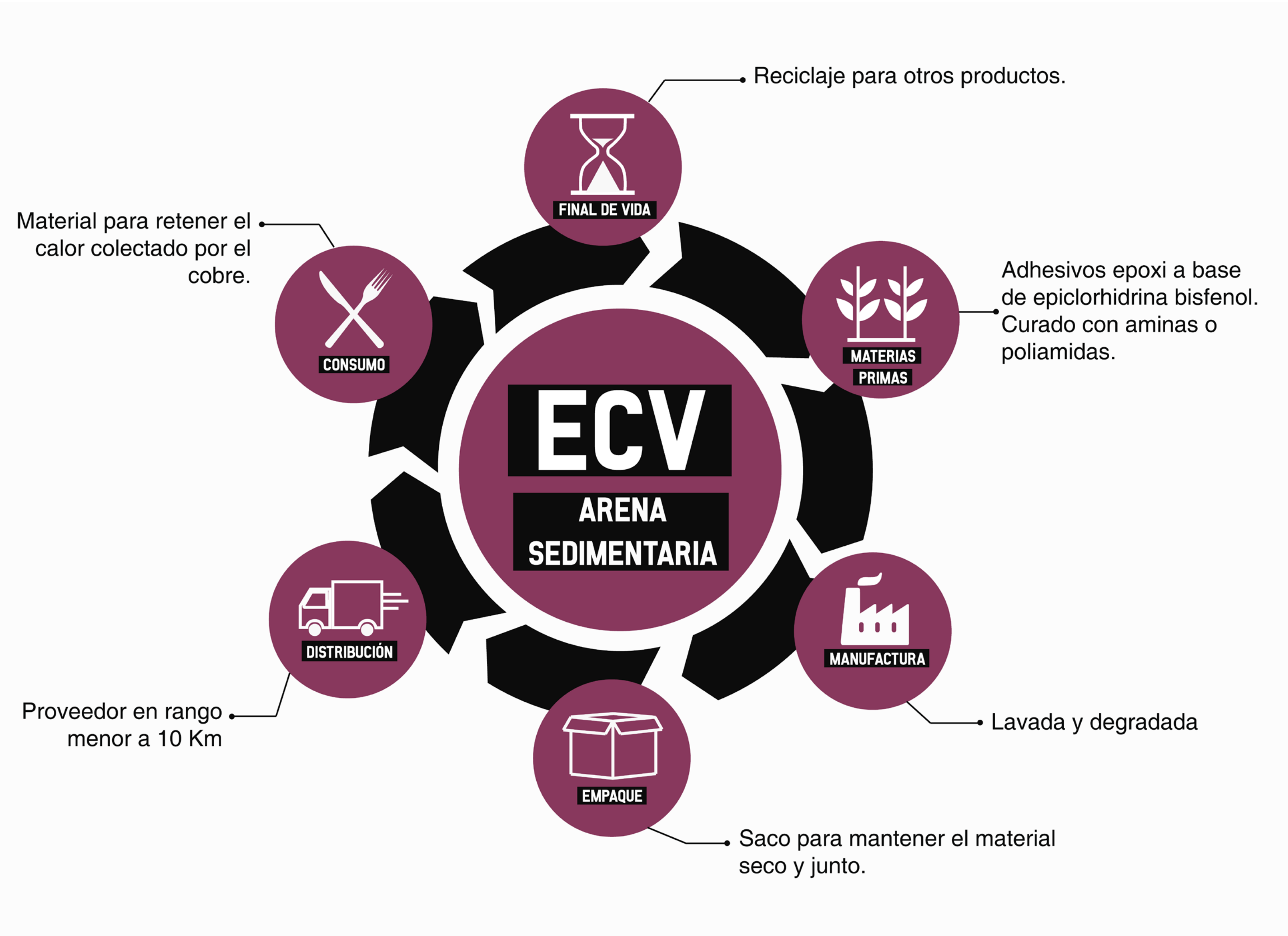

Figura 25. ECV Arena Sedimentaria.

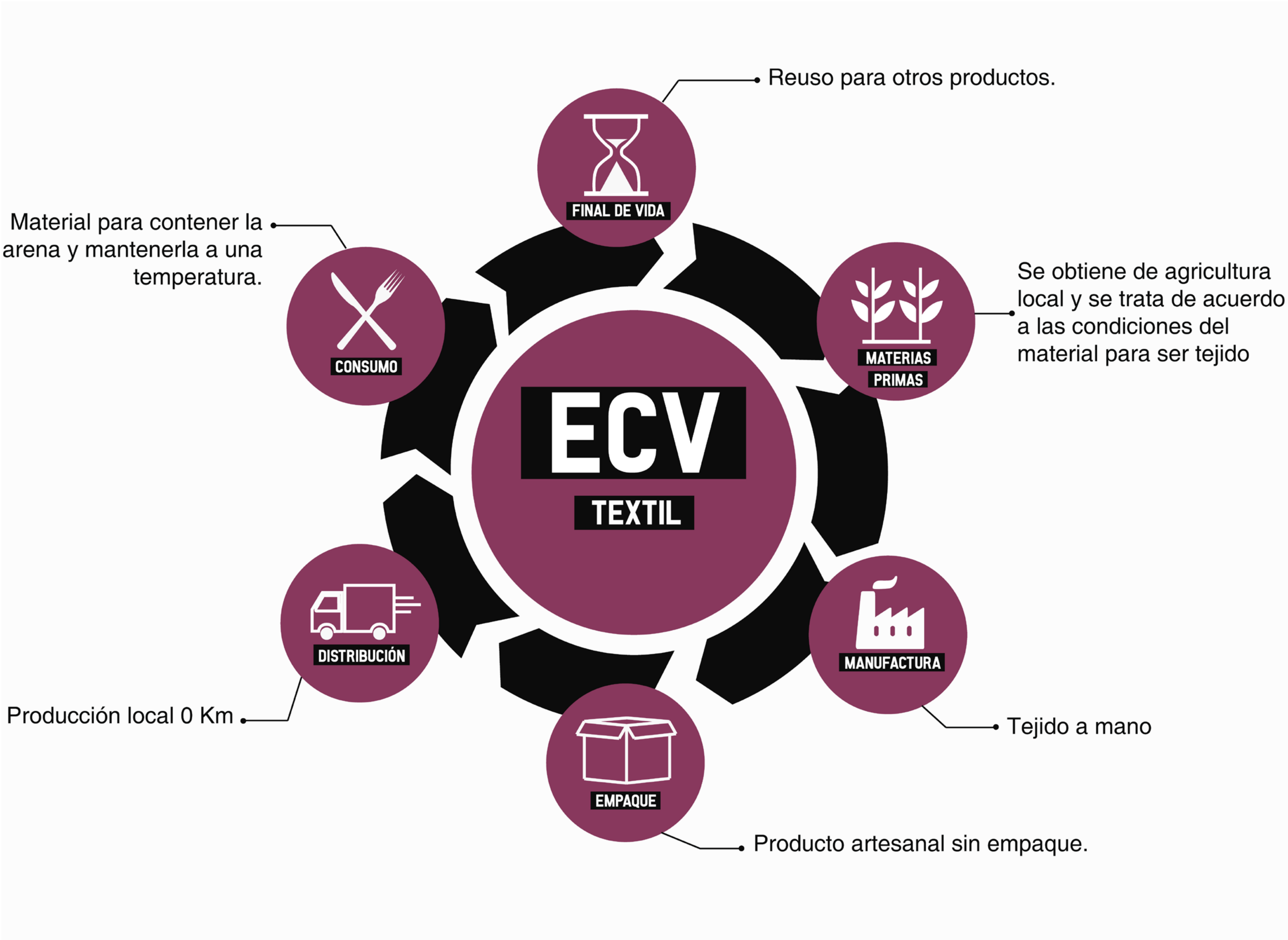

Figura 26. Textil de Algodón.

10 CONCLUSIONES

El resultado de este replanteamiento de concepto a una región del territorio mexicano es un ejemplo del alcance de adecuación que puede tener el sistema de desalinización diseñado en Suecia. El uso del contenedor textil, aunque importante, puede ser sustituido por otros materiales naturales que presentan propiedades de retención térmica, como son la hoja de plátano y la palma. Esto acorde al planteamiento de producción local de la propuesta, la cual busca que sea replicable en distintos contextos con distintos recursos.

Como se mencionó a lo largo del reporte, la propuesta es una conceptualización que aún requiere de pruebas funcionales con prototipos para evaluar su funcionamiento en la región establecida y comparar las mejoras de funcionamiento estimadas con la propuesta original. Está claro que para su desarrollo a producto funcional se requerirá de una investigación profunda sobre el contexto de uso, tomando en cuenta los hábitos y estilo de vida de los posibles usuarios. Incluso se podría extrapolar su planteamiento a un objeto de uso en caso de emergencia dadas las actuales situaciones de inundaciones y desbordamiento de ríos en la zona noroeste del país. Estos desastres naturales han resultado en la reducción de acceso al agua potable en las zonas afectadas y regiones aledañas.

No obstante el principal objetivo de este replanteamiento no es solo mostrar cómo se mencionó antes, la capacidad de adaptación del sistema diseñado. Si no dejar una aportación a la sociedad mexicana por brindarnos la oportunidad de realizar este proyecto de tesis durante un año de movilidad estudiantil en Suecia y abrir la posibilidad para su explotación a distintos contextos y circunstancias que mejoren las condiciones de vida de comunidades afectadas por los problemas relacionados al acceso a agua potable.

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12

DOCUMENTO ANEXO

UNIVERSITY OF SKÖVDE

Bachelor degree project in Product Design Engineering
Level G2E 30 ECTS
Spring term 2018

Sustainable System for Water Desalination

Wenny Fernanda Ramirez Garcia and Lucero Gutierrez Hernandez

Supervisor:	Lennart Ljungberg
Co-Supervisor:	Pamela Ruiz Castro
Examiner:	Anna Brolin

“This project report has on July 19 2018 been submitted by Lucero Gutierrez Hernandez and Wenny Fernanda Ramirez Garcia to University of Skövde as a part in obtaining credits on basic level G2E within Product Design Engineering.

This proyect was developed in colaboration with Ankarstiftelsen.

Ankar stiftelsen

ABSTRACT

Ankarstiftelsen, a non-profit organization with the mission of assuring the access to basic necessities in developing countries, presented a brief for a sustainable water desalination system, to obtain acceptable drinking water, in the region of La Guajira, Colombia. The main objective of the project is the creation of an initial proposal for a sustainable desalination system using solar energy with a minimal cost of construction.

This project required large amounts of research regarding the principles of desalination and water purification systems. As well as the living conditions, weather, and water situation in La Guajira. Empirical studies helped verify initial information and provided a better understanding of desalination systems and their principles. Methodologies such as user personas, interviews, and Function analysis were used to determine key constraints and aspects to be considered in the project development. In addition, simple functionality tests were conducted to evaluate the concepts generated. The resulting design proposal is a collection of technical functionality aspects and user identity that aims to create a meaningful and coherent product to be implemented in its designated context.

PREFACE

We would like to dedicate this work to the Wayuu people in La Guajira, for whom this project is developed and to AnkarStiftelsen for providing us with a valuable and meaningful project that has broaden our perspective towards the role of design in the development of communities and the responsibility we have as privileged members of society to use our knowledge and talent for social impact. A special thanks to everyone involved in the realization of this work, The University of Skövde and The National Autonomous University of Mexico for giving us the opportunity to carry out our final project abroad. Lastly to our supervisors Lennart Ljungberg and Pamela Ruiz Castro and our examiner Anna Brolin for their guidance and valuable feedback that were key to the development of this project.

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INTRODUCTION

Potable water is the most basic necessity for humans, yet according to a 2007 World Health Organization report, more than one billion people in the world lack the access to clean and safe drinking water. In underdeveloped communities such as La Guajira in Colombia, salted water is the only possible source for water consumption to a large portion of the population, representing high health risks. Drinking salted or brackish water is the leading cause of acute and chronic illnesses in third world countries.

Many processes provide alternatives for water purification, the most efficient being those that utilize electricity yet they are unaffordable for the communities that need them and implicate high levels of carbon emissions. They may also stop functioning due to the use of electrical components and the adverse conditions of use they are under. Having said this, there is a necessity for a system water purification that can achieve high levels of productivity and be cost efficient, to be implemented in marginal communities.

Ankarstiftelsen

Ankarstiftelsen is an organization created in 1996 by Sven Bergholm and Börje Erdtman with the mission to create solutions to basic need problematics in developing communities. Its values rely on the right for everyone to have a free and dignified life.

They currently work with volunteering projects in Colombia and Brazil, mainly with the construction of schools and supply of clean water. The dynamics of their projects rely on the support from sponsors to finance the construction and implementation of various systems across La Guajira, currently one of them being the exploration with desalination techniques to obtain potable water.

Problem Definition

As mentioned before, the most efficient processes to purify water use electricity, and represent high costs of production and maintenance. The region of La Guajira is mostly populated by low-income indigenous people, the development of this system of desalination has to consider their characteristics and daily life conditions. Thus, it should be designed to cater their needs and implement a process of desalination in a sustainable and inexpensive manner to obtain sufficient amounts of drinkable water.

Objetives

This Sustainable System for Water Desalination project aims to design a product- based proposal that can be introduced to the region of La Guajira in Colombia by considering low-cost energy sources, intuitive and understandable set up procedures and use of local materials to ensure the proper integration with the users and the context.

It is important that the final result caters to the physical and cognitive characteristics of the users as well as their social-economic capabilities. Functional requirements have to comply with the availability of materials and processes in the destined country of use while maintaining a focus on reaching a sustainable solution and requiring minimal technical assistance for assembly and maintenance. It is essential for the success of the project to provide enough drinkable water for a family, for this, certain functional requirements must be met to ensure a higher efficiency than traditional desalination methods.

Methodology

The nature of the project, being centered in the functionality and efficiency of a system, requires a set of appropriate methodologies that offer structure and allow the creation of constraints and criteria for evaluation of concepts. However, the consideration of the user culture and resources, given the extreme conditions of the users, represents a social aspect of the project. Thus, the methodology implemented must allow a flexibility to iterate between the generation and evaluation phase and a combination of creative and rational methods throughout the design process. As such, the project is carried out in the four stages of the descriptive model of design processes by Nigel Cross. The combination and structure of different methodologies allow iteration between phases of the design process in order to enable improvement of the solutions developed (Cross, 2008).

The first stage focuses on the idea that design problems are ill-defined, therefore require an initial research and acquisition of information to clearly understand the nature of the problem (Cross, 2008). Such understanding and definition are achieved through semi-structured interviews with the client and users, literature surveys regarding desalination techniques and water purification. The aim of a Semi-Structured Interview is to obtain data while also allowing exploration of issues not yet considered (Wilson, 2013).

User research is important since it eliminates assumptions and provides design insights (Faulkner, 2000) given the significant distance from La Guajira and its inhabitants; special methodologies for user research are needed in order to define their characteristics and context. Analysis of user research provided insight into the behaviors and activities of The Wayuu people and how they deal with water shortage and scarcity.

The goals and sub-objectives of this project are defined through the implementation of an Objectives Tree, which also helps identify their relationship and the means required to fulfill them (Cross, 2008). In addition, the use of a Function Analysis method to define the boundaries of the desalination system provided an initial visualization of design parameters.

With the information gathered from the exploration phase, which includes the methodologies mentioned above, a Needs and Specification lists are created in order to, in further stages, evaluate and compare concepts and solutions. Following these methodologies, a Brain-steering session allows the generation of solution concepts. Brain-steering is a thinking process guided by parameters in order to generate concepts within a highly technical context or problem (Coyne and Coyne, 2011), such as the one addressed in this project.

This project requires the realization of a sustainable product, therefore the environmental impact of the processes, materials, and use of the proposal have to be evaluated. The inclusion of a Life Cycle Analysis in the Evaluation phase will provide guidance in the selection of the most suitable solution.

Communication is key in any design process, whether it be to understand the work process between the design team or to present it to clients. Presentation material to communicate the design process and resulting proposal will be done through CAD models and renderings. As part of this communication, Figure 1 shows a graphic representation of the design process and selected methods for this project.

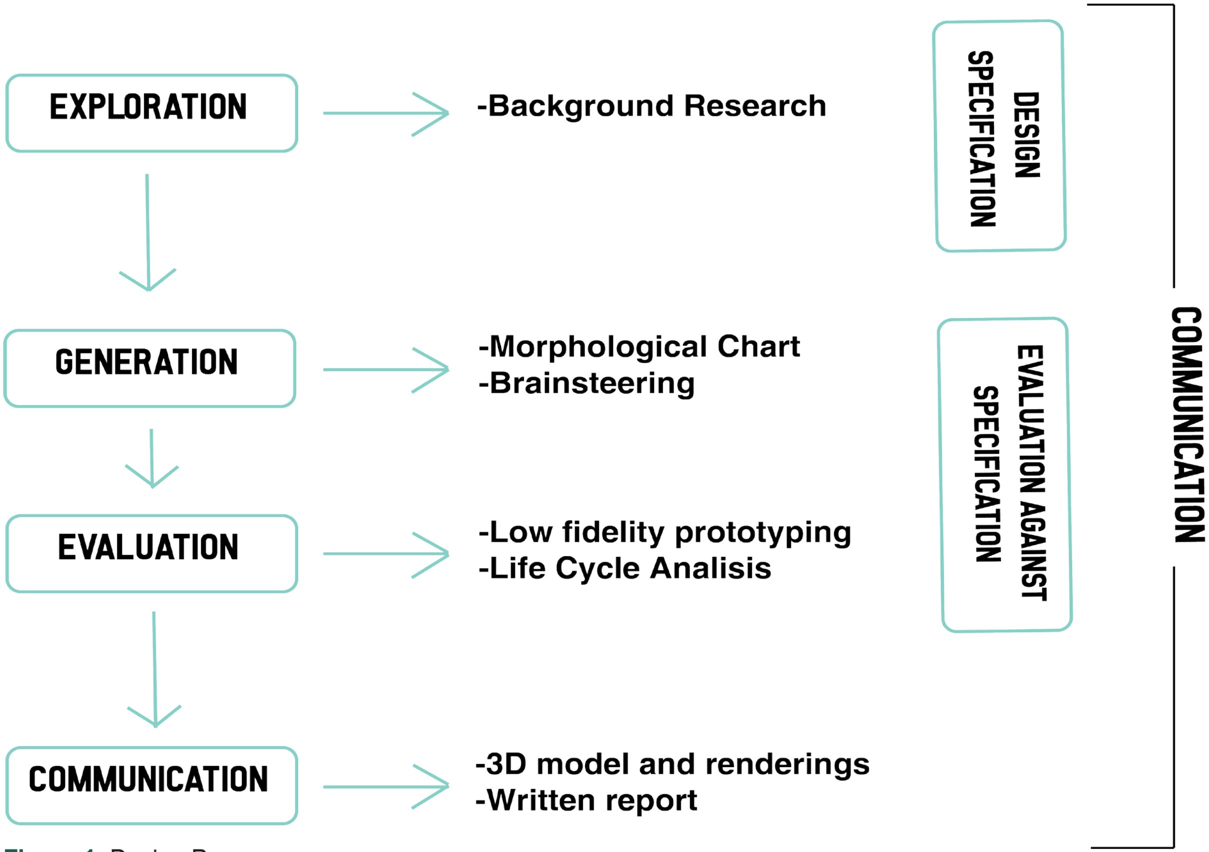


Figure 1. Design Process

02

BACKGROUND INFORMATION

According to the World Health Organization, 88% of the 4 billion annual cases of diarrheal diseases are attributed to unsafe water consumption (World Health Organization, 2012). Simple systems that can treat water at home, such as desalination systems, can save a number of lives each year in communities where clean water is not easily available.

To properly configure a system for water desalination, a clear understanding of the principles of desalination and the existing technologies behind it are necessary. As well as defining, the conditions needed to create an efficient system are key to the proper development of the project. Consideration of the designated context of use and user are of major relevance for the success of the project. Information regarding the user, context as well as a study surrounding exiting technologies for water desalination are analyzed in this chapter.

La Guajira

The region of La Guajira is one of the 32 districts in which Colombia is politically and geographically divided (The peninsula of La Guajira is shown in Figure 2). Located on the northern peninsula, the mainly deserted land has a temperature between 22 and 40 degrees Celsius. According to the department of strategic statistics of Colombia (DANE), La Guajira is one of the regions with the highest percentage of extreme poverty where 47% of the population lives in conditions that don't satisfy basic needs (DANE, 2018) such as access to clean drinkable water. The most common sources of water are natural deposits such as wells, lagoons or jagueyes, which provide water consumption to nearby communities. Within this territory, 80% of the population belongs to a native indigenous community called the Wayuu (DANE, 2018).

Defining the User

User research gives insights into how people interpret and use products and services. Innovative and profitable ideas are the result of user research and exploration (Faulkner, 2000). Product development varies depending on the users, context and customer requirements yet the success of the product relies on its functional efficiency perceived by the intended audience, which is why usability is a great starting point to the development of any project (Goodman et al., 2012).

An important and conflictive aspect of this project is the significant distance from the intended user and context, which does not allow a one on one observation of the user or context analysis. In order to define the user given the circumstances, interviews via telephone with Wayuu community members in Colombia and people who have worked with AnkarStiftelsen were implemented as a method of research

Figure 2. Map of Colombia

and analysis. In addition to this, literature research, documentaries and other studies regarding the indigenous community of the Wayuu, their lifestyle and customs helped visualize the abilities, needs, and desires of the community.

Wayuu Culture and Lifestyle

The Wayuú people are located in the peninsula of La Guajira in northern Colombia. In 2005, 270,413 people recognized themselves as belonging to the Wayuú people (DANE, 2018). The dynamics of this ethnic group is matrilocal and is characterized by settlements based on the Ranchería concept. The Rancherias are formed by several pieces of land inhabited by extensive families (Paz Reverol, 2014), forming a group of residence defined by collective land sometimes including mills to pump water or artificial wells and dams in riverbeds to store water. Their organization relies on the division of task, in which women are in charge of the activities within the Rancheria and men are responsible for grazing, hunting, and fishing. Given the difficulties of their living conditions, their economic activities have expanded to the commercialization of their native crafts such as textile weaving and, in some regions, ceramics (Paz Reverol, 2014).

In lack of the possibility to observe the Wayuu people in their daily life and gain insights into their current water collection and consumption practices, an interview via telephone with a Wayuu woman living in La Guajira, was held (Full interview Appendix A). The interview revolved around the different water collection routines in La Guajira, how they currently purify water and daily life in the Rancherias. It has been stated that the Wayuu are organized in matriarchal Rancherias where extensive families reside, sometimes housing from 10 to 12 nuclear families.

Most of the Rancherias lack their own wells, which forces the inhabitants to travel up to two hours to the nearest water source to collect the water each Rancheria requires. Even then, the water obtained is from subsoil deposits, which contain high levels of salt or external contaminants. The need for water consumption forces the Wayuu to either boil small amounts of water to better the condition or consume salted water.

Many organizations and government campaigns have worked with Wayuu communities to improve the water situation affecting thousands of people, yet their efforts have not been effective in their entirety. A common mistake on these types of aids is the lack of research regarding not only the economic situation but social and educational conditions in La Guajira. The percentage of the Wayuú population that does not know how to read or write is 61.65% (DANE, 2018). In their majority elderly people although only 10% of the current young population attended some kind of elementary education, this according to interviews held with Wayuu community members. Recent initiatives by active members of the community have started new educational programs for the younger population in order to increment the percentage of Spanish speaking Wayuus, given that their native language is Wayuunaiki, a dialect with no written expressions. The extreme living conditions of most of the Wayuu community in La Guajira regarding water shortage as well as lack of electricity in 99% of the communities calls for an analysis of a new system for water desalination in addition to proving potable water, takes into consideration their culture and capabilities.

User Profile

To create a wide understanding of the users, personas were created and will be kept in mind through the development of the project. User Personas are used generally in the beginning of a process development with the intention of using fictional characters as means to express the needs of different users (Goodman et al., 2012). Figure 3 is a graphic representation of the resulting personas; they seek to illustrate the lifestyle of different members of the Wayuu community.

Given the distance and difficulty of communication with users in La Guajira, the Wayuu culture was researched through existing studies such as Paz Reverol ´s “La Sociedad Wayuu” (2014), as well as the national statistic department of Colombia ´s online database (DANE, 2018). In addition, an interview with one Wayuu woman in Colombia provided valuable information, which was then analyzed and concluded in the classification of users based on their water collection routines. Each Rancheria has a different water source whether it be a well on their property, a pond or in most cases, they have to travel to the nearest water source. These different tasks were used as a base for the creation of user personas and represent the daily struggles of obtaining potable water in La Guajira, from health issues to environmental impact of the current water purification methods used in the communities.

Most of the water purifiers that have been developed are not affordable for low- income communities either for their production cost or the high levels of technology and maintenance needed. The complexity of use of some systems is not adequate to the educational level or experience of the Wayuu community. In addition to the slow process of desalination that does not produce enough water for a family’s daily consumption, they encourage the development of an alternative desalination system for this specific context. Having stated this and knowing the low availability of electricity in the area, as well as the concern for affordability and low maintenance, the expectations of this project, rely on an affordable, sustainable and efficient solution.

GRACIELA

- 50 YEARS OLD
- MARRIED
- 4 KIDS

graciela is the matriarch of the Cotes family, every morning she wakes up to begin various activities in the rancheria. She starts by collecting water from the rancheria well in order to boil it for food preparation. She boils it in a wood burning stove which takes a lot of time in relation to the amount of boiled water obtained, in addition, this process requires a high amount of firewood.
She feeds the family's livestock with salted water which has resulted in the death of several of them, this reduces their family's economic status.

SUNILDA

- 27 YEARS OLD
- SINGLE

Sunilda is a member of a Rancheria in La Guajira, every morning she rides her bike for 2 hours to the nearest water well in order to collect 15 liters of saline water. She fills three 5 liter plastic containers and secures them to her bike, she then makes her way back to her family's Rancheria.
The water collected is used by her family to cook food, wash clothes and as drinking water. Sometimes if the water is brackish, she boils small amounts to drink, yet most times it is consumed salted.
Sunilda knows for a fact that the water she collects from the well isn't pure but the resources in her community and the knowledge and/or abilities of those around her do not allow them to efficiently and properly purify the water.

RAFAEL

- 62 YEARS OLD
- MARRIED
- 8 KIDS

Rafael lives in a Rancheria with his family, he recently dug up 15 meters to find a source of underground salted water. This resulted in a pond from which he and his family obtain water to prepare food, drink and feed their livestock.
The frequent consumption of salted water has on many occasions caused him and his family different diseases and illnesses. Due to this, Rafael and his kids sometimes walk 10 kilometers to the nearest clean water source, which sometimes does not have any water or are denied access to it, for it is privately owned.

Figure 3. User Personas

Water Desalination

Water Desalination is a process to remove salt and other minerals from brackish or saline water in order to make it acceptable for human consumption. The main principle relies on separating the contents of water based on different boiling points (Ahsan et al., 2014). In this process, water is heated in a closed environment reaching its point of evaporation, the temperature is then maintained for large periods of time to continuously evaporate water without evaporating any other contaminants in the water. The water vapor is then condensed and collected as purified water.
One of the many benefits of desalination is the low cost of production of basic and simple stills, in addition, most of the technology can be used in either small or large scale. There are different types of desalination processes that apply new technologies to increase the efficiency of the process, yet the most popular method is still the solar desalination. There has been an extensive research and study by different organizations, universities, and researchers regarding the use of desalination in the production of potable water; an analysis of them and conclusions of their parameters are included in this section.

Desalination Techniques

With the high rate of mortality as a result of diseases related to impure water consumption, different methods for water purification have been developed, such as water desalination. Water desalination can be classified in many different ways, in this report, the existing techniques will be evaluated according to the process itself. Below, Table 1 shows the comparison between different desalination techniques regarding the process, cost, and energy use.

As Table 1 shows, most of the methods used for water desalination represent elevated costs and energy consumption due to the requirement of high amounts of electricity or high tech components such as filters, membranes, etc. Solar Desalination, on the contrary, is a simple, cost-effective and sustainable method for it operates solely off solar radiation. Solar desalination is one of the most promising simple and economic methods for water purification (Tiwari and Sahota, 2017). It can be used in large and small scale production which allows this type of process to be modified and designed for different contexts. The main challenge in the implementation of Solar Desalination is obtaining a higher efficiency system that can produce sufficient amount of drinkable water compared to existing products, with the use of solar radiation. Given the advantages of this desalination technique, it seems as the most viable option to be further developed into a product based solution. Further research regarding the limitations, advantages and other factors of Solar Desalination is carried on section 2.4

Table 1. Comparison of Desalination Methods

	SOLAR DESALINATION	REVERSE OSMOSIS	DESTILLATION	ION EXCHANGE
Process	Initiates as part of the natral hydrologic cycle in which saline water is heated by sun rays to increase vapor production. The vapor is then condensed on a cool surface and collected as water.	Occurs when pressure is applied to saline water on one side of a membrane and fresh water s effectively drawn from the salt water. The amount of contaminants discarded is dependent on the amount of pressure applied.	Consists of separating different substances based on their different boiling points. Water will boil before any of the impurities, thus the water is evaporated, collected and condensed in a separate container.	Electrodyalisis reversal desalination membrane process is an electrical process. Meaning an electric current migrates dissolving salt ions through. Periodically, the direction of ions flow is reversed by reversing the polarity applied to the electric current.
Cost	Stills themselves are mostly inexpensive to construct, and the thermal energy may be free. However, additional energy may be needed to pumo water into the still.	Among desalination processes, RO is one of the most cost effective in long term use, yet the inital investment for construction is high. In addition, this process requires special maintenance to prevent bacteria formation	Cost for building a small scale distillation device depends on the choice of energy source as it relates to the materials required.	The cost of this process depends on the level of pre and post treatment required depending on the level of purfication achieved with the process.
Energy	A solar collection area of about one square meter is needed to produce 4 liters of water per day in an ideally efficient system.	This is an energy efficient process, however it relies on the amount of pressure applied. The energy required to power a pumo is the only energy that needs to be considered	The energy source for a distiller can be either soral, fire or electricity. The energy requirements for distillers are related to the boiling point of the water and the materials used.	This process requires electric energy which may not meet the users needs and the inital requirements of the project.
Results	solar humidification units have been used in small scale for family use or for small villages where solar energy is abundant but electricity is not.	Safety concers are higher thatn any other process. I addition the high cost of construction and maintenance tarnished this process's ability to meet customer needs.	The major drawback with this method of desalination is the low amount of water production. However, a large device could speed the process but would represent higher costs and energy use.	It is a process of high cost and complexity.

Solar Radiation and Energy

Solar energy is considered, primarily as the radiation from sun rays that are used for practical means. Technologies that use solar energy can be classified as either passive or active. Active technologies convert sunlight into electricity such as solar panels, while passive techniques use materials with thermal properties and design to intensify and retain the energy obtained from direct sun rays (Tiwari and Sahota, 2017), thus reducing the need for alternative energy sources.

As mentioned before, the growing demand for cost-effective methods to purify water and the also increasing concern for environmental impact, have resulted in an unquestionable requirement to use renewable energy in many design projects. Solar energy is a clean, environmentally friendly, inexhaustible, abundantly available and high potential source of renewable energy (Machanda and Kumar, 2015). Since passive techniques rely only on the proper use of materials and geometry to concentrate, increase and retain heat obtained from sun exposure, they represent a viable option to develop a proposal for a solar water desalination system. The implementation of solar energy in water distillation although not new, has not been explored and exploited to its full potential (Mehta et al., 2011)

Classification of Solar Stills

Clean water scarcity is a worldwide problem, according to the United Nations it affects around 1.2 billion people. Many projects that make use of desalination principles to solve water scarcity; some of them will be discussed in this section. Solar desalination is a tried and true technology that can effectively purify seawater (Mehta et al., 2011) which if designed correctly and precisely can effectively remove not only salts but also bacteria and heavy metals to obtain potable water. Even though each project is different in many ways, they can be categorized into four basic designs. A simple description of each type is explained below.

Parabolic Stills

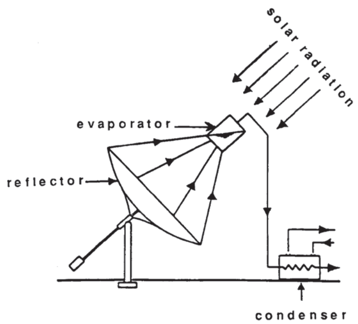


Figure 4. Parabolic Solar Still

As shown in Figure 4, parabolic stills implement solar mirrors to reflect and concentrate sunlight to a specific point thus heating water faster. They are capable of producing two liters of clean water a day for every square meter of reflective area (Arunkumar et al., 2012). The disadvantages of this type of system are the high cost of production and maintenance as well as the fragile nature of mirrors or reflective material used.

Weir Type Stills

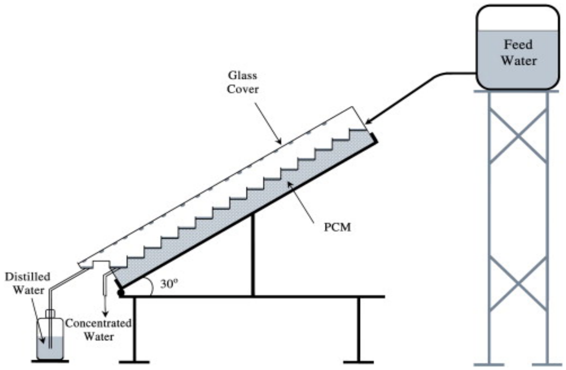


Figure 5. Weir Type Solar Still

They consist of staggered horizontal tilted trays enclosed in an insulated container in which water is evenly distributed. The principle relies on increasing the surface area for evaporation by reducing the depth of water basins, these types of stills have been proven to have high efficiency (Aghaei Zoori et at., 2013). However, they require a high number of components and considerations for assembly and maintenance. An example of a weir-type still is shown in Figure 5.

Wick Solar Stills

The use of wicking refers to the absorption and draw off liquid by the capillary action of a textile, which allows water to evaporate on the surface at a quicker pace. The use of a textile in the still as shown in Figure 6, also produces higher temperatures inside the still (Manchanda and Kumar, 2015). This type of system has been proven to have the same efficiency levels as a weir-type still, yet it represents higher costs of maintenance. The wicking textile requires frequent cleaning or replacement in case of salts and sediment building up.

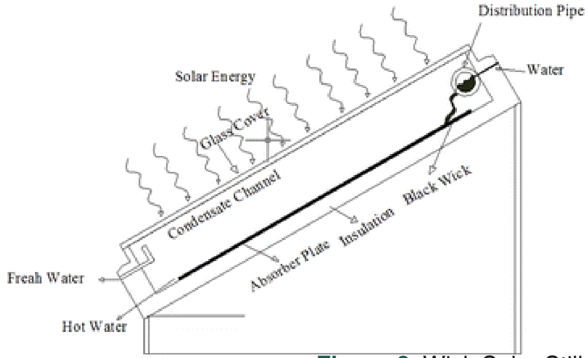


Figure 6. Wick Solar Still

Basin Solar Stills

Basin stills are the most known and used solar stills and given their simple geometry as shown in Figure 7, they represent low-cost production. Although they are cheap to construct in any environment with a variety of materials, they present the lowest efficiency of water production (Arunkumar et al., 2012).

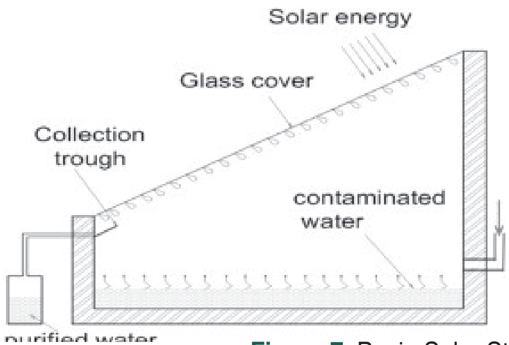


Figure 7. Basin Solar Still

Tubular Solar Stills

Concentric tubular stills, shown in Figure 8, consist of a rectangular water basin inside a glass or transparent plastic tube where water evaporates on the inner surface of the tube and is collected on the inner bottom of it. This variation of still represents a high evaporation rate compared to traditional designs, producing up to 4500ml per day per square meter of radiation area (Ahsan and Fukuhara, 2010).

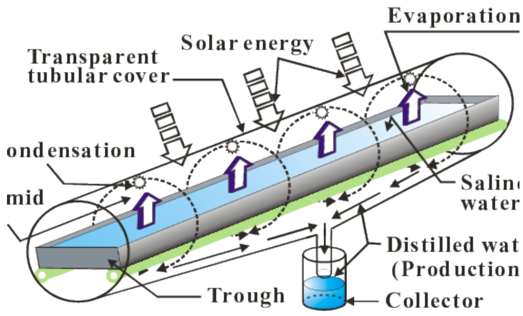


Figure 8. Tubular Solar Still

Semi Spherical Solar Stills

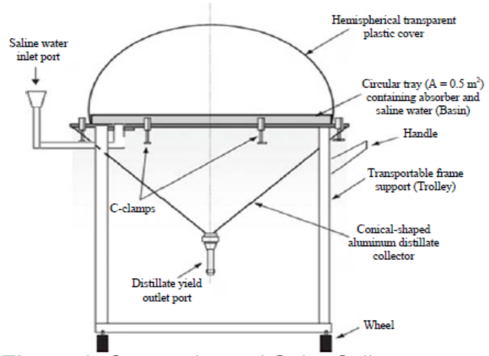


Figure 9. Semi spherical Solar Still

A schematic representation of this type of still is shown in Figure 9, as shown it consists of a circular basin inside a hemispherical cover paired with a conically shaped water collector. The efficiency of this system has been proven to produce 2.8 liters of water per meter squared of absorption area and can convert almost 50% of the saline water input into potable water (Ismail, 2009).

Given the short period of time to develop this project, references to existing evaluations and study of the above mentioned solar stills were used to evaluate their efficiency. An experimental study on Various Solar Still Designs (Arunkumar et al., 2012) evaluated the performance of six different designs. As Figure 10 shows, the efficiency of each still was measured for four months, concluding that the highest efficiency was performed by Tubular Stills. Their success relies on the high thermal efficiency, this, as a result of no having structural walls, which can cause considerable shadow decreasing the absorption of solar radiation.

However, the performance of any solar still depends in great part on the climatic conditions in which it is tested and on a wide number of parameters such as:

-Solar Radiation and other Climatic Conditions
-Water depth
-Materials
-Geometry and Dimensions
-Orientation
-Vapor Tightness

Regardless of the type and conditions, solar stills can be further tested and improved by experimenting with a combination of systems focusing on the enhancement of heat transfer materials, temperature differences from basin water containers and condensing covers (Tiwari and Sahota, 2017).

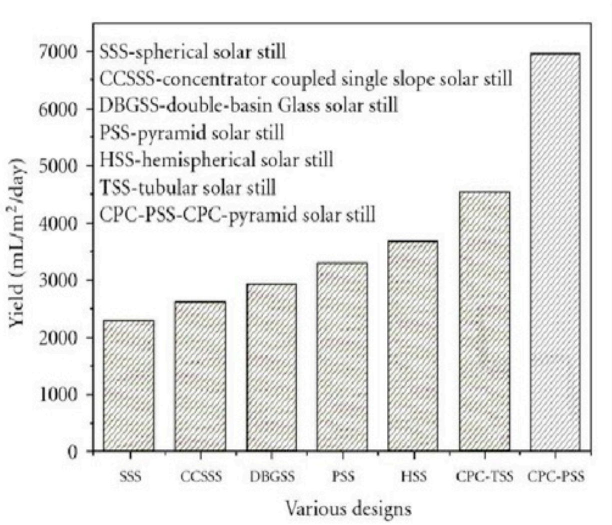


Figure 10. Comparison of efficiency of solar stills

Components and Considerations for Solar Stills

After the initial research and analysis of solar desalination and classification of solar stills, basic components were identified and gave path to the creation of subsystems in order to better understand how the principle of desalination works. The study also provided insightful information regarding considerations for the increment of efficiency and proper construction of solar stills. The subsystems and conclusions drawn for each of them are presented in sections 2.6.1-2.6.3

Heat Collection

Heat harvesting consists of the collection and increase of solar radiation in order to be transferred to the heat retention system. Its proper functioning is conditioned by the use of heat and water absorption resistant materials.

Heat Retention

This system is focused on the absorption, retention and heat transfer to the body of water in order increase temperature and allow evaporation. This system requires special observation to heat transfer coefficients of materials in order to ensure a high efficiency of the entire system.

Condensation System

The condenser is a system aimed to reduce the time of condensation of water vapor in order to increase the efficiency of the system. A proper design has to consider water absorption capacity of materials, as well as the temperature difference between the water container and the condensation area.

The design and efficiency of solar desalination stills depend on many factors which include the proper combination of materials and geometry. The pollution free technology, flexibility for domestic and commercial purposes of solar desalination stills as well as the relatively low maintenance cost are only some of the advantages of this desalination method. Their simple functioning concept and flexibility of design has resulted in the development different proposals that aim to increase the low water production of this method of water purification.

However, there are still drawbacks that have not allowed its high production or commercialization, such as the low water productivity and the absence of minerals from the resulting water. Nonetheless, this type of systems allows a rapid and viable solution for emergency cases and low-income communities to obtain potable water and offer the possibility of experimentation and perfection of existing models.

Dehumidifiers as water collectors

Dehumidification is a concept based on removing the moisture from the air in the environment, they absorb air and with the use of coolant pipes transform the moisture into liquid water. Moisture free air is then released to the environment again. A schematic representation of the function of a dehumidifier is shown in Figure 11.
There are projects of water generation and purification that implement dehumidifiers, mostly to reduce the water generation time. However, they require high amounts of energy to function, thus representing high costs. In spite of the variety of such projects, there are still doubts regarding the hygiene of water obtained through these processes.

According to the United States Environmental Protection Agency, stagnant condensed water can harbor biological contaminants when maintenance is not frequently given to dehumidifiers. Moreover, the cooling pipes and other components can spread metal residues to the resulting water (Martin, 2015). Unlike other water purification processes, dehumidifiers do not sterilize the water obtained from the environment thus require an additional process to ensure clean and drinkable water.

There also many appliances that obtain potable water from the air, however, they can cost up to 8,000 SEK according to Wood's, one of the biggest home appliances suppliers in Sweden. This cost however does not include the electricity consumption and maintenance needed throughout the use of the product. The water obtained from these appliances, as well as water obtained from solar desalination stills, has a low mineral content. The difference in cost and similarity of water output quality indicates that desalination stills are a more viable and cost-effective solution than dehumidifiers or similar appliances. Furthermore, the introduction of a foreign technology in a rural and vulnerable community presents a high possibility of failure given that the objects often used are far from the users' comprehension and collective knowledge. In consequence resulting in a refusal of the product not by choice but rather by a misunderstanding of its purpose.

Having stated the above, the solution developed should focus on the implementation of solar desalination techniques to improve the efficiency of water production compared to existing products while also maintain an independency from external resources such as electricity and foreign technology.

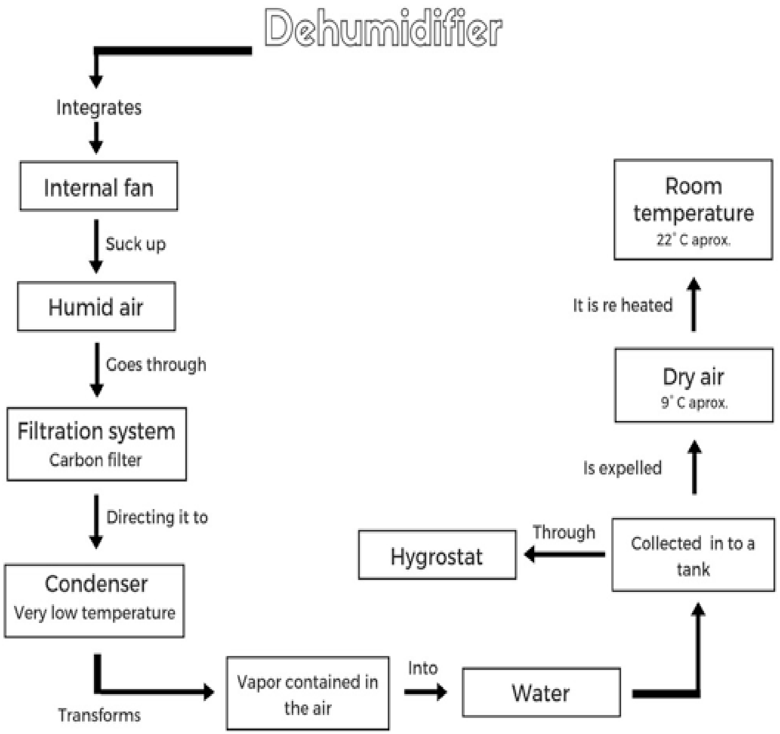


Figure 11. Schematic representation of a Dehumidifier

03

PRELIMINARY STUDY

This stage of the project integrates the conclusions drawn from the Background study and research of existing desalination products and projects, as well as an analysis of their components in relation to their efficiency.

As well as methodologies such as Objectives Tree and Function analysis which helped converge the information obtained and guide the project to a specific functional goal while providing parameters and criteria to evaluate future concepts and solutions.

Benchmarking

A study and analysis of existing products were carried out to compare their efficiency in relation to the materials and geometry used in their production. The objective of this study is to find an area of opportunity to improve existing models. It also serves as a basis for the project given the difficulty to simulate a working prototype in the Winter Swedish weather, studying and analyzing existing desalination products will provide insights into design considerations and design opportunities.

Different solar stills have been developed and tested, some of the most relevant and efficient models are shown and described below, including the reason for their high efficiency as well as drawbacks of the system.

F-Cubed

F-Cubed is a solar desalination system which requires no filters, chemicals or power source to produce 10 liters of potable water per day at an average temperature of 30 °C (Fcubed, 2018). This system allows rainwater harvesting to increase the water input as well as a solar pump to automatize the water flow. F- Cubed panels, shown in Figure 12, work based on a weird type solar still and wicking techniques. Saline or Brackish water enters from the top of the panel and flows down an internal fabric allowing the heat inside to evaporate the water faster by evenly spreading it across the panel. The water vapor then condenses on the inside of plastic covers and runs down to a collection canal.

Although f-cubed provides high amounts of potable water with the use of only solar radiation and has been installed in many communities, there are some drawbacks considering the inner black textile used for wicking. Such textile will eventually need to be replaced or cleaned to ensure a constant and reliable potable water output.

Figure 12. F-Cubed

Figure 13. Eliodomestico

Figure 14. Solar Ball

Eliodomestico

Designed by Gabriel Diamanti, Eliodomestico is a solar household desalination still for developing countries (Gabrielediamanti, 2018). Its operation is based on an upside-down coffee maker, in which solar radiation heats the metal water basin, evaporating the water inside. The water vapor then creates pressure inside the basin and is forced down a metal pipe to a condensation lid and ceramic water container to be collected by the user. Eliodomestico, shown in Figure 13, is capable of providing up to five liters of drinkable water per day (Gabrielediamanti, 2018). In addition to its high efficiency, it caters to the habits and culture of the intended user as well as their economic activities. However, the water collection container must be emptied frequently to avoid overflow, which requires the user to have a constant supervision of the system.

Solar Ball

Solarball is a project developed by Jonathan Liow at the Monash University, consists of a sustainable water purification system based on solar desalination. The spherical model, shown in Figure 14, can produce up to three liters of clean water every day (PhysOrg, 2011) by absorbing sunlight through the clear upper dome, causing water in the lower black semi sphere to evaporate and condensate on the inner clear dome. The condensed vapor trickles down to the sides of the ball allowing users to drink or collect the resulting water.

The portable design of this system allows it to be used in any context or reduced spaces and does not require a structural assembly or high technical maintenance, yet the selection of plastic materials present a possible conflict when destined to be used in vulnerable communities. Such materials must be able to withstand high temperatures and constant exposure to the sun as well as overall harsh environmental conditions.

In order to evaluate the before mentioned systems against each other and assess their advantages and disadvantages, Table 2 was created and contains the material selection for each part of the desalination still as well as an analysis for such decision. The comparison also includes the highest water productivity the system can provide and observations made on their design, development, and functionality.

From this analysis, it is clear that the transparency of sun collector parts is closely linked to the selection of plastic materials, Elidomestico uses a metal collector given the thermal conductivity of steel therefore not requiring a transparent cover. F-Cubed produces the most water output, although not proven, it can be based on the combination of wicking and weir type solar desalination methods. Weir type stills equally divided water into smaller bodies to faster evaporate the surface of them, while wicking increases the humidity inside the still allowing a faster temperature increase.

The selection of black textile in F-Cubed panels and Black lining in Solarball, is due to the capacity of this color to absorb and retain heat, thus allowing a more efficient water heating system. Eliodomestico includes this method with the implementation of a metal container thus heating water faster, in addition to this, it separates the condensation surface from the sunlight collection surface, resulting in a more efficient system than Solarball. Eliodomestico takes into consideration the destined context and makes use of local activities and materials to create a sustainable system of water desalination.

Table 2. Benchmarking Comparison

	F-CUBED	ELIODOMESTICO	SOLAR BALL
Sunlight collection material	Transparent Plastic Cheet	Black steel cover	Transparent plastic sphere
Water basin material	Black textile in weir type plastic base	Steel container	Black plastic sphere
Heat Retention material	Wicking Textile	Ceramic structure and insulation	Black lining on water basin sphere
Condensation surface material	Transparent plastic sheet	Metal pipe and aluminium surface	Transparent plastic sunlight collection sphere
Water Input System	Automatic solar pump	Hand-filled	Hand-filled
Water Collection System	Metal canal in lower end of panel	Ceramic basin	Circular canal in inner sphere
Water Productivity	10 L / day	5 L / day	3 L / day

Objectives Definition

With the conclusions drawn from the background study and benchmarking analysis, objectives were defined in relation to different areas of improvement of desalination techniques. The main objectives are listed below in order of importance, the first and foremost is the goal of producing desalinated water acceptable for human consumption. Taking into consideration the context of use and users, a sustainable and low-cost method is required while maintaining a high or competitive efficiency in comparison to existing products.

- Provide Clean Water
  - Desalinate Water
  - Filter Contaminants
- Sustainable
  - Locally Available Materials
  - Low energy consumption
  - Low Maintenance
- Ergonomic
  - Simple Assembly
- Reliable
  - Stable
  - Efficient
- Adequate
  - Reflect community values
  - Congruent with the context

To clarify the above-mentioned objectives and state the means to reach such goals (Cross, 2008), via a system for water desalination, the objectives tree method was implemented and a graphic representation is shown in Figure 15. The key to this method is the questioning of the essential purpose of the project, why they are important, how they can be achieved and which implicit goals underlie them (Cross, 2008). The stated objectives and the way they will be achieved will be clarified and determined according to conclusions drawn from Function analysis methodologies and Benchmarking research.

Figure 15. Objectives Tree

Function Analysis

In order to establish the functions that the system requires to work, a function analysis was developed. This method expresses the overall function of the design in terms of inputs and outputs considering the fundamental purpose of the product (Cross, 2008).

The main purpose of the project is to desalinate water and provide acceptable drinking water to communities in La Guajira. Ankarstiftelsen had an initial proposal to implement a dehumidifier within the Desalination Still. This idea is based on the assumption of the dehumidifier increasing the amount of drinkable water obtained. In order to assess such proposal, function analysis was done for both a system that integrates a dehumidifier and a Solar Desalination Still. Figure 16 shows the functional analysis of a basic system for water desalination. As it can be observed in Figure 16, the system boundary encloses the main functions of the desalination system from water retention to evaporation and condensation, yet it does not include water collection or additional steps like infusions of minerals and other substances to the resulting water in order to reach the maximum quality for potable water.

This boundary works as a guide for the project development and allows the identification of components needed for the working system.
As means of comparing the number of inputs, outputs, and components needed in a system that integrates a dehumidifier in the desalination process, a function analysis was also carried out and is expressed in Figure 17. The complexity of the Function analysis in this model of the device resides in the use of an electric appliance. Not only will this proposal require the implementation of solar panels or another electricity source to work, but the cost of maintenance and repair results in a high level of inputs, not only as components. In addition, the introduction of a foreign technology in an indigenous community where less than 1% of the population has access to electricity (Uriana, 2018) and 61.65% are illiterate, demands previous education regarding the use of dehumidifiers and delays the project development in the time given.

Design Oportunity

Different solar desalination products and projects have been tested in developing communities, for they are a suitable technology where supply for conventional energy or resources is scarce. The use of solar energy implicates an independence from energy sources and ensures water access at a low environmental impact, easy operation and a possible low maintenance.

A wide variety of the existing solutions make use of plastic production technologies for they aim to develop a large-scale product that can be widely distributed, yet they lack consideration of environmental factors that negatively affect the long run performance of the system, for example many of them implement different plastic materials which in long periods of exposure to sun light can release toxins or can lose many of their properties. This project in comparison to others seeks to create a solution that takes into consideration the culture of the Wayuu people, the resources of their community and the environmental characteristics of La Guajira.

Looking at the existing products and principles of desalination, there is an opportunity to increase efficiency by dividing the overall system into sub- systems. This will result in a more efficient condensation since the evaporation chamber will not function as a condensation surface. Allowing the implementation of temperature differences and other methods to increase the water output.

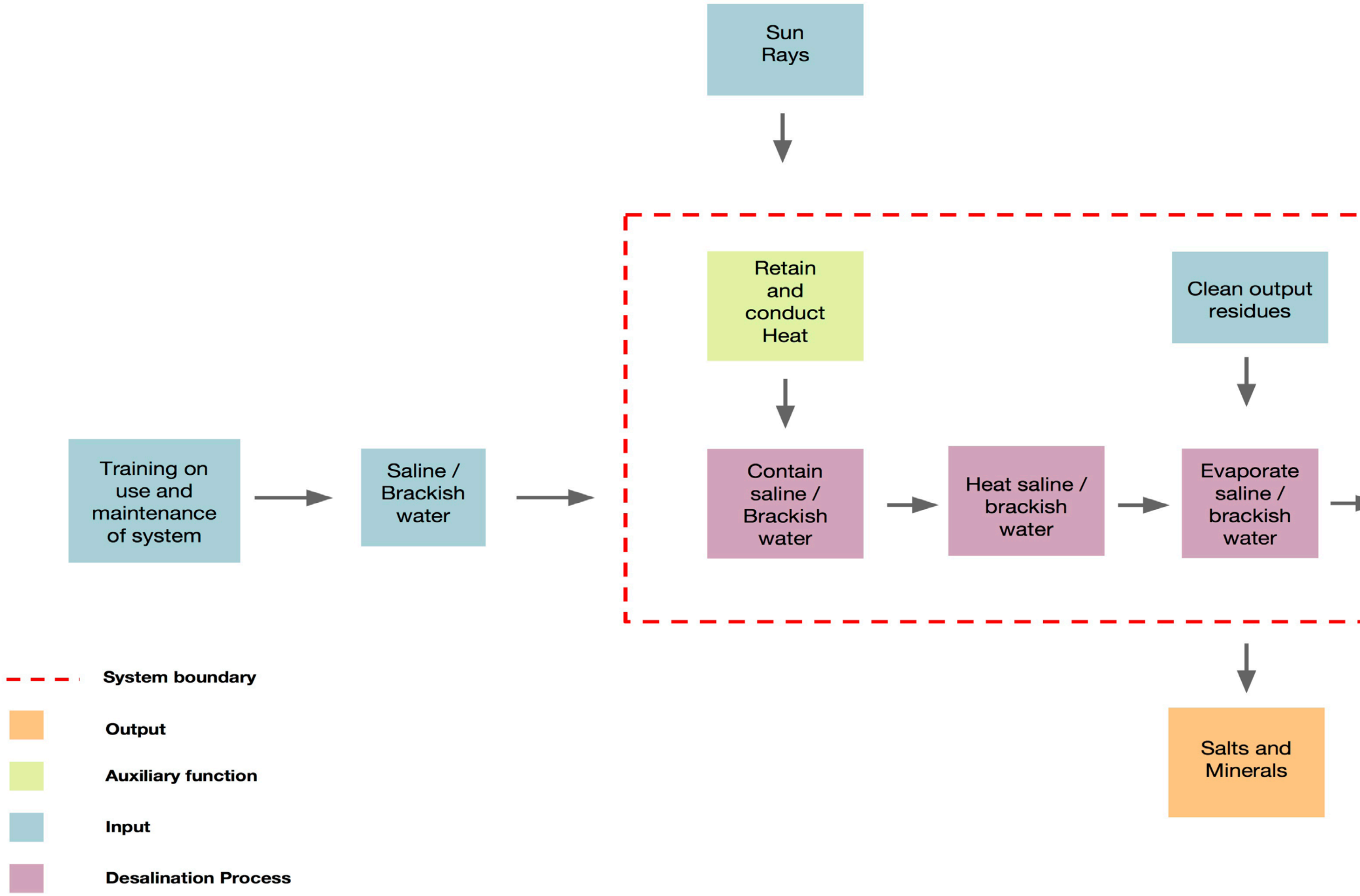
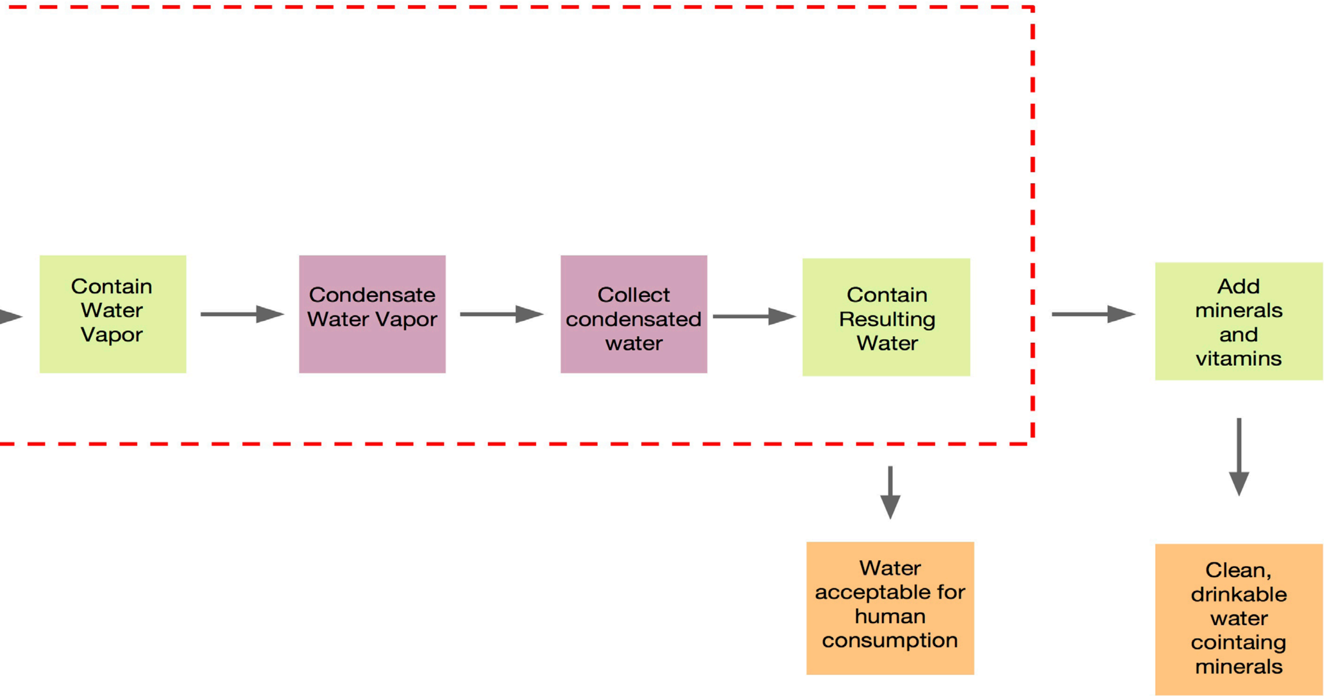


Figure 16. Function Analysis of basic system for water desalination



Contain Water Vapor
Condensate Water Vapor
Collect condensated water
Contain Resulting Water
Add minerals and vitamins
Water acceptable for human consumption
Clean, drinkable water cointaing minerals

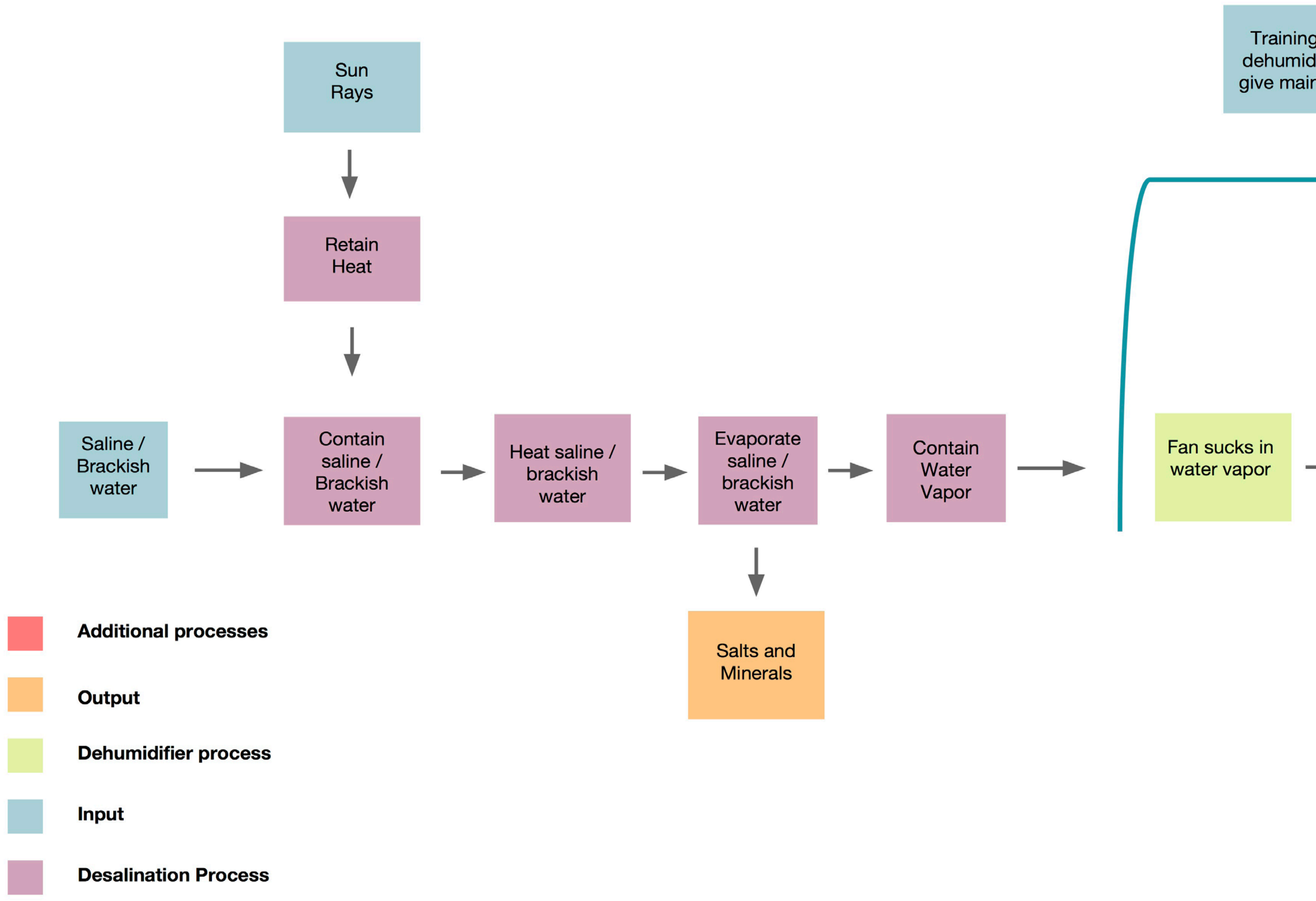
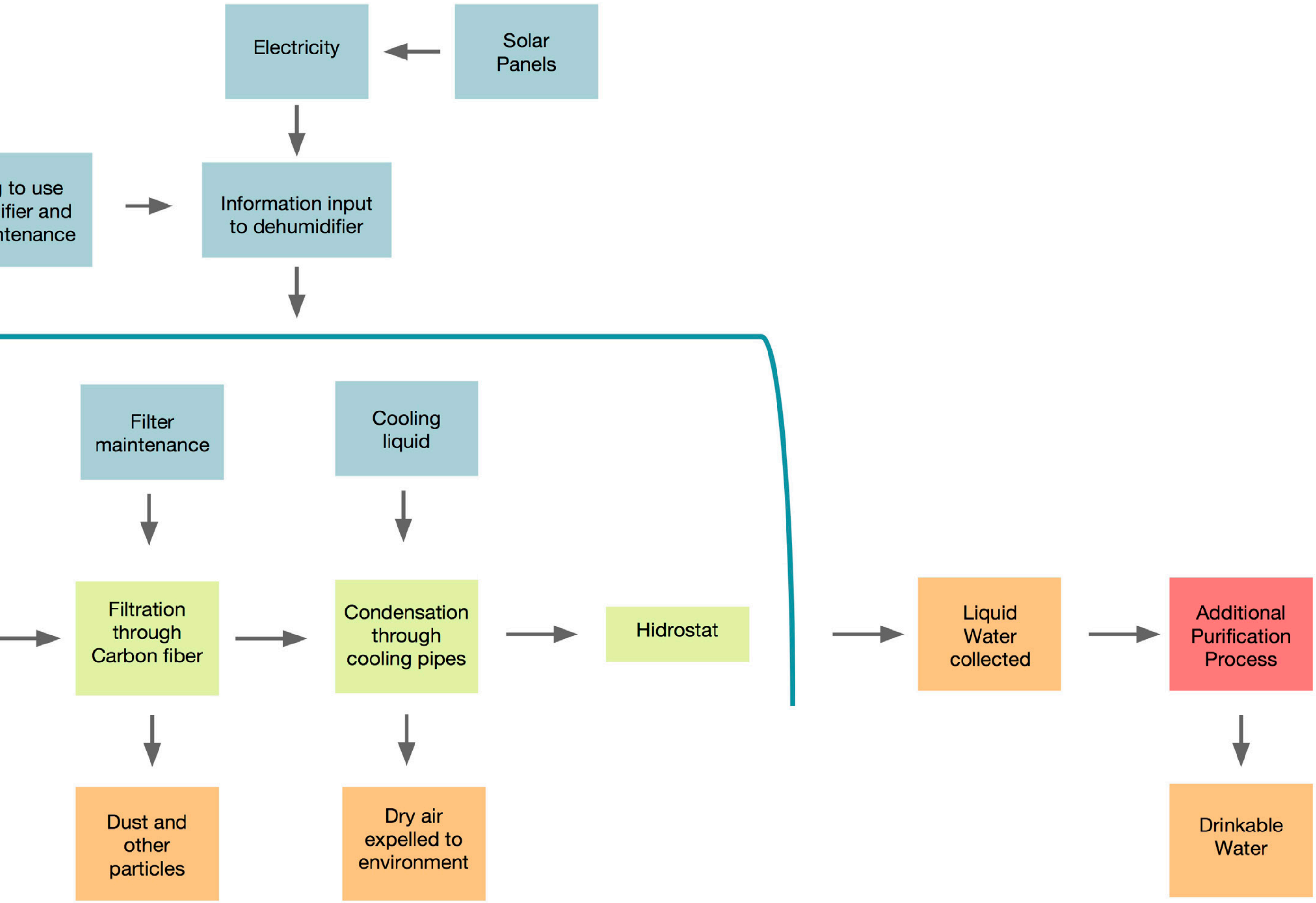


Figure 17. Function Analysis of desalination with dehumidifier.


Electricity
Solar Panels
to use
ifier and
tenance
Information input to dehumidifier
Filter maintenance
Cooling liquid
Filtration through Carbon fiber
Condensation through cooling pipes
Hidrostat
Liquid Water collected
Additional Purification Process
Dust and other particles
Dry air expelled to environment
Drinkable Water

04

DESIGN SPECIFICATION

This chapter draws the conclusions from the Preliminary study as guidelines and constraints for the conceptualization and development of possible solutions (Cross, 2008). Such conclusions can be stated as initial attributes and requirements, these can then be introduced to a performance specification which provides a graphic and organized way to state the general characteristics for the evaluation of solutions (Cross, 2008).

Defining Performance Attributes

In order to help define the design problem in terms of functions, initial performance attributes were set in a list of demands and wishes as shown in Table 3. The classification in demands and wishes is based on the importance or relevance each attribute has over the main function of the system, which is the production of desalinated water. Demands are attributes that directly affect the performance of the system, while wishes are attributes related to the personal goals of the design team or the client and although desired to be met, if they are not achieved, they do not compromise the overall goal.

The purpose of this list is to create a base on which criteria for evaluation can be determined depending on the importance of the attribute and their individual parameters for fulfillment. A basic description of the fulfillment of each performance attribute is also included in the table to communicate how each attribute is to be defined. This list of initial performance attributes lies on a general level of description, the evaluation parameters will be stated as measurable data in a specification list further into the design process.

Product Specification

Performance Attributes are an expression of what the design solution must achieve yet they do not express precisely how those parameters are to be evaluated (Cross, 2008). The specification of the attributes is done by means of objective and qualitative data gathered from initial literature study and conclusions from the first stages of the design process. Such specifications are directly related to physical characteristics of the possible solutions, thus, resulting in sets of measurable data against which concepts will be evaluated. The established specifications should be set in ranges within which desirable or acceptable performance lies (Cross, 2008), not stating sets of precise limits allows flexibility in the concept generation as well as an iteration to improve solutions.

Table 3. Performance Atrributes Table

NUMBER	NEED	DEMAND / WISH	DEFINITION
1.1	Desalinate Water	Demand	Produces Water with up to 10^4 ppm salt concentration (Tiwari, 2017)
1.2	Filter Contaminants	Demand	Does not allow filtration of particles and other contaminants to the output water container.
2.2	Low Energy Consumption	Demand	Relies on the use of solar radieton to function.
2.3	Low Maintenance	Demand	Does not require the use of filters or membranes to function. Neither does it require extensive or special and frequent maintenance.
3.1	Usable	Wish	The system has an understandable set-up procedure and water collection system.
4.1	Stable	Demand	The possibility of collapsing or tilting over is slim and does not represent risk of injury to the user during assembly or use.
4.2	Long Life Span	Wish	Does not require component replacements or technical maintenance for wide periods of time,
5	Efficient	Demand	Provides sufficient amounts of acceptable drinking water with the use of solar radiation and no other power source.
6	Congruent with Context	Wish	Takes into consideration the environmental characteristics of the location as well as the economic activities and culture of the users in order to integrate the system into their daily life.
7	Sustainable	Demand	Seeks to better the community's well-being by simultaneously considering the social, economic and environmental aspects of the context.

Table 4 shows the set of attributes before mentioned and the physical characteristic of the product they are related to, the relationship can be traced by the Xs marked on each attribute and their correspondent x marked on each physical characteristic. This analysis serves as a guide to establish the measurable parameters of evaluation and the importance each one has on the performance of the possible solutions. For example, the attribute “Low maintenance” is directly affected by the life span of the components as well as their temperature and corrosion resistance, for these physical characteristics will determine how often the system must be cleaned, or how frequently components will need to be replaced to maintain a high efficient system and proper water output quality suitable for human consumption. The Attributes are ranked in importance based on the relevance they have over the main function of the product, which is the production of consumable water.

Table 4. Attributes and Characteristics

Physical Characteristics												**Importance**
Quality of Output Water											X	3
Type of Assembly between components										X		5
Steps to Assemble									X			1
Heat Transfer Capacity of Materials								X				3
Heat Retantion Capacity of Materials							X					3
Corrosion Resistance						X						3
Temperature Resistance					X							5
Daily Water Output				X								2
Dimensions			X									3
Life span of components		X										3
D or W	**Attribute**											**Ranking**
D	Desalinate Water		X	X			X	X		X	X	6
D	Filter Contaminants									X	X	2
D	Low Energy Consumption						X	X				2
D	Low Maintenance	X			X	X						3
W	Usable								X	X		2
D	Stable		X							X		2
W	Long Life Span	X			X	X						3
D	Efficient		X	X	X		X	X		X	X	7
W	Congruent with Context				X							1
D	Sustainable	X			X	X						3

As table 4 shows, the physical characteristics are also ranked, those of higher importance are the type of assembly between components and the temperature resistance of materials for they are related to most attributes. These characteristics are of great importance, for example, the type of assembly will determine how well vapor is contained in the still and prevent water leaking from the system. The temperature resistance of the selected materials dictated the lifespan of the system as well as the resistance to climatic conditions. The characteristics are ranked in importance given their relationship to the heat retention capacity for they directly dictate the time it will take to evaporate saline water consequently affecting the efficiency of the system. Heat Transfer refers to the capacity of heat retention of a material, therefore this value will be one of the most important parameters of concept generation and evaluation. The physical characteristics were then translated to measurable data, for example, the quality of output water can be measured by the concentration of salt in it, while the low energy consumption is measured by watts consumed. The next step to create a specified requirement for evaluation is the defining of how characteristics will be measured and based on initial research, set ranges of ideal and marginal performance. Table 5, shows the specification table. As Table 5 shows, characteristics related to usability were not included given the difficulties encountered in the user research.

Table 5. Specification Table

NEED	UNITS	MARGINAL VALUE	IDEAL VALUE
Salt Concentration in Output Water	PSU (Practical Salinity Units)	,05%	< ,05%
Energy Consumption	Watts	0	0
Time to Evaporate Water	Hours	24 hrs	< 24 hrs
Amount of Daily Water Production	Litres	2 Lt	> 2 Lt
Area of Solar Collector	m^2	1 m^2	> 1m^2
Temperature Resistance	Degree Celcius	30 C	42 C
Use of locally available materials	Yes or No	Yes	Yes
Gas and water proof assembly	Yes or No	Yes	Yes
Life Span	Years	5 years	10 Years
Heat Transfer Capacity	(W/(m2K))	17	< 5

The distance from the context of use and time given to develop the project do not allow a proper experimentation and testing of usability with real users, thus the project only provides the development of a first proposal focusing on functional aspects.

The most important requirement is the amount of salt in the resulting water, given that this will determine if the produced water is safe for human consumption. The Salt concentration in water is measure by PSU (practical salinity units) and the values for drinkable water are equal or less than .05% PSU, this value can be measure with the use of a refractometer.
The energy consumption is an important aspect of the proposal development, as stated before, electricity is not available in more than 90% of the communities in La Guajira, meaning that the proposal must rely on other sources of power to function such as solar radiation. In order to produce 2 liters of water, which is the minimum recommended for consumption per person in a day, the device must have a minimum of 1 meter square of solar collection area, this can be described as the area directly exposed to sunrays.

The climatic conditions of the region also require the use of materials that can perform and maintain their properties even after long periods of sun exposure or other environmental factors such as rain, wind and humidity. These conditions will also determine how often the components of the system or the entire

05

CONCEPT GENERATION

This chapter synthesizes the information gathered from literature review, user analysis and benchmarking to identify different techniques and elements that influence the efficiency of desalination systems. Using such information, morphological charts were created to develop concepts of possible solutions, followed by brain-steering sessions to design in detail certain components of the product. Selected concepts will then be tested using low fidelity prototypes and evaluated against the specification table.

Morphological Chart

This methodology is adequate in order to generate concepts based on existing technologies that can increase the efficiency of the desalination process. In addition, it allows a wide range of alternative design solutions for a product and widens the search for potential new solutions (Cross, 2008).

A morphological chart, as seen in Figure 18, was generated based on the division of the desalination still in three sub-systems, not including a source of water input as it lies outside the system boundary. Based on conclusions from the classification of desalination stills and benchmarking analysis, possible solutions were introduced for each sub-system. The possible sub-solutions were then used to generate different concepts taking into account the context, user needs, and the specification list.

This methodology is adequate in order to generate concepts based on existing technologies that can increase the efficiency of the desalination process. In addition, it allows the exploration of alternative design concepts for a product and widens the search for potential new solutions (Cross, 2008).

This morphological chart provides a general level of concept generation which allows the improvement of concepts in case those initially created do not satisfy the stated requirements. The authors of this project set up the creation of four initial concepts that combine existing technologies and methods for water desalination with the purpose of increasing the efficiency of the system and considering the context of use. The concepts generated were based on the feasibility of their production and use, for example materials such as glass, ceramics and mirrors were discarded since they are quite fragile and could result in a constant need to be replaced if broken. Other sub solutions such as the use of a fan or cooling pipes were not implemented for they represent a use of electricity or additional chemicals and membranes which can increase the cost of production and maintenance. Therefore, the resulting concepts integrated materials and mechanisms that have been proven to have a high efficiency in desalination, based on existing literature.

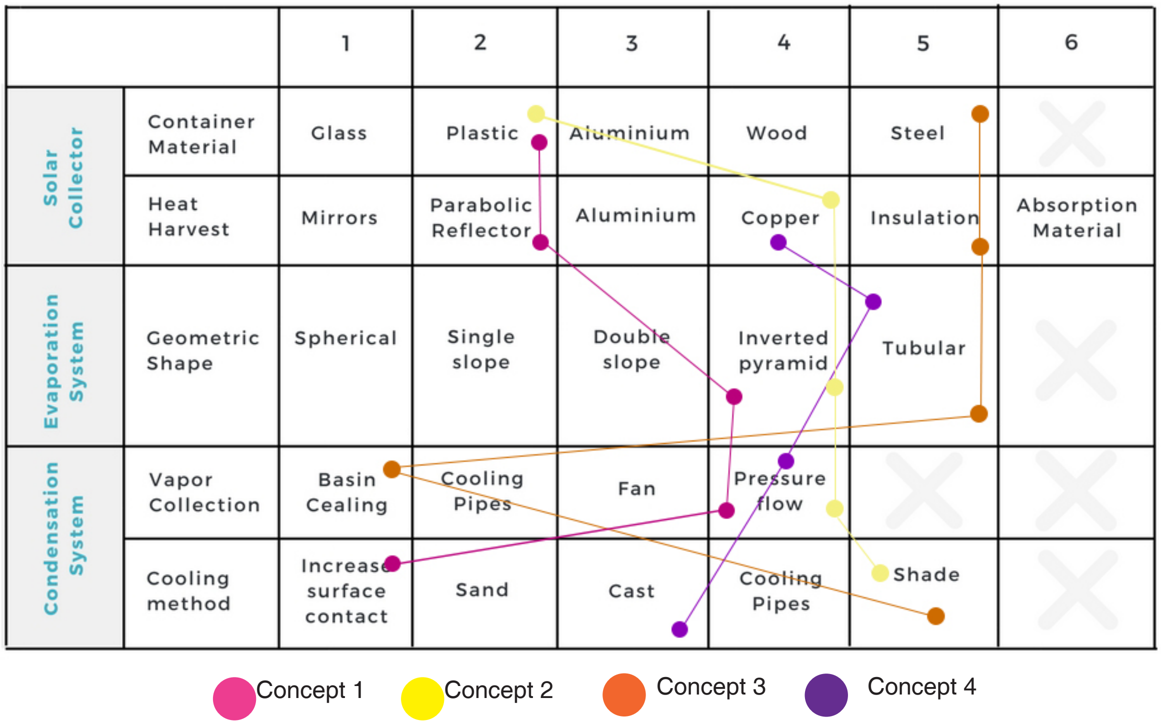


Figure 18. Initial Morphological Chart

Concept one, illustrated in Figure 19, consists of transparent plastic containers with parabolic reflectors that concentrate solar radiation on the saline water and uses an inverted pyramid roof to collect water compensated on the top of the container allowing it to fall through a pipe to a second container.

Concept two resembles the first in geometry, however instead of a parabolic reflector it implements the use of copper to transfer heat to the body of saline water. This concept is shown in Figure 20. On the other hand, concept three, shown in figure 21, implements a tubular copper container, the use of copper as the evaporation basin reduces the need for components or sunray collection systems given the properties of copper. The vapour is then collected via pressure flow in a separate container with cast lining to decrease the temperature of the condensation surface.

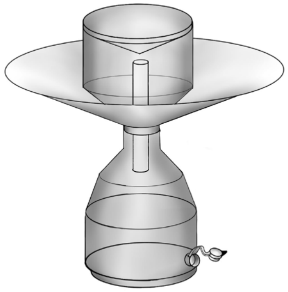


Figure 19. Concept 1

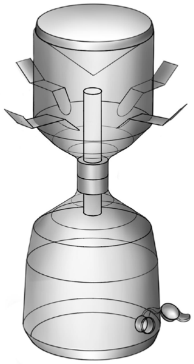


Figure 20. Concept 2

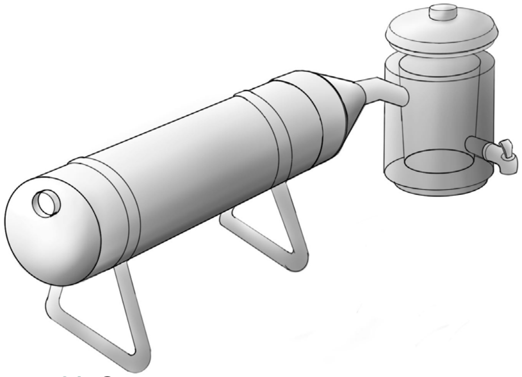


Figure 21. Concept 3

Finally, concept 4 implements a tubular geometry as concept 3, given the proven higher efficiency of such systems. This concept implements an outer steel tube with a metal basin inside, this allows the concentration of heat inside the steel tube, when the water in the inner basin evaporates and the vapour condenses, it is then collected on a separate container. The collection container is covered with a tent to prevent sunrays from heating the collected water and causing its evaporation consequently decreasing the water output. This fourth concept can be seen on Figure 22. Concepts one and two given that they implement different techniques to increase efficiency were selected to be build and tested in order to prove their expected performance.

Rapid prototyping for Functionality Tests

Prototyping is a methodology often used to test ideas in the early stages of a product development phase (Martin and Hanington, 2012). The implementation of this methodology has the purpose of evaluating the selected concepts with-out requiring high fidelity of construction. Low fidelity functioning prototypes were created at a small scale for the first two concepts, shown in Images 23 and 24, in means to obtain an approximate test of the basic function of the concepts. This collection of empirical studies have the purpose of evaluating the combination of materials and geometry for the configuration of a proper solution to the design problem.
The test were conducted in a closed environment at an average temperature of 23 degrees Celsius. The relevant date that was sought to be collected included the evaporation rate in relation to the water

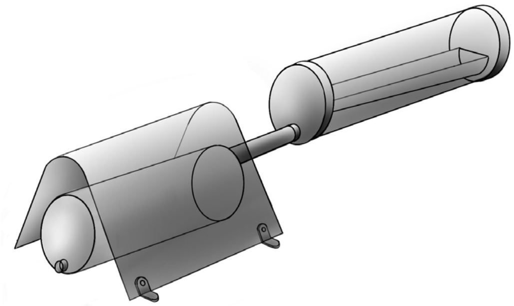


Figure 22. Concept 4

Figure 23. Prototype Concept 1

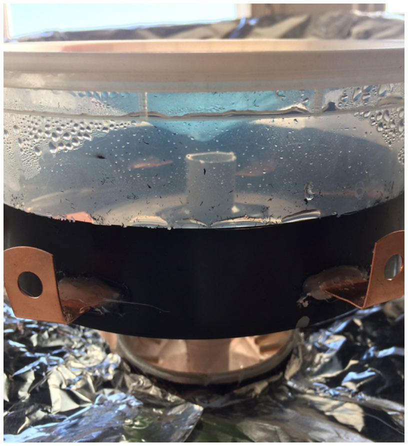


Figure 24. Prototype Concept 2

input and the water output of the system. The time for condensation was considered as the moment in which the first condensed water is collected, the simulations after one hour did not result in a measurable amount of water. They were left for several hours to assure the system did not need more time to condensate. However, after several hours of exposure to light and a stable room temperature, no considerable amounts of water output were produced.

The climatic conditions of the testing location, Skövde Sweden, during the winter months, make it difficult to simulate even an approximate amount of solar radiation and heat to assess the overall performance of the prototypes. Given these complications the data collected was insufficient to properly evaluate the concepts against the specification table. As a result, the concepts will be selected based on previous and existing experimental studies of desalination techniques.

Given that tubular solar stills are able to produce up to 4500ml of desalinated water per day per meter squared of radiation area (Ahsan and Fukuhara, 2010), concepts that included tubular geometry were considered for further development. The majority of tubular stills use glass or plastic containers even though such materials are cheap and free from corrosion, they have low thermal conductivity and present expansion when exposed to heat (Reali and Modiga, 2008) for large periods of time, reducing the efficiency of the system. Concept three uses a copper tube as the saline water basin and sun collector thus reducing the number of components needed to evaporate water. The use of copper tube increases the operating temperature since copper is the second best heat conductor (Escarzaga, 1997), it is capable of conducting heat received form solar radiation rapidly across its surface, consequently reducing the time for water to star evaporating.

It has been mentioned before that one of the main drawbacks of traditional solar stills is their low production rate of potable water. This slow rate production is mainly due to the low operating temperature of the systems and the low pressure of steam (Lindblom, 2011) inside the evaporation chambers. While many efforts in the development of new desalination products are being focused on using cheaper materials and simpler designs (Lof, 1961) not enough have been made in technical functional improvements.

Technical improvements do not necessarily require state of the art technology or specialized components, rather an observation of basic functions that can be improved within the principles of desalination techniques. Currently classic basin stills and other products use glass or plastic covers as heat collector and condensing surface which reduced the efficiency of the system. The division of the still in sub- systems has the purpose to completely separate the evaporation chamber from the condenser. This separation can then be used to create a temperature difference between the two sub-systems increasing the evaporation and condensation rate (Lindblom, 2011).

Concept three provided a viable and innovative general proposal to continue the generation phase given the use of copper and the division of the desalination still in sub-systems gives the opportunity to generate different alternatives to solve each individual function. The following chapters will be oriented to the ideation and testing of detailed concepts.

Brain-steering and Detailed Morphological

Given the high technically of the project, a methodology that could guide the idea generation in a convergent manner was needed. In order to generate ideas parting from a tubular desalination still, brain steering sessions were held. Brain steering relies on the use of analysis to originate new ideas, it states that by asking the right questions or “thinking inside the right box”, ideation process are more likely to succeed in finding proper solutions (Coyne and Coyne, 2011). This thought process is important when working on highly functional projects that require a focus on proven or highly probable functional innovations.

Several ideas were generated for the different systems and their possible solutions maintain a focused on the use of a copper tube as the evaporation chamber. The solutions generated in this session were then introduced in a morphological chart, showed in Figure 25, allowing a systematic generation of design proposals (Cross, 2008).

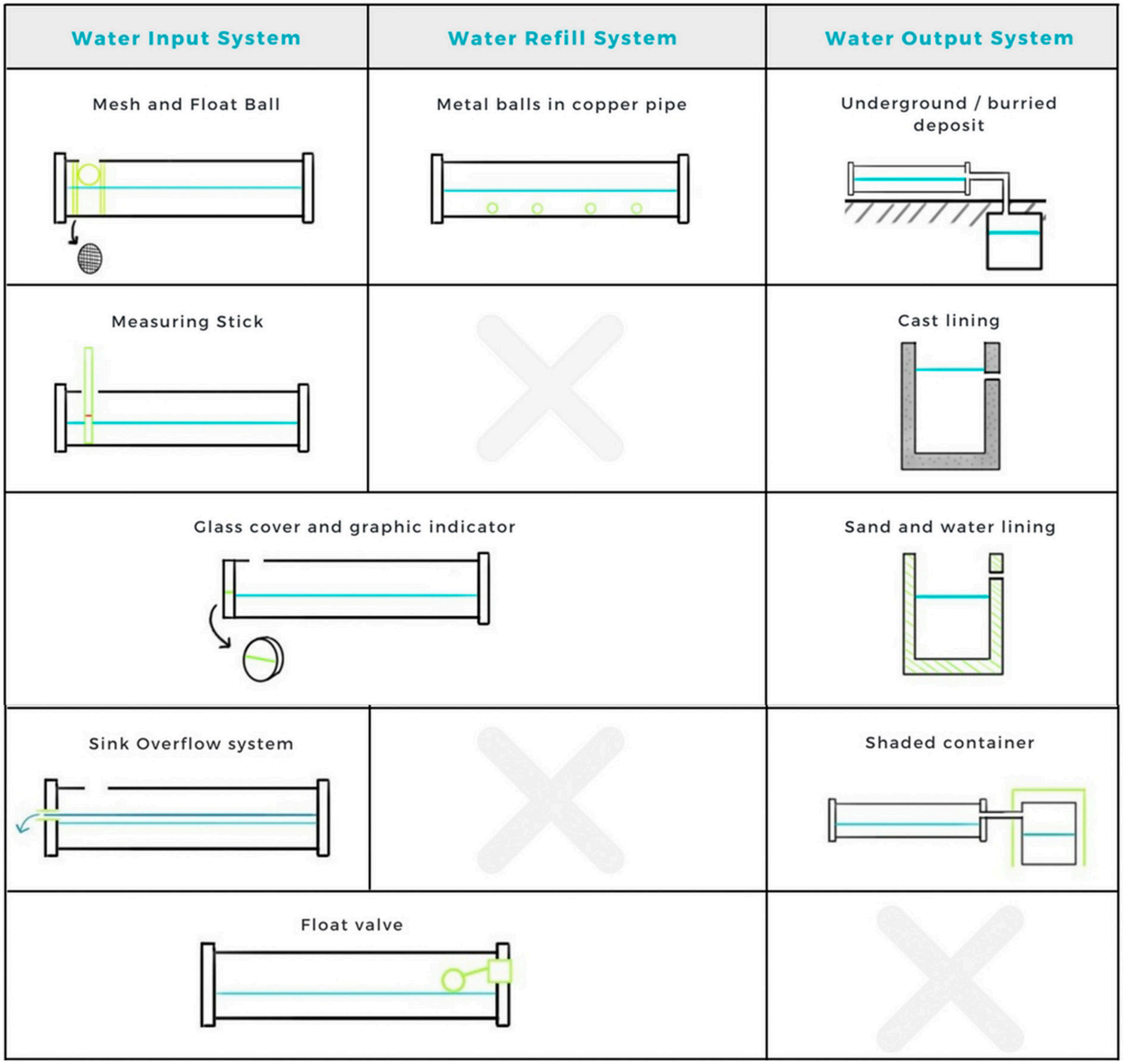


Figure 25. Detailed Morphological chart

The solutions considered for each system were the result of brainstorming sessions using synectics, a creative thinking method focused on creating ideas towards a specific solution by using direct analogies (Cross, 2008). For example, water output systems had to create a difference in temperature, therefore ideas regarding cooling systems or methods were presented in the sessions. Such solutions resembled ecological refrigeration methods used in different middle- eastern communities or simple ideas such as creating a shade to block sun exposure to the container. Pot in Pot is a system of a small container inside a bigger one, the area difference is filled with wet sand, the evaporation of the water causes the inner container to cool as low as 4 degrees Celsius (Strauss, 2016). Several products use the same concept by using different types of clays to insulate sustainable refrigeration systems. Implementing a separation of evaporation chamber and condenser reduces heat loss in addition, the creation of a cooling system in the condenser enhances the evaporation rate (Lindblom, 2011). Additionally the use of sand or clays to reduce temperature in the output water container makes use of locally available materials in La Guajira. Water input ideas were focused on how the evaporation system was to be filled and refilled to the adequate water quantity. Several ideas were manually manipulated by the users and required additional personalized components to function. By implementing a float valve, often used in coffee makers and other filling systems, constant supervision of the user is no longer required. Moreover, it can be set to a specific amount of water input consequently ensuring a proper quantity of water inside the evaporation chamber.

By using tubular stills and separating the condenser from the evaporation chamber, a system to conduct water vapour into the final container is required. Given the principles of vapour behaviour, the pressure created in the copper tube when water evaporates, buoyancy forces will suck the vapour from the copper tube into the condenser (Lindblom, 2011). This evaluation and consideration of possible solutions resulted in the creation of a fifth concept, shown in Figure 26. Such concept, in theory, will result in a competitive efficient system based on literature study and analysis of existing solar desalination techniques and products. However, a functionality test is required to prove such principle, given that the efficiency of this concept relies on the capacity of water vapour to be conducted to the condenser.

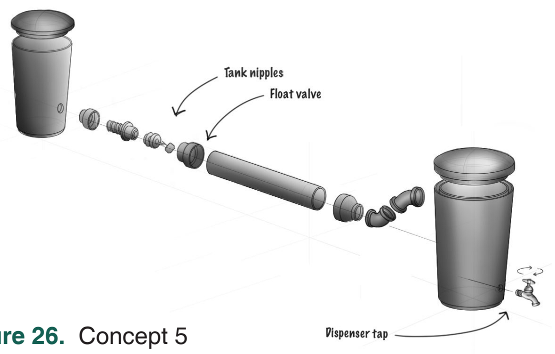


Figure 26. Concept 5

Specific Function Test

The performance and efficiency of Concept 5 relies on the principle that water vapour will travel horizontally from the evaporation chamber to the condenser, this basic function has to be proven true in order to continue developing the selected concept and assure a high possibility of success. For this, a function model was created, these types of prototypes are used to demonstrate the general function or particular functions of a product (Erlhoff and Marshall, 2007) before they go into detailed design or production.
The aim of the test was to prove water vapor under pressure will move vertically through a connector to a lower temperature container, considering the high difficulty of recreating environmental conditions in Sweden this prototype was heated in water vapour to speed the water heating process. Given that this basic functionality test only aims at proving a water vapour behaviour, there is no need to recreate sun exposure or temperature. The prototype consisted of a glass tubular container sealed on both lateral faces, with a plastic tubular connector to a plastic container of greater volume. Previously heated water was introduced in the glass container, which was then sealed and placed on top of water steam (shown in Figure 27 and 28). It is important to stress that although the prototype is in no way accurate to concept 5, it is useful to simulate the horizontal flow of water vapour.

This Functionality test was proved successful, as water vapour travelled from the initial container to the condenser, an explicit table of the test can be found in Appendix C. This phenomenon is based on the increase of pressure inside the evaporation chamber, the pressure created forces the steam to travel to an area of less pressure and or temperature (Shankar, 2014). Given that the condenser is of larger area and has a lower temperature than the evaporation chamber, stem will travel through a connector pipe and then will expand increasing the efficiency of the system.

Figure 27. Functionality Test

Figure 28. Detail of Functionality Prototype

06

EVALUATION OF SELECTED CONCEPTS

The use of a planned design methodology allows the process of construction or production to be separated from the creation process, enabling the proposals to be evaluated before having them produced (Cross, 2008). By comparing the selected concept against the specification table and applying other methods of evaluation, facilitates the identification of possible errors in the design and improvements to be made. This chapter presents the result of the evaluation phase of the selected concept for further development.

Comparison against Specification Table

The evaluation of Concept 5 against the specification table can be seen in Table 6, evaluation criteria for water production, the concentration of salts in the resulting water and the time for water evaporation is marked as Unknown information. This is due to the failed attempts to simulate environmental conditions needed to evaporate water with solar radiation.

The Area of solar Collection is calculated by measuring the area of the copper type exposed to sun rays, while the temperature resistance and Heat Transfer capacity is given by the properties of copper.
Nevertheless, it allows an initial evaluation of the concept, and as shown on the comparison table, concept 5 complies with the majority of the measurable parameters, exceeding only the needed Heat Transfer capacity to retain heat.
Copper is one of the best heat conductors yet it has a high heat transfer capacity (Escarzaga, 1997) meaning when exposed to wind or water flow its temperature reduces. Such results led to the implementation of a heat retention system, focusing on researching traditional and easily available materials.

Table 6. Evaluation of Concept 5

NEED	UNITS	MARGINAL VALUE	IDEAL VALUE	CONCEPT 5
Salt Concentration in Output Water	PSU (Practical Salinity Units)	,05%	< ,05%	Unknown information
Energy Consumption	Watts	0	0	0
Time to Evaporate Water	Hours	24 hrs	< 24 hrs	Unknown precise information
Amount of Daily Water Production	Litres	2 Lt	> 2 Lt	Unknown precise information
Area of Solar Collector	m^2	1 m^2	> 1m^2	3.9 m^2
Temperature Resistance	Degree Celcius	30 C	42 C	46.8 C
Use of locally available materials	Yes or No	Yes	Yes	Yes
Gas and water proof assembly	Yes or No	Yes	Yes	Yes
Life Span	Years	5 years	10 Years	10 Years
Heat Transfer Capacity	(W/(m2K))	17	< 5	17 Copper

Iteration of Concept Development

Due to the result of the first comparison against the specification, the selected concept 5 requires the implementation of a heat retention system that prevents heat loss when exposed to wind, rain or humid environments. Initial research regarding cooling systems, the properties of different kinds of sands showed the possibility of using them as cooling or heating systems.
Sedimentary Sand is often found in deserts and beaches around the Caribbean, this particular type of sand is known to have a low heat transfer capacity as low as .06 W/m2 K (Joshi and Jani, 2005). This low coefficient makes this particular material the ability to retain heat for extended periods of time, for example, one kilogram of sand will take up to five hours to reduce its temperature from 40 °C to 20 °C. In addition to sedimentary sand, certain natural fibers also present high heat retention properties, such as wool and cotton (Energy.gov, 2018). Both fibers are abundant in La Guajira and are used to fabricate woven goods such as bags and hammocks, this practice is one of the main economic activities of the Wayuu (Reverol, 2014), and it not only represents income to their community but also part of their cultural identity.

According to Wayuu mythology, knitting is a way to maintain a connection to the environment and communicate their history (Reverol, 2014). By implementing the use of woven textiles to contain sedimentary sand, not only are the insulation properties being used but also the economic activities of the users are incorporated into the production of the proposal. The use of sedimentary sand and natural fibers to Concept 5 resulted in the creation of Concept 6, shown is Figure 29. The Wayuu have been able to adapt to harsh conditions since the beginning of their culture and have in the same manner adapted their traditions, such as knitting, to their current circumstances. One of the main objects woven by the Wayuu women are used as transportation containers, including tubular bags used to transport water containers as shown in Figure 30.

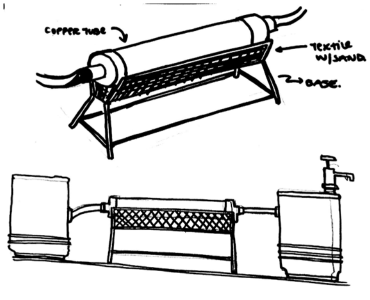


Figure 29. Concept 6

Figure 30. Wayuu woman

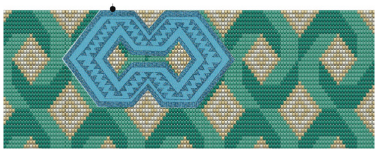


Figure 31. Pa'ralouas Kanna (Serrada, 2009)

Wayuu woven textiles represent daily activities and community values, such representations are made in geometric shapes called Kanaas. By including the use of this cultural element of the Wayuu people in the production and function of the desalination system, a sense of belonging and identity is created regarding the product (Unger and Chandler, 2012). The purpose of a woven textile as an insulation element is not sufficient to create a valid and respectful use of their cultural practices. A synchronization of the element and the Kanaas patters is needed. Although not a specific design is stated, in this case, the use of the Pa'ralouas Kanna (Figure 31) was chosen in the proposed textile stating the meaning "One above the other" as a representation of a piling of efforts or community work (Serrada, 2009). Said concept is also compared to the specification table as shown in Table 7 and complies with the measurable needs meaning it can be further developed to a formal proposal for a sustainable system of water desalination.

Table 7. Specification Table comparison

NEED	UNITS	MARGINAL VALUE	IDEAL VALUE	CONCEPT 5
Salt Concentration in Output Water	PSU (Practical Salinity Units)	,05%	< ,05%	Unknown information
Energy Consumption	Watts	0	0	0
Time to Evaporate Water	Hours	24 hrs	< 24 hrs	Unknown precise information
Amount of Daily Water Production	Litres	2 Lt	> 2 Lt	Unknown precise information
Area of Solar Collector	m^2	1 m^2	> 1m^2	3.9 m^2
Temperature Resistance	Degree Celcius	30 C	42 C	46.8 C
Use of locally available materials	Yes or No	Yes	Yes	Yes
Gas and water proof assembly	Yes or No	Yes	Yes	Yes
Life Span	Years	5 years	10 Years	10 Years
Heat Transfer Capacity	(W/(m2K))	17	< 5	0.06 Sedimentary sand

Risk Analysis

According to Murphy's Law "whatever can go wrong will go wrong" (Kirilenko and Lo, 2013), given this theory, a Risk Analysis was implemented as an evaluation method to identify and improve on the potential failures of the system. Frequently, errors in the performance of a product can be a result of inadequate or improper design (Human-system Integration in the System Development Process, 2007). To further develop an appropriate design solution, the resulting qualitative and quantitative data from this analysis can be used to assess the objects function and possible risks (Wu et al., 2010). Such possible risks are measured by a Risk Priority Number (RPN) which is obtained by multiplying the severity of the system failure, the probability of occurrence and the difficulty of detecting such failure. Figure 32 shows the criteria used to carry out the Risk analysis and the aspects considered in this evaluation method for both the initial assessment and the considerations to reduce the risk probability.

INITIAL RISK PRIORITY NUMBERS (FMEA)

FUNCTION OR PROCESS STEP	FAILURE TYPE	POTENTIAL IMPACT	SEV (SEVERITY)	POTENTIAL CAUSES	OCC (OCURRANCE)	DETECTION MODE	DET (DETECTION)	RPN
A brief description of the process, system, function, step or item to evaluate.	Description of what can go wrong.	Description of the impact that could be caused by that failure.	The participants will rate from 1 to 10 how severe does the failure affect the system.	Description of the causes that could cause the failure.	The participants will rate from 1 to 10 how commonly this is to occur.	Prevention measures to detect or avoid the failure.	The participants will rate from 1 to 10 how easy the failure is detected.	Risk priority number.

CONSIDERATION TO REDUCE RPN (FMEA)

FUNCTION OR PROCESS STEP	RECOMENDED ACTIONS	RESPONSABILITY	TARGET DATE	ACTION TAKEN	SEV (SEVERITY)	OCC (OCURRANCE)	DET (DETECTION)	RPN
A brief description of the process, system, function, step or item to evaluate.	Actions to reduce the occurance of the failure or improve the detection.	Whose responsability is the urged action?	The target date for the urged action.	Actions that have to be taken to recalculate the RPN in order to reduce the risks.	The participants will re-rate from 1-10 how severe does the failure effect the system with the taken actions.	The participants will re-rate from 1-10 how commonly this is likely to occur with the taken actions.	The participants will re-rate from 1 to 10 how easy the failure is detected given the taken actions.	Recalculation of Risk priority number.

Figure 32. Risk Analysis criteria

In order to perform this analysis, brainstorming was made focusing on the possible failure of each part of the system. The scenarios created were accompanied by an analysis of the cause of the problem, an explanation of how the failure could occur and how it affects the main goal of the entire system. The resulting possible scenarios were then analyzed to identify the severity of their impact in relation to the effect they have on acceptable drinking water production, for example a failure that contaminated the clean water produced would be given a higher value in severity than a failure that does not affect the quality of the water produced. The following step consisted in identifying how such failures could be detected and prevented and rated on the likelihood of their occurrence.
The qualitative results were then introduced in the RPN equation, which multiplies Severity by Occurrence by Detection, qualifying each action from one to ten according to its severity (Shown in Table 8).
RPN values are classified into four categories, identified by color. Green represents an acceptable value, yellow a low reasonable risk, orange a reasonable risk and red an intolerable value. RPN values shown in the initial Risk Analysis, conclude that the possible failures lie within an acceptable probability and severity.

However, with the goal of improving the results in all the possible errors, another analysis was developed introducing improvements in the product in order to reduce PRN values (Shown in Table 9).
Within the main improvements of the existing concept to reduce the severity of failures and errors, are the design of stable and leveled base as well as the consideration of simple and sealed joints between components as means to reduce vapor and water leaks. The overall assembly of the system must be simple and understandable to ensure a proper functioning of the system, life expectancy of materials is also a key factor to the performance and low error probability of the system, components selected must be resistant to sun exposure and waterproof. An explicit comparison between the initial Risk analysis and the improvements analysis can be found in Appendix D.
Design evaluation is the most important phase of a design process that focuses on functionality, because not only it allows the identification of possible failures but it also allows an iteration of concept development for improvement. The evaluations presented in this chapter allowed the implementation of local economic activities of the Wayuu in the functional requirements of the product, thus incorporating the identity of the users in the design of the desalination still. In addition to implementing systems that do not rely on electricity or any other source of power to function, the selected concept represents the most viable proposal to be presented as a result of this project.

Table 8. Initial Risk Analysis

RISK ANALYSIS
FMEA
(Failure Mode and Effects Analysis)

Initial Risk Priority Numbers

FUNCTION OR PROCESS STEP	FAILURE TYPE	POTENTIAL IMPACT	SEV	POTENTIAL CAUSES	OCC	DETECTION MODE	DET	RPN
Base level	-Ground level. -Assembly failure. -Poor manufacturing.	-Inappropriate filling of the tube. -System collapse. -Filtration of salt water to clean water.	9	-Ground level	4	-Level. -Fix to the ground. -Adjustable design that does not allow movement.	2	72
Disassemble for cleaning	-Neglect or bad use by the user.	-Break pieces. -Disarrange systems. - Affect systems.	6	-Bad or invisible use codes. -Complex assemblies. - Bad training.	5	-Salted output water. - Puddles under joints.	6	180
Overflow on output container	-People do not empty it. -No desalination on wáter. -No supervisión. - No use.	-Water going back to the tuve. - Water contamination and system failure.	10	-Bomb failure. - User is not emptying it.	1	-Overflow of wáter. -Salted wáter. - Irregular time of filling.	1	10
Floating valve	-Valve stops working or it does not work at all since the beginning.	-Overflow do not allowing evaporation.	9	-Not properly screwed. - Leakage on the lide for deterioration or bad instalation.	3	-Irregular time of filling of the output wáter container. Salted water.	1	27
Sealing between joints	-Not properly sealed.	-Vapor escapes. -Minor drips.	10	-Weak sealing. -Corrosion, cracks, perforations. - Bad quality materials.	3	-No output water. - Leaking.	2	60
Output water container	-Water exposed to the exterior.	-Contaminants in non-drinking water.	10	-Failures on the container material. (corrosión, breaking, holes) -Lide not well colocated. -Inappropriate lide. -Exposed water. - Bad sealing of other components.	8	-No lide or bad colocated. -Solid waste. -Leaking or water escape. - Atypical colour, smell or flavor	1	80
Water extraction	-Failure on the extraction bomb.	-Water is not dispensed. -Overfilling of water. Contamination by contact with salted water. - Unexpected expenses by the user.	10	-Corrosion or deterioration. -Filtrations of solids. - Defective piece.	7	-No output wáter. (the action is difficult)	1	70

Table 9. Risk Analysis with improvement consideration

RISK ANALYSIS
FMEA
(Failure Mode and Effects Analysis)

Considerations to reduce RPN

FUNCTION OR PROCESS STEP	RECOMMENDED ACTIONS	RESPOSABILITY	TARGET DATE	ACTION TAKEN	SEV	OCC	DET	RPN
Base level	- Adjustable base. - Install it or add a level.	-Secondary user: Manufacturing and installation people. -Designers.	When installing the device and check the ground periodically.	-Have an adjustable base with an added level. - Precise manufacturing	9	2	1	18
Disassemble for cleaning	- Visible and clear use codes. - Simplify the sequence of use to assemble and disassemble. - Simple assemblies. - Clear user manual.	-Secondary user: Installation people. -Designers.	When designing the user manual.	-Siemple assemblies. -Clear and descriptive use codes. -Descriptive user manual.	4	3	3	4
Overflow on output container	- Proper maintenance when needed. - Empty the container.	Primary user.	-Give the proper maintenance. - When it is full or by the constant use.	-Constant use. - Maintenance and periodically check ups.	2	1	2	4
Floating valve	- Purchasing a good quality valve. - Install it according to the instructive.	- Designers. - Secondary user: Installation people.	-While deciding the right valve. - While installing.	-Purchasing a good quality valve. -Emphasize that it is properly installed.	4	1	1	4
Sealing between joints	- Proper welding. - Good quality material. - Applying enough strength to avoid leakage.	- Designers. - Users.	-While choosing materials. - While building it and installing.	-Good component election. - Explain detailed and schemed how does it suppose to look like on the instructive.	6	2	2	24
Output water container	- Cover the water appropriately. - Place a water pump or tap. - Seal adequately other components. - Choose the right materials.	- Users. - Material suppliers outside the system boundaries. - Secondary user: Building people. - Designers.	-All along.	-Good sealing lid. - Fitting lid. - Good quality water tap.	5	5	1	25
Water extraction	- Consider the piece. - Using it carefully.	- Designers. - User.	-While using it and take out water. - While designing and choosing pieces.	-Carefull use. -Choosing good quality pieces	3	5	1	15

07

FINAL DESIGN PROPOSAL

This chapter includes the description of the design proposal, communication tools such as CAD renderings and blueprints are included as well as graphic diagrams to explain the functions of the system. In addition, a life cycle Assessment of the proposal is presented to validate the use of each component and assess the systems general environmental impact.

General DescriptionChart

The design proposed is an initial configuration for a desalination system of low production, specifically designed for La Guajira in Colombia. This product is aimed for use in Wayuu Rancherias, as such, it is a simple and understandable system which integrates local materials and crafts for functional purposes. The configuration of the desalination system consists of three different systems that work in unison to desalinate water and are as follow:

Input water system
Evaporation system
Condensation system

The Input Water System integrates a set of components that allow an automatic refilling of the evaporation chamber. Following, the input water goes into the Evaporation system, as the name implies, this system is where saline water evaporates due to the thermal conductivity of the copper tube and insulation system. Finally, the water vapor is then pushed into a condenser where pressure and temperature are lower than the evaporation chamber resulting in the condensation and collection of desalinated water. The final design solution is presented in Figure 33 and an exploited view of the components that integrate it is shown in Figure 34.

The water obtained from this system can be used for human consumption, although for its optimal quality minerals have to be added. Nonetheless, it can also be used to clean clothes and utensils, given that desalinated water can improve the hygiene of cooking processes and products. In addition, using the output water for bathing or wound cleaning can reduce the risk for infections and illness.

Figure 33. Final Design Proposal

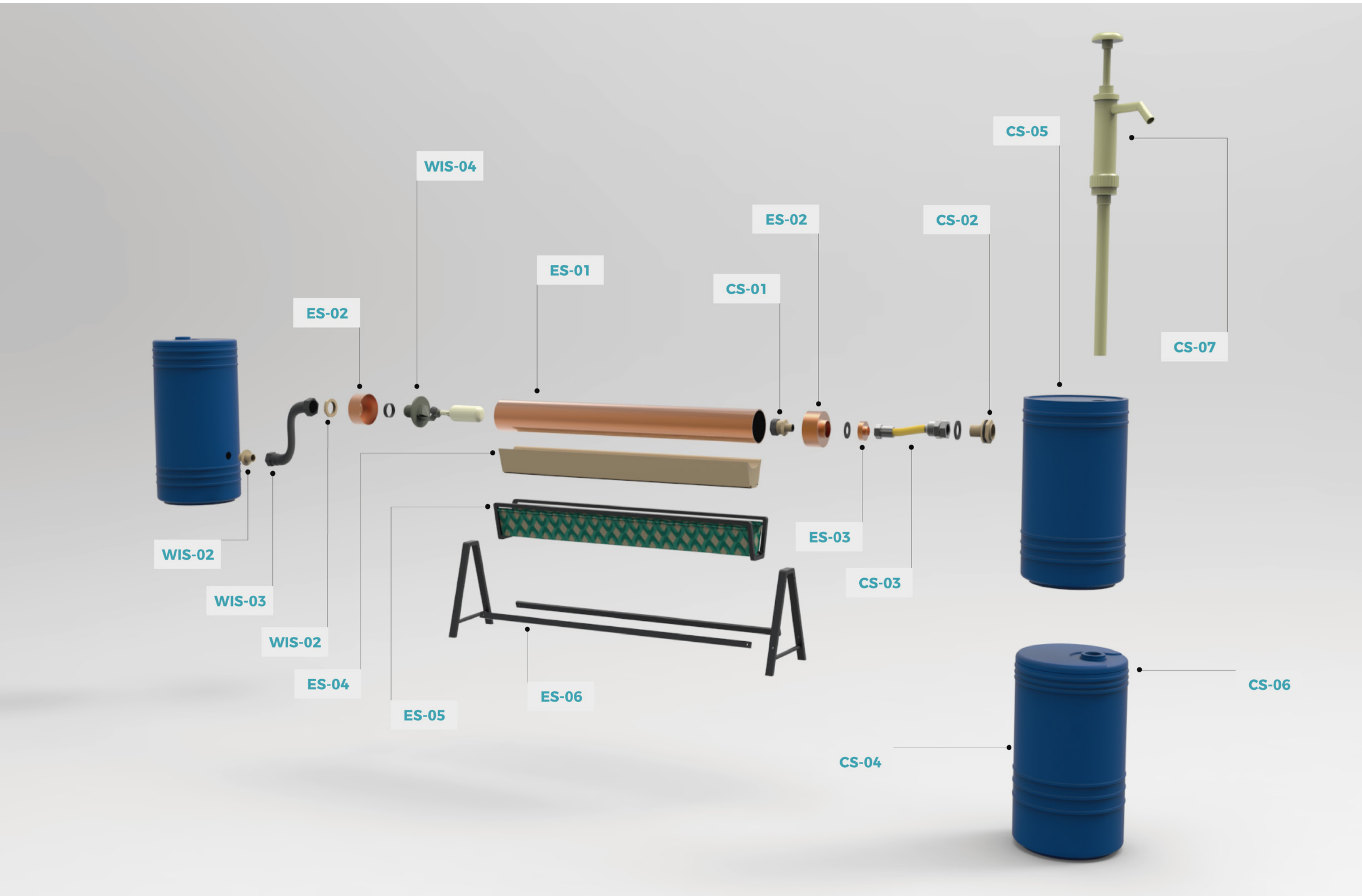


Figure 34. Final Design Proposal, exploited view of components

Technical and Descriptive Product Specification

As stated previously in the report, the proposed system is divided into sub- systems for efficiency purposes. A technical and descriptive specification by sub- system is stated below, in which each component is shown with its specific nomenclature, material, quantity, and production process. This classification will be used to specify and guide the production of the proposal as well as a form of communication of the design. In addition, blueprints for the proposed design can be found in Appendix E.

Water Input System

The Input Water System, illustrated in Figure 35, begins with a hose and tank nipple that can be connected to any water container or source given that the system boundary begins with the desalination basin, in this case, the copper tube. Accordingly, the existing containers have to be perforated to connect the hose that will provide water to the system, in order to connect them, tank nipples and O-rings will be located in all unions to avoid any leakage.

The use of a floating valve will allow water flow up to one-fourth of the tube and prevent overflow while also sealing the entrance of water and water vapor escape. In addition, this component enables an automated refilling of the tube once the saline water is evaporated, preventing any errors from the user's lack of ability or knowledge while filling the tube, it also does not require the user to have a constant supervision of the desalination still. Table 10 describes each component in this system.

Table 10. Water Input System Technical Description

Component	Code	Quantity	Material	Process
Tank Nipple 1 ½"	WIS-02	1	PVC	Plastic injection
Connector hose 1 ½"	WIS-03	1	PVC	Plastic injection
Float Valve	WIS-04	1	ABS and Polyethylene.	Plastic injection

Figure 35. Water Input System, exploited View

Evaporation System

The evaporation system is composed of an evaporation chamber, an insulation system, and a supporting structure, the specified components are shown in table 11. The main functional objective of this system is the evaporation of input saline water and makes use of the high thermal conductivity of copper by implementing a tube as a solar collector and basin. The use of a copper tube is permissible for it is resistant to corrosion and is nontoxic, having applications in food preparation equipment (Escarzaga, 1997).

Solar radiation will be received by the outer face of the copper tube, subsequently transferring heat to the water inside enabling its evaporation. When the contained water is evaporated it increases the pressure inside the sealed tube, as a result, the compressed vapor will be ejected under pressure through a connecting hose into the condenser following the theory of Mechanical Vapor Compression (MVC). The implementation of this evaporation system improves the thermal efficiency of the entire desalination still, for it prevents water vapor to condense in the evaporation chamber.

Furthermore, to prevent heat loss in case of wind or humidity in the environment, the use of sedimentary sand and wool and cotton textile retain heat conducted through the copper tube and increase the evaporation rate inside the tube. This insulation consists of a knitted container which in addition to its thermal properties will retain the sedimentary sand (Figure 36). This type of sand, as stated before has a low heat transfer coefficient, which enables the retention of heat transferred through the copper tube for long periods, reducing energy loss. The quantity of sand used is obtained by calculating the container area of the knitted textile.
The mentioned components are held together by a metal structure, which provides stability and height needed to transfer vapor into the condenser without presenting the risk of water overflowing into the evaporation tube.

Table 11. Evaporation System Technical Description

Component	Code	Quantity	Material	Process
Copper Tube 4”	ES-01	1	Copper	Metal Extrusion
Copper Reducer 4”-2”	ES-02	1	Copper	Metal die cutting
Copper Reducer 2”- ½”	ES-03	1	Copper	Metal die cutting
Crushed Wash Sand	ES-04	5 kg	Sand	-
Knitted Textile	ES-05	1	Wool and Cotton	Hand knitted
Base	ES-06	1	Square profile 1/2x ½ Steel bar 1/2"	Smith work and welding
Nuts and Bolts	ES-07	8	Steel	Commercial Part

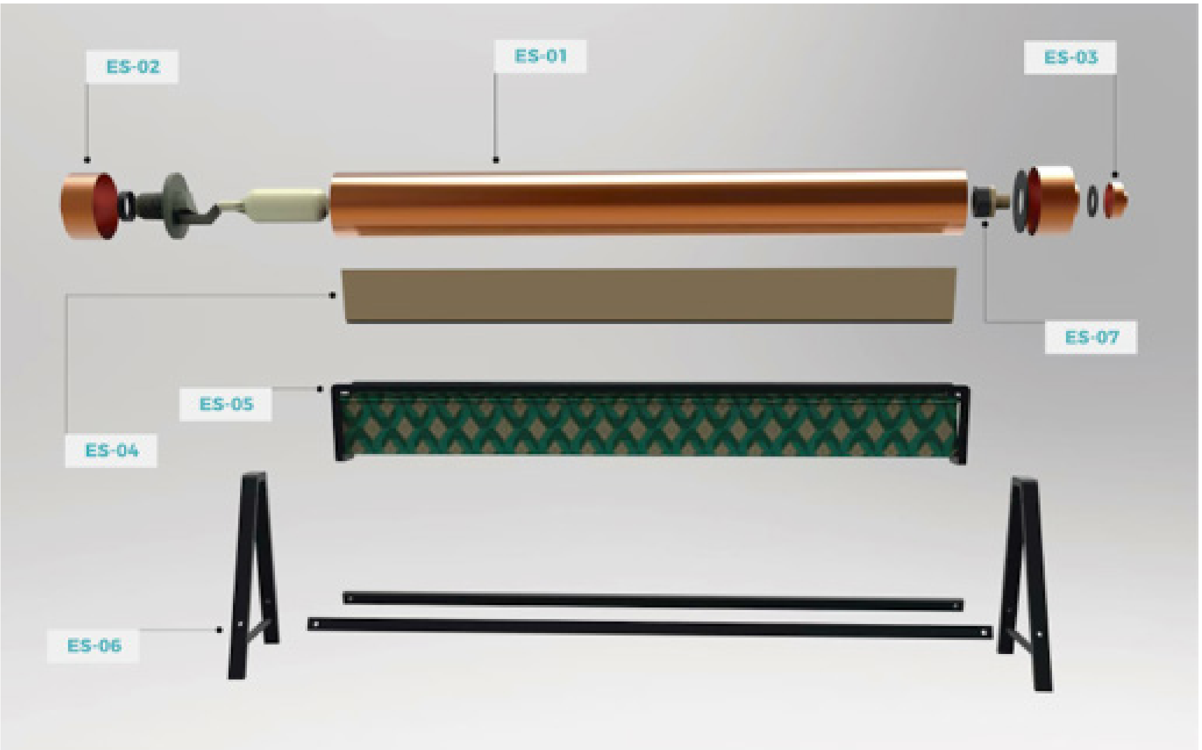


Figure 36. Copper tube, Sand and Textile container

Condensation System

This sub-system comprehends the condensation of water vapor and the collection of the resulting desalinated water. The water vapor produced in the evaporation chamber due to the high pressure created in the copper tube moves through a gas connector plugged into the tubes' end reducer. This movement is based on the effect of compressed vapor and how it pushed through reduced areas into greater containers of lower pressure (Al-Juwayhel et al., 1997). The reduced area, in this case, the hose connector will lead the vapor into a water tank, expanding the area to decrease the pressure and thus enabling the condensation at a faster rate. Additionally, to prevent output water from evaporating due to the exposure of high temperatures and solar radiation, a Pot- in-pot effect is implemented in the collection container.

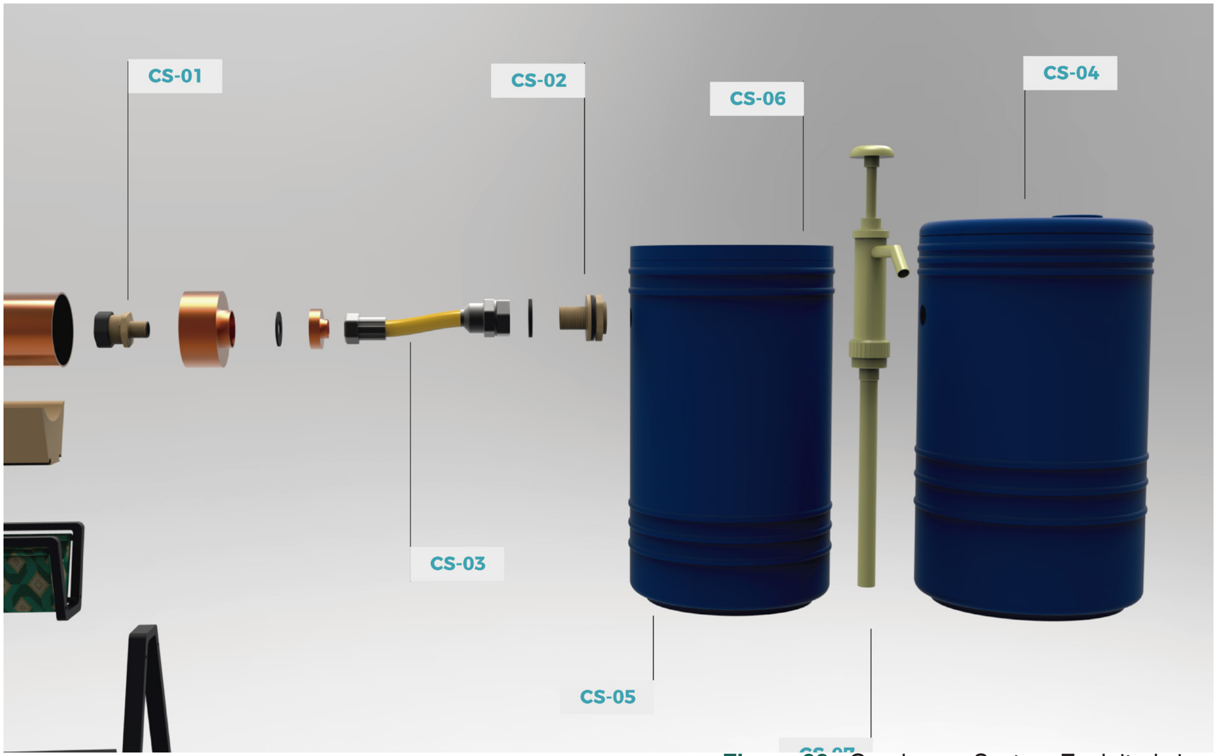


Figure 38. Condenser System Exploited view

This effect works on the evaporative cooling principle and makes use of a small clay container inside a one of bigger size, the annular space between the containers is then filled with clay or humid sand. This set up results in convective and radiative heat transference from the hot and dry environment which evaporates the humidity in the clay or water in the sand, resulting in a cooling effect inside the inner container (Date, 2012). In this case, the effect is created by filling the area of the annular space of two plastic containers with Gypsum powder plaster; such are results in the use of 7 kilograms of cast lining. The cooling effect and the use of water vapor under pressure results in an increase of efficiency in water condensation and collection in the same container yet separated from the evaporation chamber avoiding energy loss. The resulting water is collected in the condensing inner container allowing the user to retrieve it using a water pump (Figure 37), the components of this system are described in Table 12 and shown in Figure 38.

Table 12. Condensation System Technical Description

Component	Code	Quantity	Material	Process
Tank Nipple	CS-01	1	High Density Polyethylene	Plastic injection
Tank Nipple	CS-02	1	PVC	Plastic injection
Gas connector hose	CS-03	1	ABS and Polyethylene.	Plastic injection
Outer Container	CS-04	1	High Density Polyethylene	Rotational molding
Inner Container	CS-05	1	High Density Polyethylene	Rotational molding
Cast Lining	CS-06	7 Kg.	Gypsum powder plaster	Molding
Hand Pump	CS-07	1	Polyethylene	Plastic injection

Figure 37. Desalination system and human scale

Water Output Calculations

Although the proposed system cannot be tested in the environmental conditions it is aimed at performing in, an approximate calculation of the water input and output ratio was made. A great part of the configuration of the design is based on existing commercial components and how well they adapt to required specifications. Correspondingly, the amount of water introduced in the evaporation chamber cannot exceed 2.5cm (Arunkumar, 2013) for efficiency purposes, thus the amount of water introduced in the tube is needed to assure it does not exceed 2.5cm of depth.

The calculation to obtain said volume is as follow:

V=h (r2)4

Where one tube with a diameter of 10 centimeters per one meter of length will contain 1.962 Lt in 2.5 cm of depth. According to literature, the typical basin still produces on average 3 liters of purified water per day per square meter of solar irradiation area (Ahsan et al., 2014). This project does not consist of a typical basin still, however, this calculation can provide an approximation of the expected performance of the system.

In order to calculate the solar irradiation area of the tubular still, the exposed surface area of the copper tube is calculated by:

$$Surface\ Area = 2\pi\ (R)(h)$$

R	Radius of cylinder	5cm
h	Length of tube	1m

The total solar irradiation area of the tubular still is then 1.5 m2. Therefore, if according to literature a still produces 3 liters of purified water per day per square meter of irradiation area, the proposed solar still has an assumed daily production of water of 4.7 liters per day. A full description of the calculations can be found in Appendix F. However, this calculation cannot determine the amount of daily output since function tests cannot be made given the development time and distance from the La Guajira.

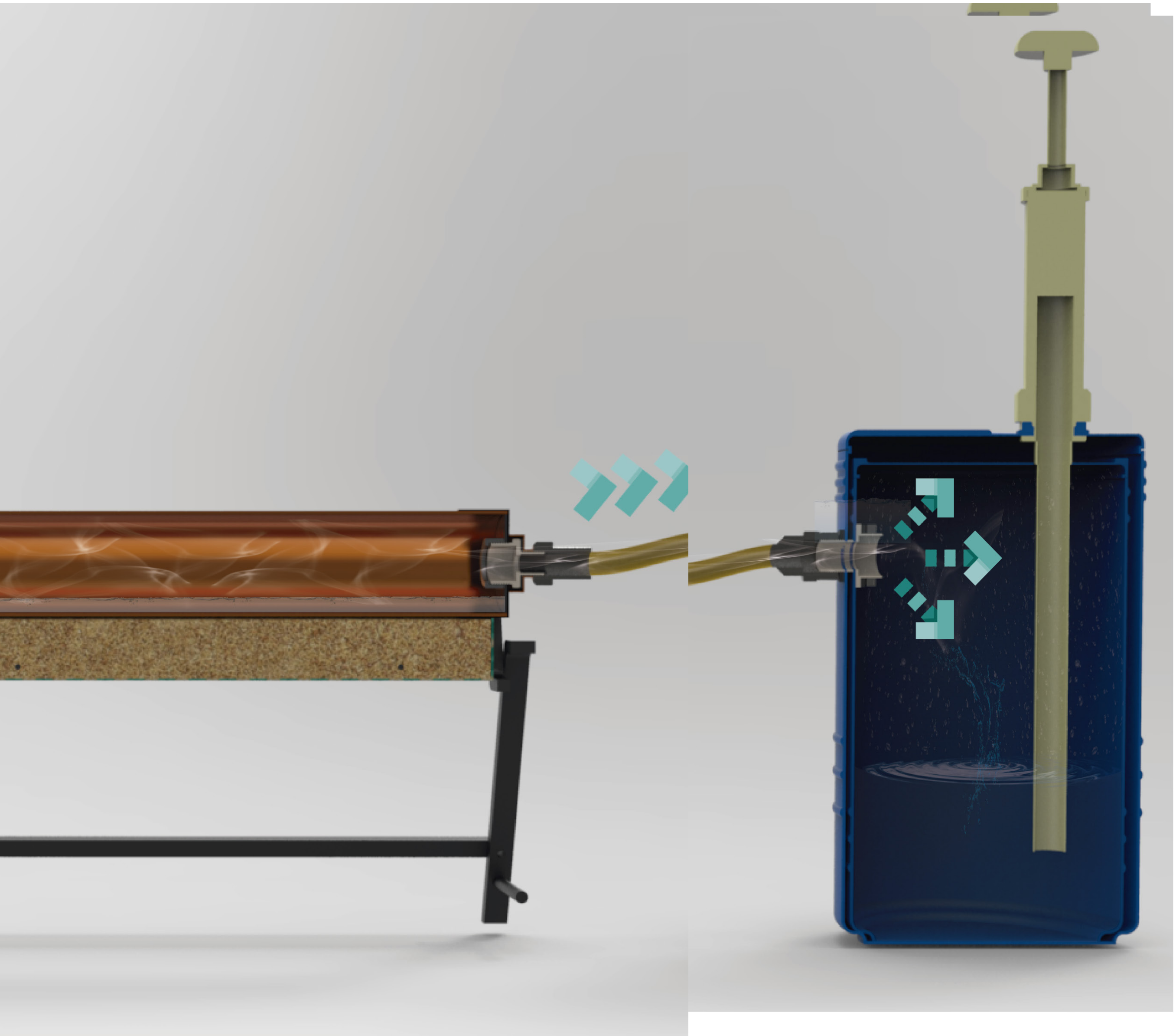
Sequence of Use

The design of this system does not only rely on the functional requirements of the desalination still, it also takes into account the feasibility of materials, production, and distribution in the location of use. Therefore, the product is proposed in a set of ready to assemble components in addition to the difficulty of transportation and lack of proper roads in La Guajira. Proposing a ready to assemble product facilitates distribution and reduces the number of resources needed for transportation. As stated by Ankarstiftelsen, this product is most likely to be donated and then distributed and assembled by volunteers or the final users, the product only requires eight nuts and bolts to be assembled. Once set up, the functional process can begin, and as explained in section 7.2, it consists of introducing water through a hose into in a copper tube. The outer surface of the tube collects sun rays, raising its temperature which is maintained and stored as heat by the sand and textile resulting in the evaporation of the water contained inside. The temperature and tightness of the evaporation system creates water vapour pressure, forcing it to flow through a gas connector hose and into the condenser. Once the vapour is inside de condenser, it expands on the container surfaces which are kept cool via pot-in-pot system, resulting in the condensation and collection of desalinated water. The user can then access the resulting water with the use of a hand pump. A schematic representation of the sequence of use in shown in Figure 39.

As the calculations of water output state, the system is assumed to produce 4 liters of potable water per day, which, although enough for one person, the system aims at being able to provide for one entire family in La Guajira. Given that the Wayuu live in communal lands as an extended family, it is difficult to determine the average number of members in one family. Having said this, the system is required to be modular and able to be set up in a way that allows any needed number of stills to be arranged depending on the number of members in each Rancheria. This arrangement (Shown in Figure 40) considers individual containers for each still, however, individual stills can also be plugged into one larger condenser in a circular arrangement, reducing the number of individual condensers by creating one communal water output container. The length of the tubular copper still can also be increased to produce more water in individual stills, by increasing the length however, the distribution of the desalination systems will increase in price requiring a larger transport or higher number of travels given they will occupy more space in the transport.

On the other hand increasing the length could also potentially represent a reduction of production costs given that the original copper tube will require less numbers of segments to be produced. The possibility of increasing the length can be assessed by conducting user research and evaluating the existing transportation methods in the region to conclude if this variation is a more suitable solution to cater the needs of the Wayuu family lifestyle.

Figure 39. Sequence of use.



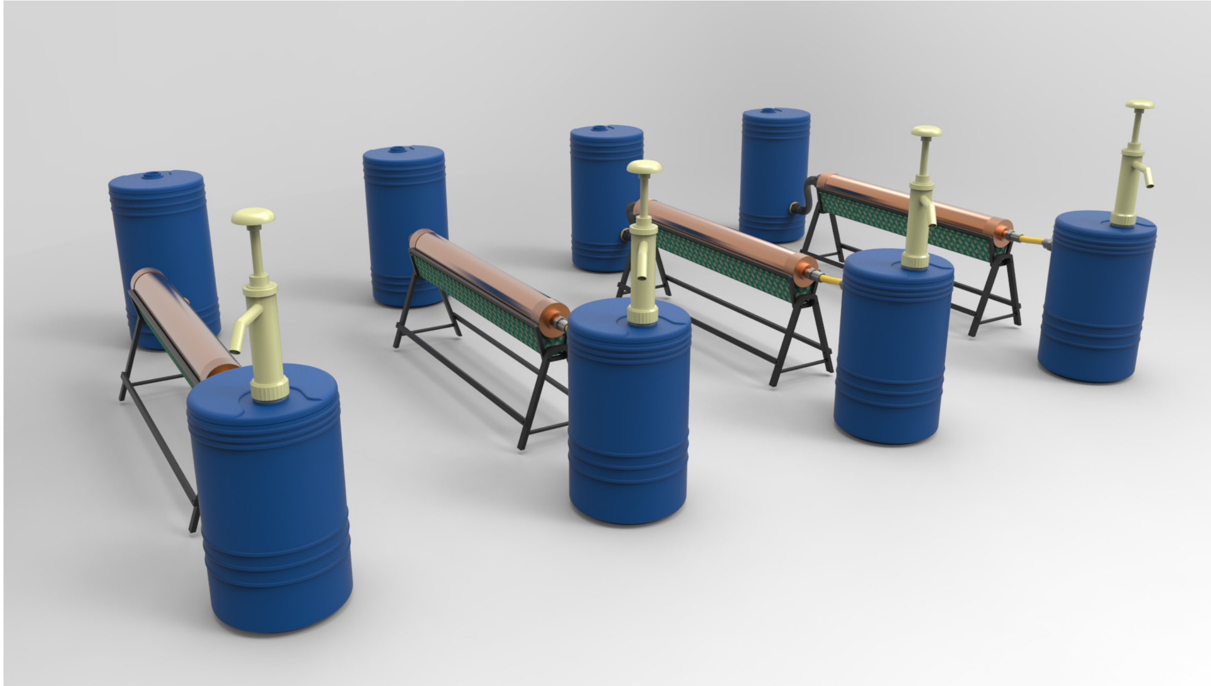


Figure 40. Arrange of desalination systems

Life Cycle Assesment

Consideration of the environmental impact the components, fabrication, and use of a product along the design process should be a requirement of any project involving product development. Evaluating the use of materials and their life can significantly reduce the probability of products ending as landfills, therefore, minimizing the negative impact it has on the environment (Klöpffer, 1997).
Life Cycle Assessment is an evaluation of the inputs and outputs of a product throughout its life cycle considering the environmental impacts and potential use after it is disposed of (ISO, 2006). This evaluation is relevant for it increases the understanding of a product from its production chain to the relationship between its parts (Finnveden et al., 2009). It also enables the visualization of the relationship between components, their materials and their specific function in a product in order to assess their environmental impact.
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This analysis takes into consideration all the phases in the life of a product, such as raw material extraction, manufacturing processes, packaging, distribution, useful life of the product and its disposal. A detailed LCA for each component of the proposed desalination system can be found in Appendix G.
This type of assessment shows only qualitative results (Bovea & Gallardo, 2006), in order to validate the Life Cycle Assessment CES Edu Pack, an educational program for sustainable material selection, was implemented to obtain quantitative data regarding environmental impact in terms of energy use and CO_2 footprint. Figure 41 shows the overall assessment of the product obtained from CES Edu Pack.
The environmental impact of a product not only depends on the selected materials and their individual impact, rather it contemplates the entirety of the product and the potential use of each component after its functional life. In this case, the CES Edu Pack evaluation shows how some of the selected materials have a major impact on the environment such as epoxy adhesives and landfilled gypsum powder. However, their selection cannot be at this point of the project substituted for they represent key elements in the goal of the performance of the system.
Furthermore, the estimated product's life according to the stated life span of the components in their specification provided by the distributors is in average 10 years, thus not requiring replacement of components if they are not broken or damaged by the user. The long life span and the use of solar radiation as the only energy source, represent no emission during its useful life. This sustainable proposal of a desalination system considers also the use of locally available materials and practices thus reducing the transportation and packaging required for production.

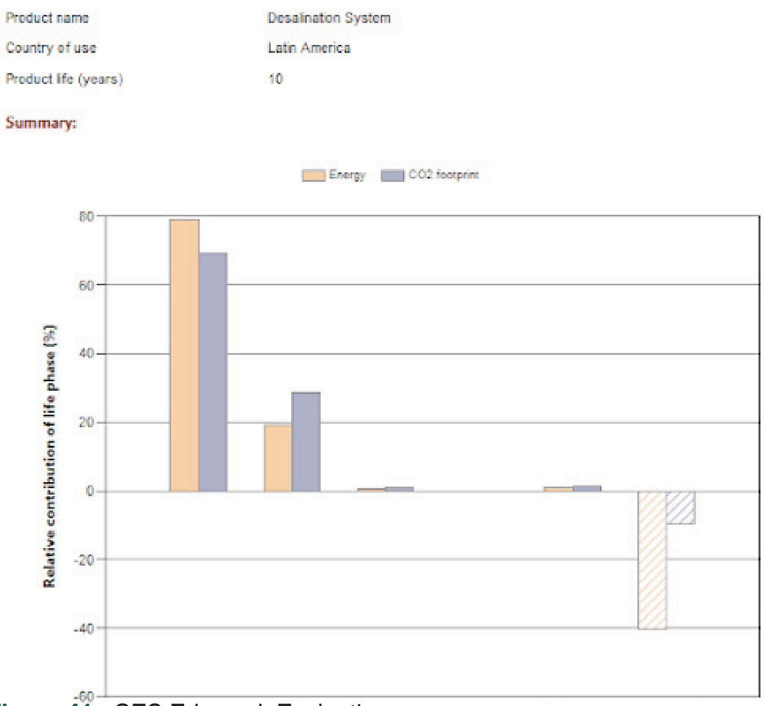

Figure 41. CES Edu pack Evaluation

Conclusion and Further Improvements

The design of any product aimed to be used in developing communities has to be simple to understand and integrate traditional archetypes as well as local materials and processes allowing the understanding of the product and how it is used by the community. The resulting design is an initial function concept that aims to create a much-needed solution for potable water scarcity in La Guajira, which in addition to providing water for human consumption is also adequate for the location and culture of the users.

The use of locally available materials and the use of only solar radiation as the source of power creates an independence of electricity, such characteristics of the product also reduce the cost per unit. Introducing traditional practices in the production of the desalination system, such as the woven textile, results in a sense of identity and belonging with the users, reducing, in consequence, the probability of refusal or misuse of the product. Even though the requirements related to the user and context are considered fulfilled by the design proposal, they are not reliable for they have not be tested by users. The same applies to the functional specifications, the resulting proposal has yet to be built and tested under real or similar environmental conditions as La Guajira to assess the efficiency and determine if it complies with the design specifications.

Furthermore, the resulting proposal needs to be improved by a series of iterations in the design process in order to fully comply with the user requirements and context and be considered a proper solution. The presented design is only a first approach to the solution required and is still in an evaluation phase. For

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DISCUSSION

The Development of this project in cooperation with Ankarstiftelsen provided an initial approach to the role of design in social development areas which presented certain limitations in the elaboration of a solution given the vulnerability of the target user. An important aspect of social projects, more than in any other product development, is active user participation and evaluation given that the user acceptance and understanding is key to the success of the product.

For example, in this case, the functional problem can be stated as the need for a water desalination system, yet the conditions under which the product will be used requires the inclusion of a water collection system that integrates the available resources and culture of the Wayuu. Ankarstiftelsen is an organization that works through donations and volunteering, in other words, people from any professional background can participate in the development and realization of their many projects. This structure of volunteering is not applicable to the project given that this particular product-based solution requires the participation of users in the production, set-up, and maintenance of the desalination system in order to assure an understanding and acceptance by the community.

The user participation in the production and assembly requires the construction sequence to be simplified to be produced by the Wayuu. The resulting proposal as a result of this implements adhesive welding in copper parts instead of welding. This last method although it can be made gas proof requires experience in practice and specific tools. In addition, the proposal is aimed at being produced with commercially existent components and does not require unique parts to be produced aside from the woven textile and base, which can be built at any blacksmith workshop. Still, direct user research is needed to conclude on the most proper assembly method and set up to be used by the Wayuu and the available resources in La Guajira.

Even though this product base solution is not aimed at being a high production system, the production requirements and viability have to be assessed for a low/medium production, thus not requiring industrialize processes or detailed components. Moreover, the cost of production of the proposal is estimated by prices found online in retail hardware stores available in Colombia, this estimation does not consider possible lower prices that can be found in local hardware stores (Cost estimate found in Appendix H).

In addition proper user research and input throughout the design process is needed to create an adequate product. During the user research it was initially planned to carry out user diaries, but given the difference and difficulty of communication with the communities in La Guajira, the information had to be obtained from existing documentaries, interviews, reports and statistical data from the Colombian government.

Said difficulty to establish communication with users, resulted in only one interview which in addition to the documentaries and statistical data, is not a reliable source of user research and conclusions. In order to fully assess the culture and conditions of the users, proper observation methodologies need to be carried out.

Moreover, the development of a proper and successful design requires technical knowledge in water processes, desalination principles, and technology, for this reason, the participation of multidisciplinary members in the project would be beneficial. With this, the level specificity of the specification table would have been increased and possibly led to the use of more technological materials and process to obtain a more efficient and innovative desalination system. The current specifications are in a general level aimed at guiding the development of an initial proposal for a solution which once tested in the correct environmental conditions needs to be evaluated regarding the quality of water produced from it and would have to be constantly checked to ensure clean and potable water with the use of Refractometers. The generation phase of this design process was defined by the initial literature review and benchmarking analysis to conclude on existing and tested desalination methods that could be implemented in the solution, given that proper functionality test could not be fully reliable. This limitation did not allow a wide exploration of all the possible solutions that could be used in the development of a desalination system for La Guajira.

Furthermore, the evaluation phase is a compilation of assumptions and calculations based on existing tests and only provide an estimation of the performance the resulting system could have once built and tested. During the concept evaluation, certain prototype tests were made but did not provide enough measurable data to assess the performance of the systems tested due to the complexity of simulation the necessary environmental conditions need for solar desalination during the Swedish winter months. As a last resource to prove the primary function of the selected final concept, a functionality test was performed, however it was not a proper representation of the materials, assembly or environmental conditions of the real product. However it only aimed to test the water vapor behavior under pressure and given the time left to develop the project, only one test was performed.

Nevertheless, the goal for this project is to provide an initial proposal for a sustainable desalination system with the given time for development and resources available, regardless of the limitations the resulting proposal represent one step towards the creation of a proper and satisfactory system for water desalination that can be implemented in communities across La Guajira.

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APPENDICES

Appendix A - Semi Structured Interview

Interviewer: Lucero Gutierrez Hernandez
Note Taker: Wenny Ramirez Garcia
Interviewee: Rita Uriana
Setting: Interview conducted via telephone in the Library of the University of Skövde to La Guajira, Colombia.
Affiliation with interviewee: Rita Uriana has been an active member with Ankarstiftelsen to better the living conditions of communities in La Guajira.

Interview

Which areas in La Guajira have you been more involved with and what are their living conditions in your perspective?
I have been actively involved in the education programs and sustainable development in the southern regions of La Guajira. Most of the communities across La Guajira live in vulnerable and extreme poverty situation.

Approximately how many people live in each Rancheria?
There is no precise number of habitants per Rancheria, Wayuu people are organized in clans and have from 300 to 400 families per clans. Each Family lives in their Rancheria and are not determined by the typical nuclear family, rather they are extensive.

A typical family is composed of how many members?
In reality families are extensive and generally composed of 10 to 12 nuclear families.

What are the typical or most common economic activities of the Wayuu?
They are mostly dedicated to fishing and hunting, although recently many are employed in desalination plants which are dedicated to the extraction of salts for commercial purposes. However they also rely on the commercialization of their arts and crafts.

How is the educational system organized in La Guajira?
A couple of years ago it was inexistent, many of the older generations have no education whatsoever, and they only speak Wayuuniaki, their native tongue. Recently we have made progress in recent years with education by building schools in which the younger generations can learn Spanish and finish elementary school, still only about 10% of kids finish their primary school.

Is it common for people to interact with electronic devices or is there a rejection to new technology?
Some communities, mostly in the south are more likely to be near urban areas and thus have access to electronic devices or home appliances, but the rest of the population does not, at most some have cellphones but they are not useful since reception in La Guajira is extremely low.

We know there is a limited access to potable water in La Guajira, we would like to know what the main concerns people have when obtaining water are.
There are some big desalination plants that use reverse osmosis, mostly in the southern peninsulas, these plants supply potable water to nearby communities by producing around 10 thousand liters daily. Although the production varies depending on the climatic conditions. Communities that are relatively near these plants have to travel to them in order to collect 80 liters daily, sometimes requiring two or three travels per day.

Where is water obtained from in communities that are not near big desalination plants?
It really depends on the community, some of them have dug into the soil in order to reach underground deposits or have wells (Figure 42) some have ponds or juagueys (Figure 43) which are some sort of ponds but the water on any of these sources is salted or brackish. Since these communities have to travel farther to a potable water source they sometimes have to drink or use salted water to prepare food, sometimes they boil it but it takes a lot of time and a lot of water is wasted. Sometimes certain organizations have managed to provide water containers and in some occasions deliver potable water to some communities via water pipes (Figure 44).


Figure 42. Water Well. Photo obtained from Rita Uriana.


Figure 43. Juaguey. Photo obtained from Rita Uriana


Figure 44. Water supply via Pipes. Photo obtained from Rita

Are there any current water projects working in the area?
There have many projects, including those that resulted in the construction of desalination plants that use reverse osmosis, but they only supply water to a few communities. Some projects do not consider that the Wayuu do not speak Spanish or even write their own language and they end up not being used.

Why do you think they result in being not used?
Because they are not focused on vulnerable communities that have very limited resources, projects that have been successful work directly with the communities in order to evaluate the real conditions and implement systems that work with the people.
Thank you for your time and for the information.
You're Welcome and thank you for taking interest in the project.

Appendix B - Empirical Studies

What needs to be tested?
Desalination system in a controlled Environment and the time it takes for a certain amount of water to be desalinated in a room temperature of around 22 to 30 degrees Celsius.

Why are we testing it?
To decide which combination of materials or systems of desalination provide a higher chance of success in the project, meaning the most production of water in the less amount of time and with the less use of energy.

How will it be tested?
Characteristics:
Average temperature of: 22 and 30 degrees Celsius in a controlled environment, the temperature is reached with the help of a heater in a closed room.
Measure:

-Constant room temperature
-Water temperature
-Time for water to start evaporating
-Time for first condense water to be collected
-Total time for water evaporation
-Amount of water introduced
-Amount of water obtained
-Ration of water input and output

Variations

-Condensing surface: plastic and glass.

-Reflective or heat absorbent material

-Use of wicking

Simulation 1

#1 - Represents a combination of a metal container with glass condensation surface #2 - Represents a combination of a metal container with a metal condensation surface
#3 - Represents a combination of Plastic Container and condensation surface with the use of wicking cotton textile inside the still.
Table 13 shows the results of this simulation.

The time for condensation was considered as the moment in which the first condensed water is collected, the three simulations after one hour did not result in a measurable amount of water. They were left for several hours to assure the system did not need more time and the results were the same, no measurable amount of water was collected.

Table 13. Simulation 1 results

Number of test	Room Temperature	Water input quantity	Time for evaporation to happen	Time for condensation to start	Amount of Water collected after one hour
#1	23 °C	2 liters	15 minutes	16 minutes	-
#2	23 °C	1 liter	10 minutes	18 minutes	-
#3	23 °C	1 liter	8 minutes	20 minutes	-

Appendix C - Specific Function Test

Purpose of the test: Prove that water vapor will flow horizontally from a container of high temperature through a connecting pipe into a container of lower temperature given the high pressure created on the initial container.
How will it be testes: A sealed glass container with water inside will be heated via water vapor in order to enable evaporation inside the container, the vapor will then travel through a connecting pipe on one end of the glass tube into a plastic container maintained at a lower temperature than the glass container.

During the test, the water input, time for evaporation to happen, time for vapor to move through the pipe and condense into the second container will be measured. The results of the test are as shown in Table 14. Although this principle is supported by literature and thermodynamic theories, it was necessary to create a simulation to prove this basic function in order to apply it into the development of the product and assure a probability of success.

Table 14. Simulation 2 Results

Number of test	Water input quantity	Time for evaporation to happen	Time for vapor to form in the pipe	Time for water to travel into the second container
#1	25 ml	30 seconds	5 minutes	7 minutes

Appendix D - Risk Analysis

RPN: Severity x Probability x Detectability

FMEA: International Policy Definition

1- 100	Broadly Acceptable Region.
101- 150	As Low as Reasonable Practicable Region PART I
151- 250	As Low as Reasonable Practicable Region PART II
251- 1000	Intolerable Region

1. Base Level

RPN: 72 ⟶ **RPN: 18**

- Design an adjustable base.
- Install a level in the base's design.
- Schemed manufacturing Intructions.

2. Disassemble for cleaning

RPN: 180 ⟶ **RPN: 36**

- Simplified assemblies and error proof throughout the system.
- Clear and descriptive use codes throughout the system.
- Design a schemed and graphic manual.
- Visual codes.

3. Overflow on output container

RPN: 10 ⟶ **RPN: 4**

- Design a manual for cleaning.
- Instructive with indications for periodical check-ups.
- In extreme cases adding another container.

4. Floating Valve

RPN: 27 ⟶ **RPN: 4**

- Investigate reviews and types of valves.
- Emphasize an adequate installation in the instructions.

5. Sealing between joints

RPN: 60 ⟶ **RPN: 24**

- Survey and research of good quality materials to seal properly.
- Analysis between adhesives and copper welding.
- Explain on the instructive how the tank nipples should look like.

6. Output water container.

RPN: 80 ⟶ **RPN: 25**

- Sealing lid.
- Fitting lid.
- Efficient and good quality water tap or pump.
- Emphasize a total sealing.
- Emphasize to the company the importance of good quality external materials.

7. Water extraction.

RPN: 70 ⟶ **RPN: 15**

- Visual codes and a careful use.
- Choice and research of excellent quality parts.

Appendix E - Water Calculations

Given that the copper tube is 4" in diameter and following:

$$V = h(\pi r^2)$$

The resulting volume for the tube is:

$$V = 100(3.14(5^2))$$

Where V= 78.50 m^3, the allowed maximum depth for a high efficient desalination still is 2.5 cm, by dividing the tube in four equal parts it results in 2.5cm parts. Then the Volume for one fourth section of the tube is then:

$$\frac{7.850}{4} = 1.96 \; liters$$

Amount of Water Output

The daily water output is unable to be calculated given the difficulty to simulate similar environmental conditions, however according to other literature, the typical basin still produces on average 3 liters of purified water per day per square meter of solar irradiation area (Ahsan et al., 2014). This project does not consist of a typical basin still, however this calculation can provide an approximation of what is expected of the system.

The area of the copper tube exposed to sun light, this area was calculated by:

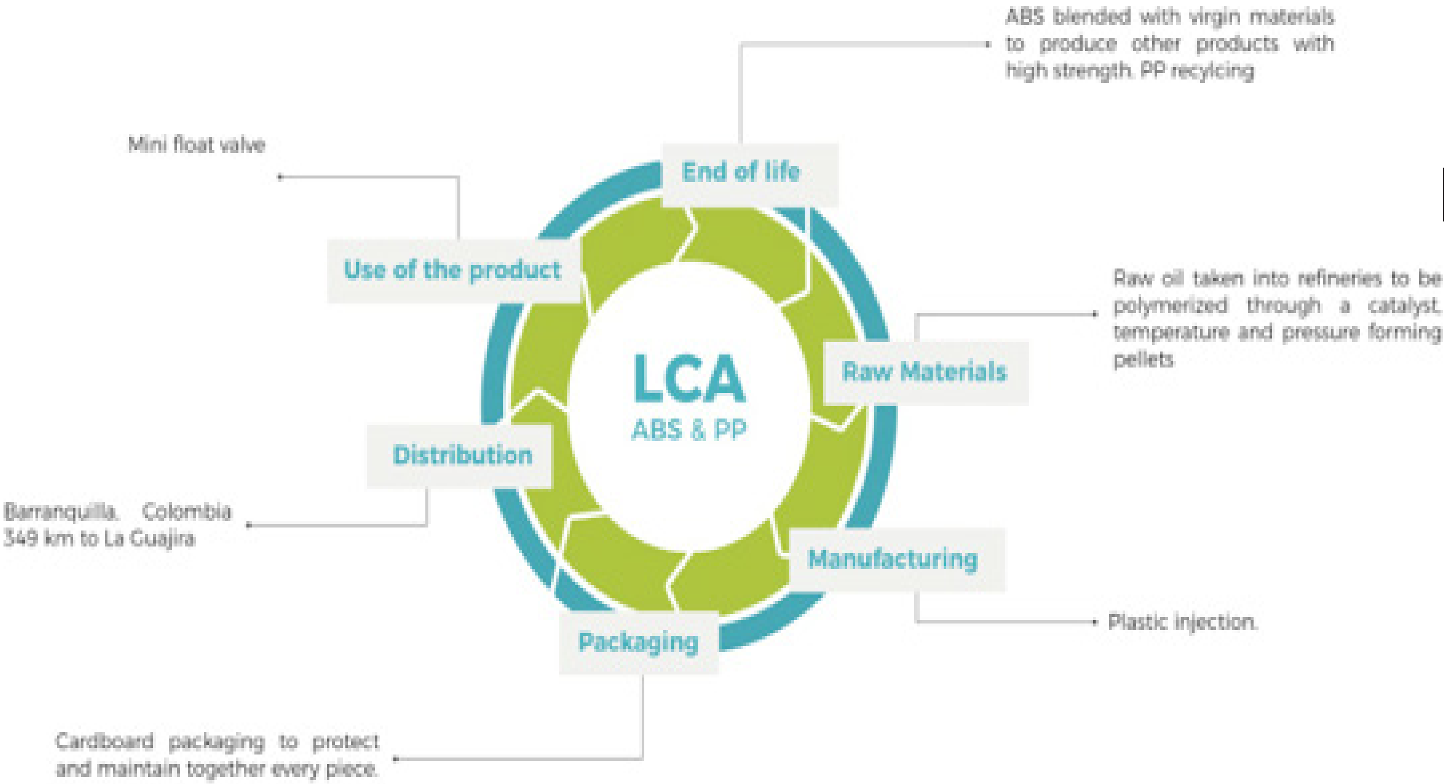
$$Surface\ Area = 2\pi\ (R)(h)$$

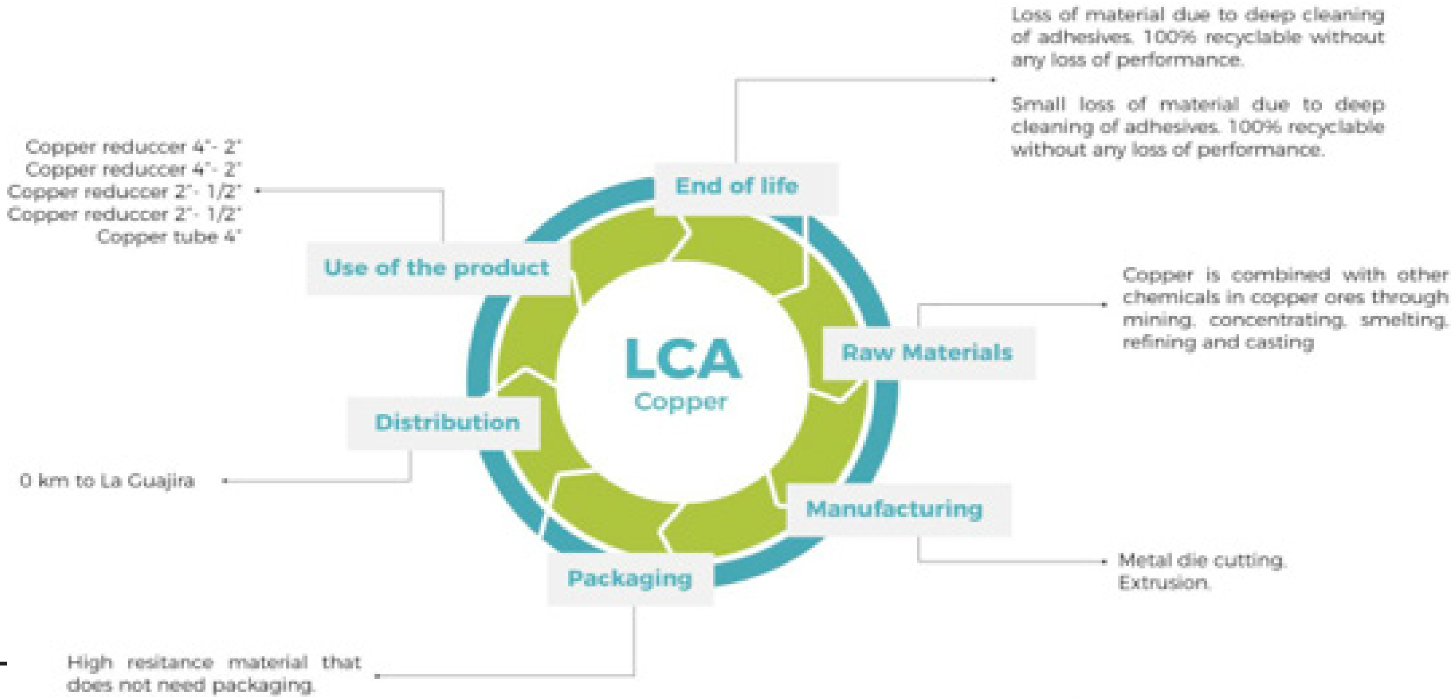
R	Radius of cylinder	5cm
h	Length of tube	1m

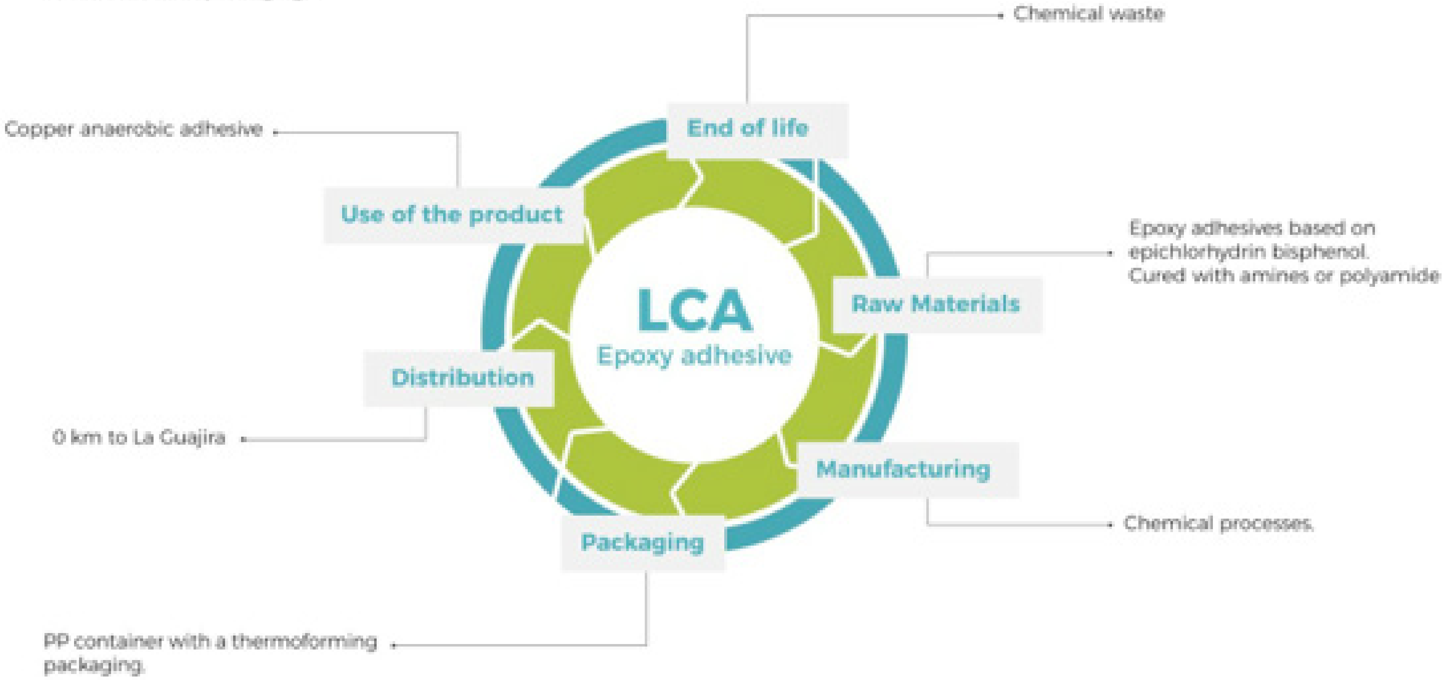
The total solar irradiation area of the tubular still is 3.141 m^2 but when supported by the textile only one half is exposed resulting in a 1.5705m^2. Therefore, the resulting water produced daily would be 4.7115 liters of water. This data cannot be proven correct and relies on existing studies and assumptions based on a typical basin still.

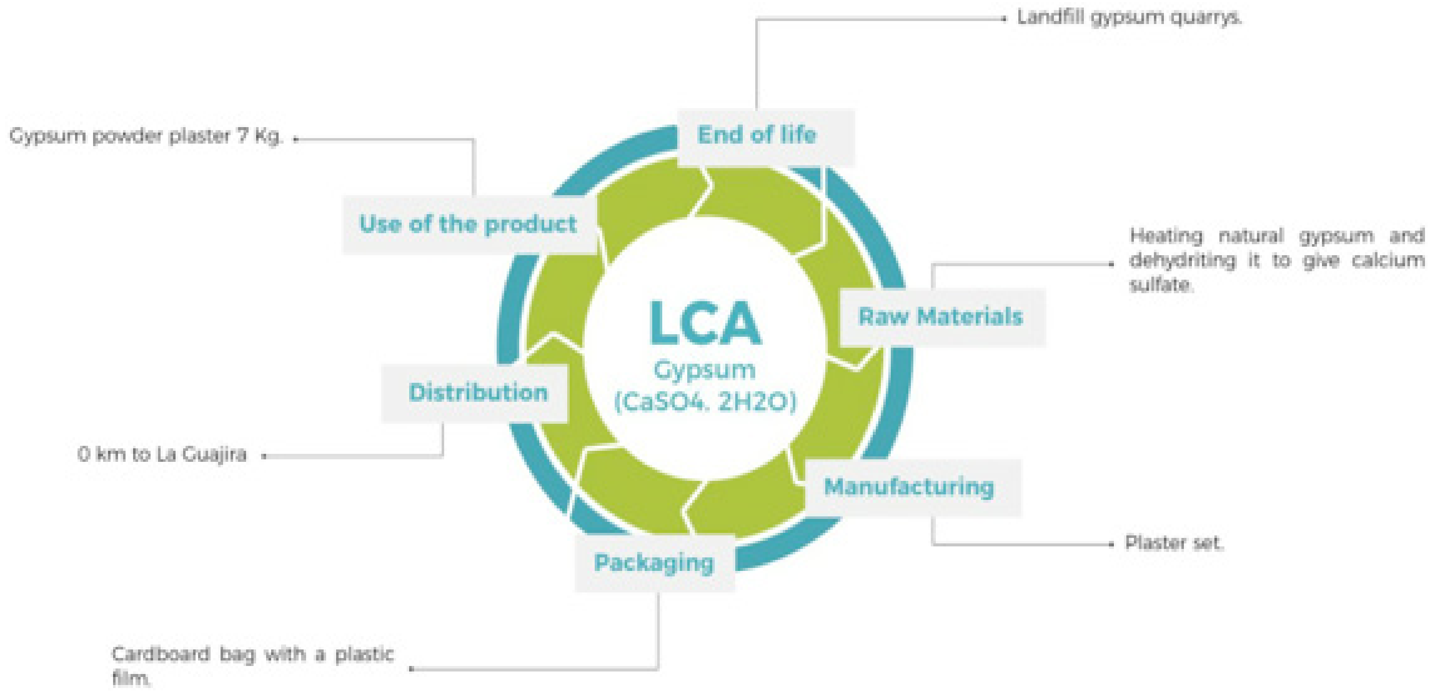
Appendix F - Life Cycle Assesment

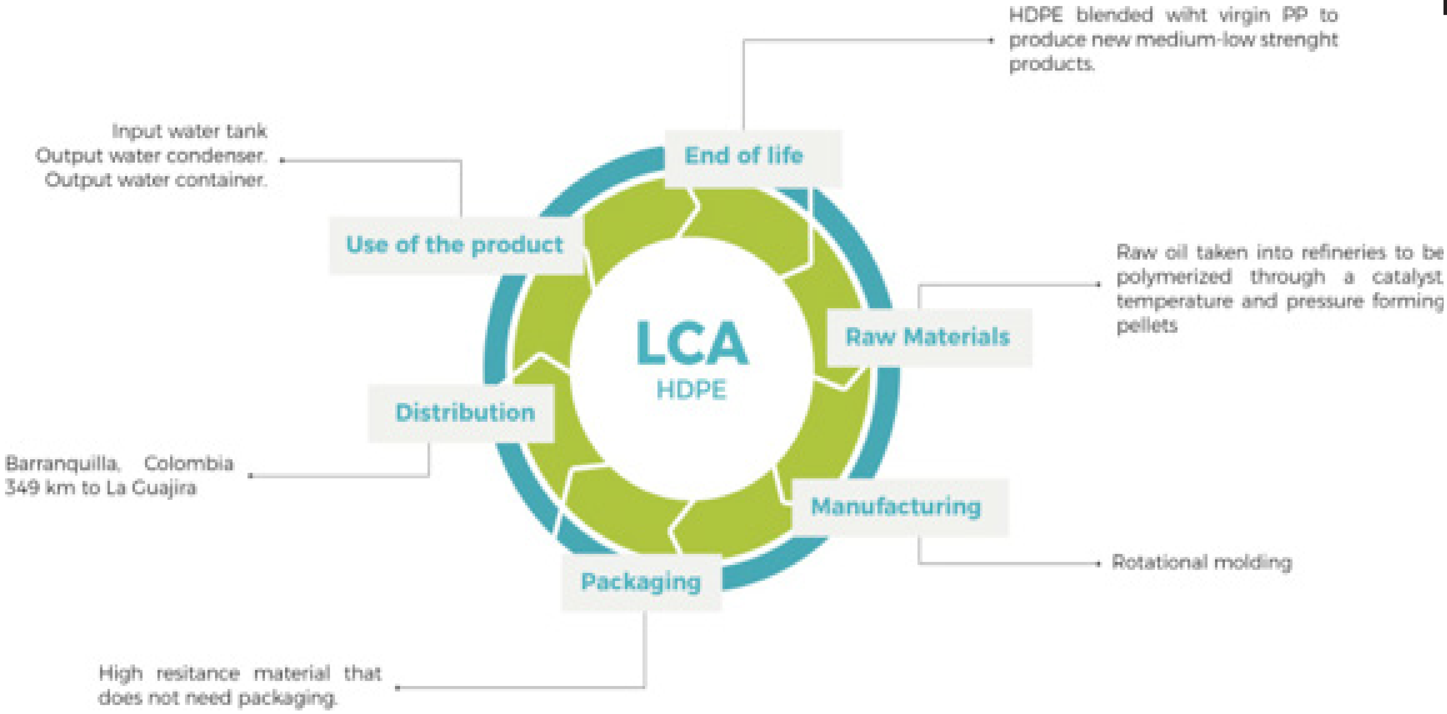
The assessment was made with the following graphics showing each stage of the life of the component.

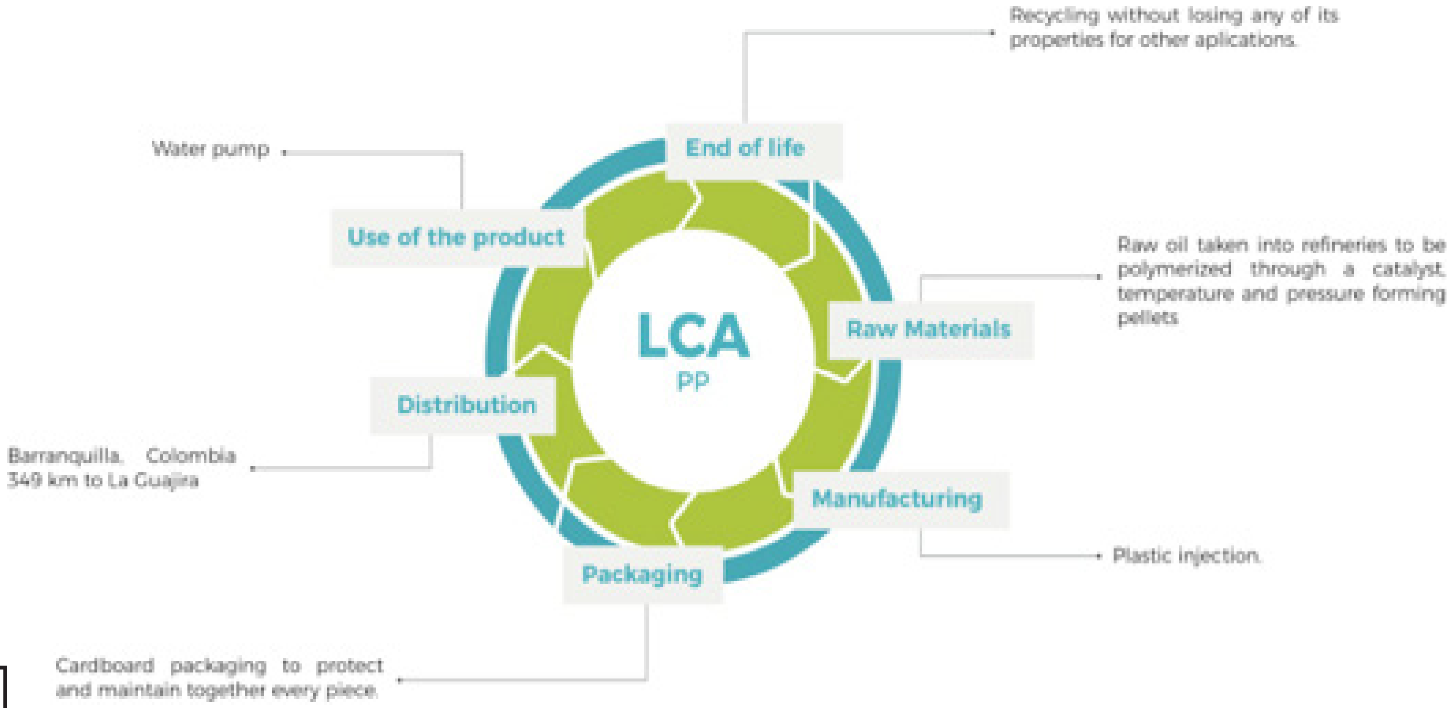


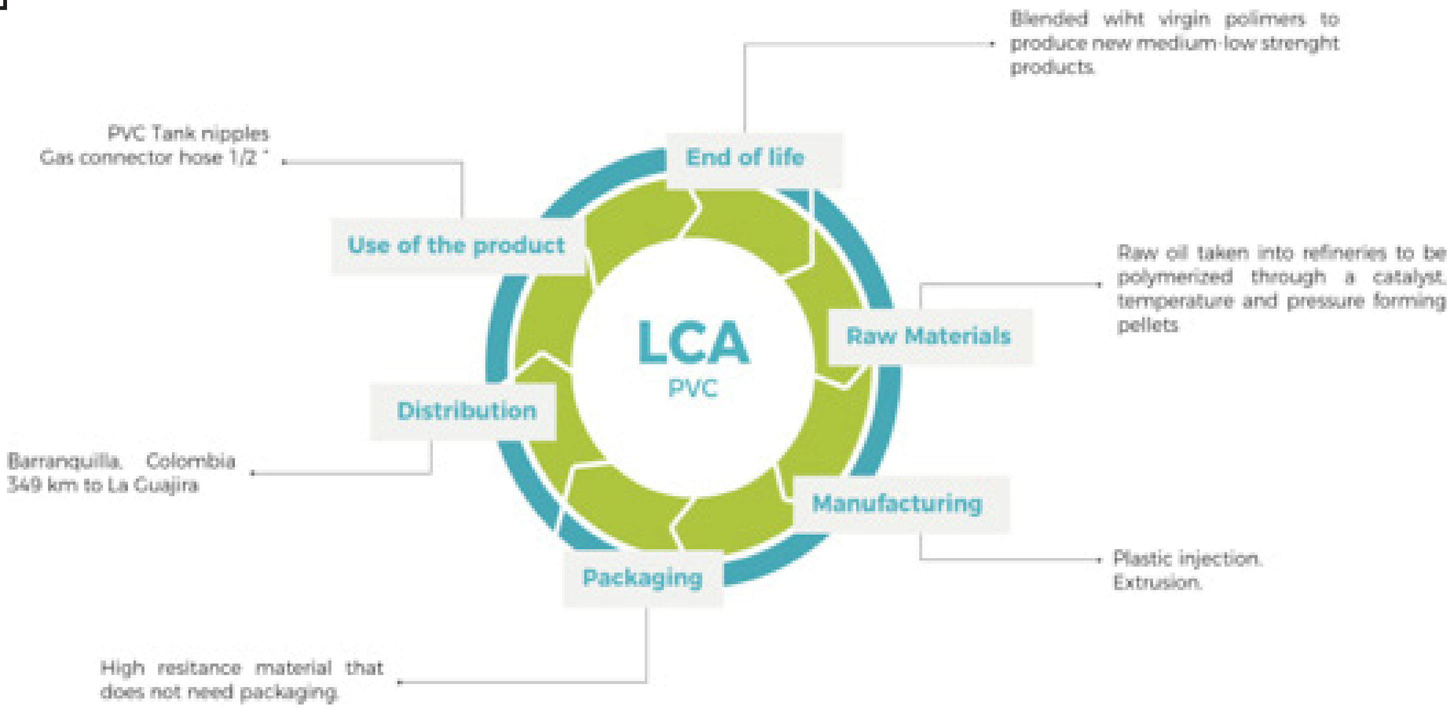

Loss of material due to deep cleaning of adhesives. 100% recyclable without any loss of performance.
Small loss of material due to deep cleaning of adhesives. 100% recyclable without any loss of performance.
Copper reduccer 4"- 2"
Copper reduccer 4"- 2"
Copper reduccer 2"- 1/2"
Copper reduccer 2"- 1/2"
Copper tube 4"
End of life
Use of the product
LCA
Copper
Raw Materials
Copper is combined with other chemicals in copper ores through mining, concentrating, smelting, refining and casting
Distribution
0 km to La Guajira
Manufacturing
Packaging
Metal die cutting.
Extrusion.
High resitance material that does not need packaging.

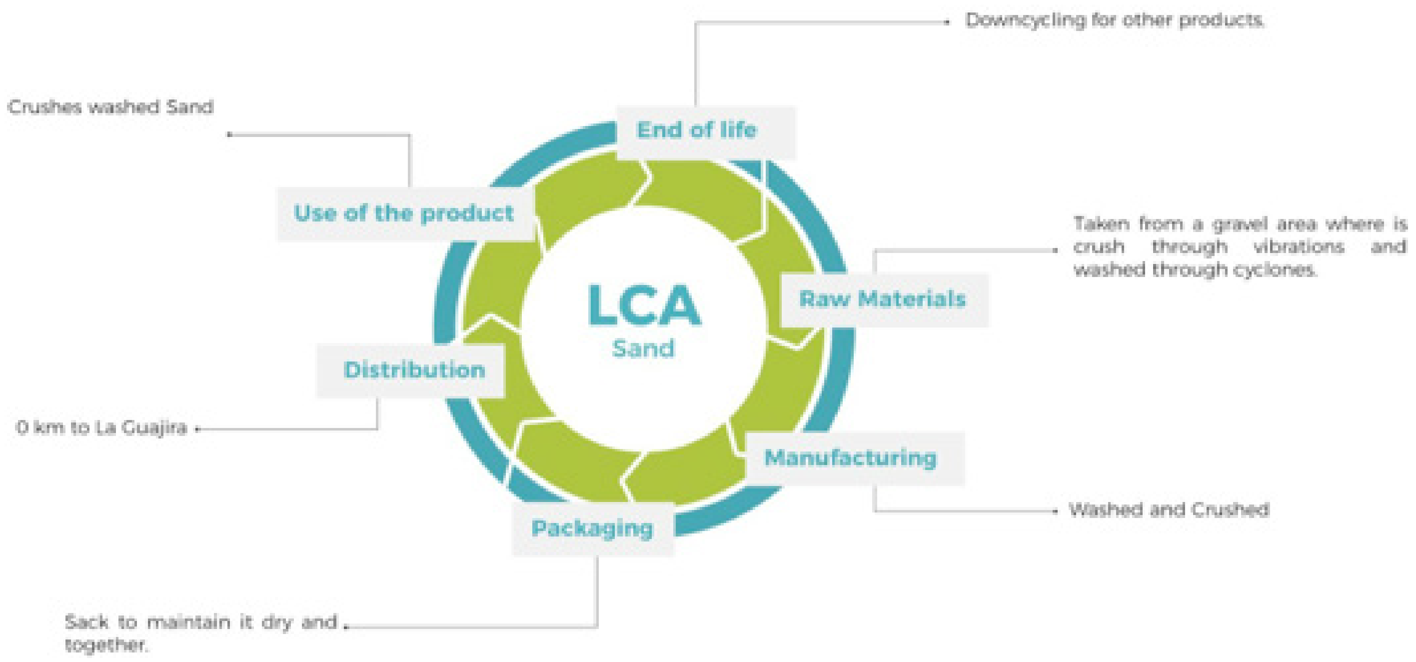

Chemical waste
Copper anaerobic adhesive
End of life
Use of the product
Epoxy adhesives based on epichlorhydrin bisphenol.
Cured with amines or polyamide
LCA
Epoxy adhesive
Raw Materials
Distribution
0 km to La Guajira
Manufacturing
Chemical processes.
Packaging
PP container with a thermoforming packaging.

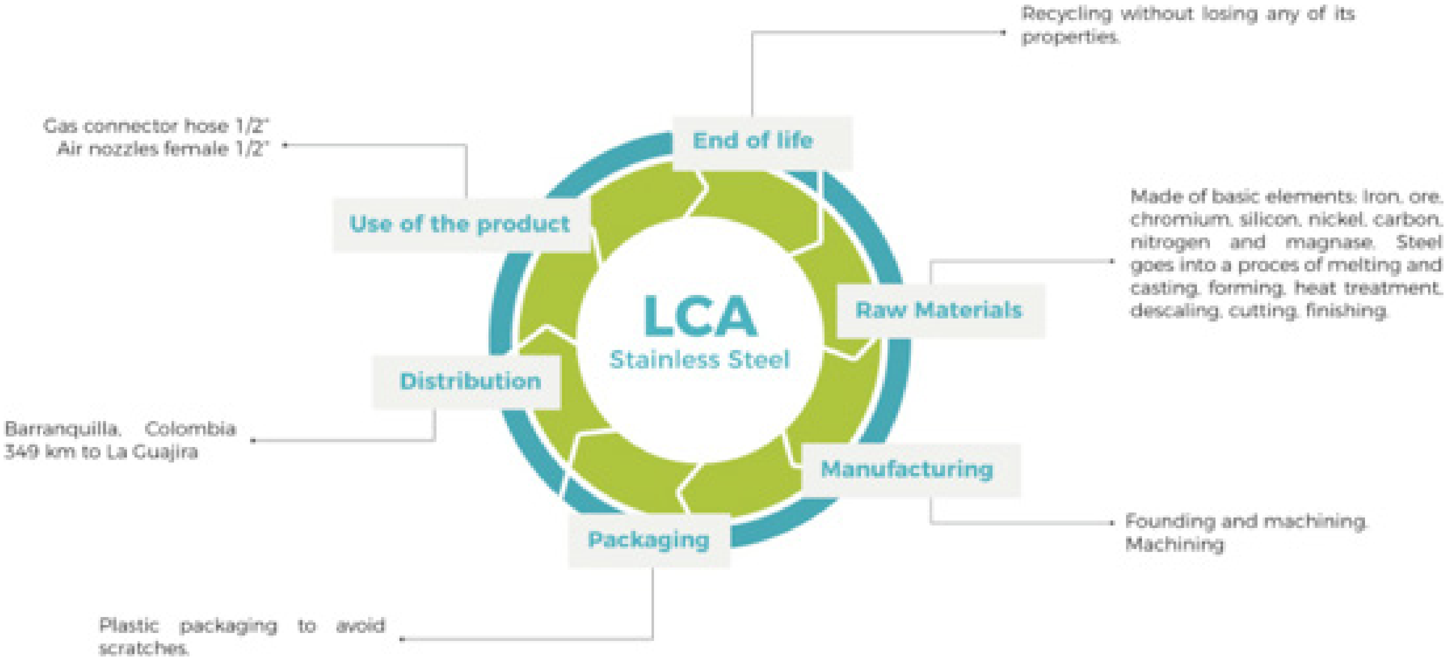

Landfill gypsum quarrys.
End of life
Gypsum powder plaster 7 Kg.
Use of the product
Heating natural gypsum and dehydriting it to give calcium sulfate.
Raw Materials
LCA
Gypsum
(CaSO4. 2H2O)
Distribution
0 km to La Guajira
Manufacturing
Plaster set.
Packaging
Cardboard bag with a plastic film.

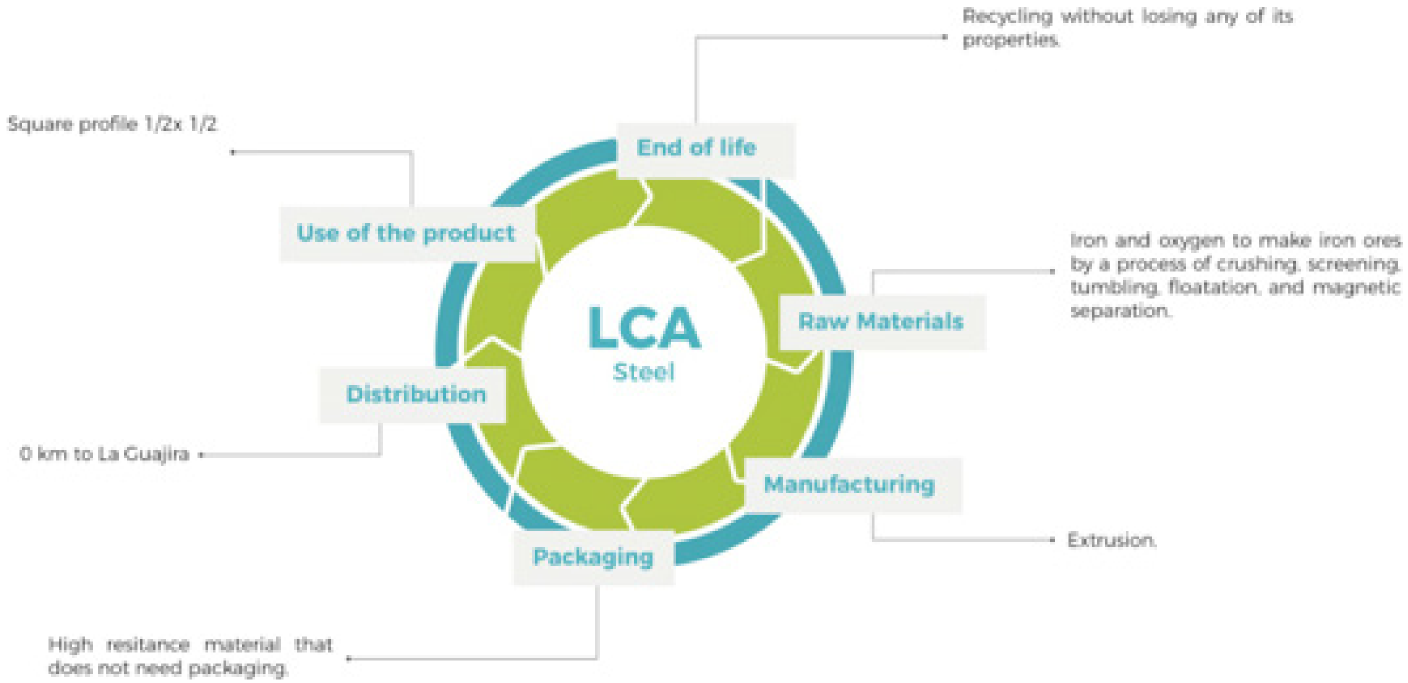

HDPE blended wiht virgin PP to produce new medium-low strenght products.
Input water tank
Output water condenser.
Output water container.
End of life
Use of the product
Raw oil taken into refineries to be polymerized through a catalyst, temperature and pressure forming pellets
Raw Materials
LCA
HDPE
Distribution
Barranquilla, Colombia
349 km to La Guajira
Manufacturing
Rotational molding
Packaging
High resitance material that does not need packaging.

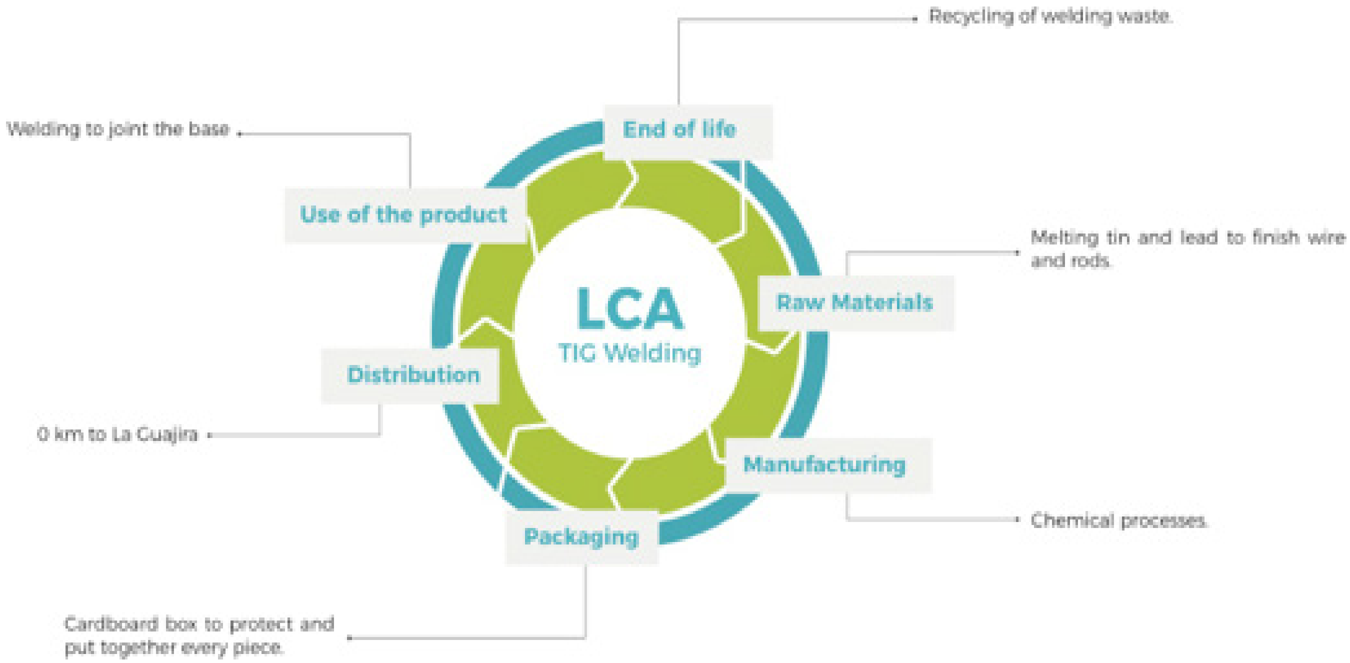

Recycling without losing any of its properties for other aplications.
Water pump
End of life
Use of the product
LCA
PP
Raw Materials
Raw oil taken into refineries to be polymerized through a catalyst, temperature and pressure forming pellets
Distribution
Barranquilla, Colombia 349 km to La Guajira
Manufacturing
Plastic injection.
Packaging
Cardboard packaging to protect and maintain together every piece.

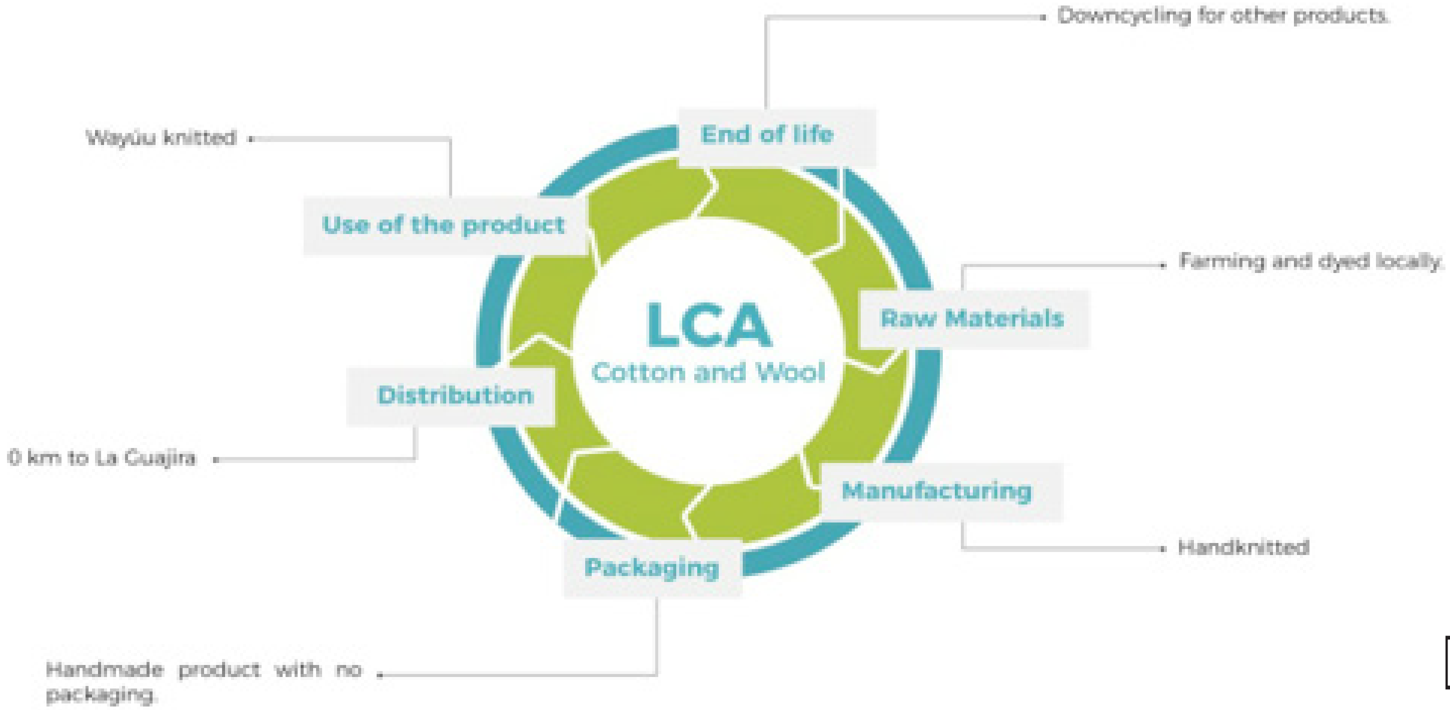

Blended wiht virgin polimers to produce new medium-low strenght products.
PVC Tank nipples
Gas connector hose 1/2 "
End of life
Use of the product
LCA
PVC
Raw Materials
Raw oil taken into refineries to be polymerized through a catalyst, temperature and pressure forming pellets
Distribution
Barranquilla, Colombia 349 km to La Guajira
Manufacturing
Plastic injection.
Extrusion.
Packaging
High resitance material that does not need packaging.


Downcycling for other products.
Crushes washed Sand
End of life
Use of the product
LCA
Sand
Taken from a gravel area where is crush through vibrations and washed through cyclones.
Raw Materials
Distribution
0 km to La Guajira
Manufacturing
Washed and Crushed
Packaging
Sack to maintain it dry and together.


Recycling without losing any of its properties.
Gas connector hose 1/2"
Air nozzles female 1/2"
End of life
Use of the product
LCA
Stainless Steel
Made of basic elements: Iron, ore, chromium, silicon, nickel, carbon, nitrogen and magnase. Steel goes into a proces of melting and casting, forming, heat treatment, descaling, cutting, finishing.
Raw Materials
Distribution
Barranquilla, Colombia
349 km to La Guajira
Manufacturing
Founding and machining.
Machining
Packaging
Plastic packaging to avoid scratches.


Recycling without losing any of its properties.
Square profile 1/2x 1/2
End of life
Use of the product
Iron and oxygen to make iron ores by a process of crushing, screening, tumbling, floatation, and magnetic separation.
LCA
Steel
Raw Materials
Distribution
0 km to La Guajira
Manufacturing
Extrusion.
Packaging
High resitance material that does not need packaging.


Recycling of welding waste.
Welding to joint the base
End of life
Use of the product
Melting tin and lead to finish wire and rods.
LCA
TIG Welding
Raw Materials
Distribution
0 km to La Guajira
Manufacturing
Chemical processes.
Packaging
Cardboard box to protect and put together every piece.

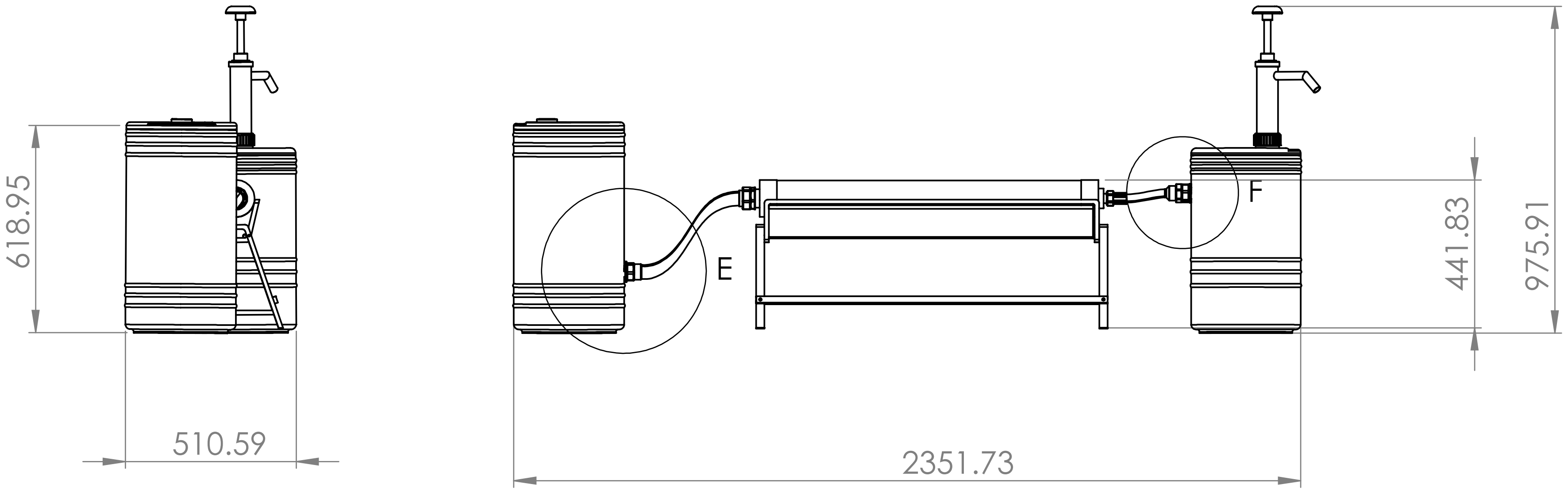

Downcycling for other products.
Wayúu knitted
End of life
Use of the product
Farming and dyed locally.
LCA
Cotton and Wool
Raw Materials
Distribution
0 km to La Guajira
Manufacturing
Handknitted
Packaging
Handmade product with no packaging.

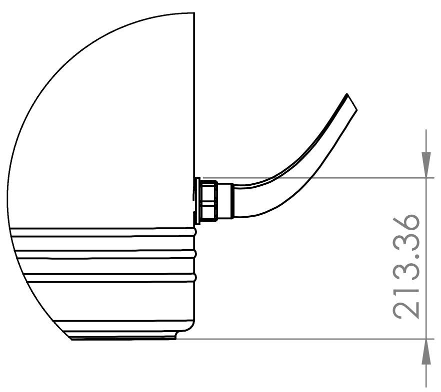
Appendix G - Cost Estimate

PIECE	BULK	PRICE IN COLOMBIA	PIECE IN SWEDEN
Drum tank 120 lt.	Existing item	Existing item	Existing item
Drum tank 60 lt.	Existing item	Existing item	Existing item
Drum tank 50 lt.	Existing item	Existing item	Existing item
PVC tank nipples	25.65 SEK	0.57 SEK	58.00 SEK
PVC tank nipples	25.65 SEK	0.57 SEK	58.00 SEK
PVC tank nipples	25.65 SEK	0.57 SEK	58.00 SEK
Copper reducer 2"-1/2"	12.50 SEK	0.25 SEK	0.35 SEK
Copper reducer 4"-2"	16 SEK	0,32 SEK	0,44 SEK
Copper reducer 4"-2"	16 SEK	0,32 SEK	0,44 SEK
Copper reducer 2"-1/2"	12.50 SEK	0.25 SEK	0.35 SEK
Copper tube 4"	2,555.65 SEK	51,113 SEK	81.66 SEK
Mini float valve	2,938.24 SEK	58.76 SEK	58.76 SEK
Gas connector hose 1/2	40,43 SEK	0,80 SEK	2.13 SEK
Gas connector hose 1/2	858.50 SEK	17,17 SEK	45.00 SEK
Water pump	3,973.00 SEK	79,46 SEK	79,46 SEK
Gypsum powder plaster 7 Kg.	540.00 SEK	12.00 SEK	14.00 SEK
Copper anaerobic adhesive	68.38 SEK	1,37 SEK	25.00 SEK
Square profile 1/2x 1/2	4,138.3 SEK	91.97 SEK	160.00 SEK
Steel bar 1/2"	4,590.00 SEK	102.20 SEK	177.00 SEK
TIG welding	141.05 SEK	2.82 SEK	3.50 SEK
Wayuu knitted	Existing item	Existing item	Existing item
Crushed wash sand	99.36 SEK	12.42 SEK	17.38 SEK

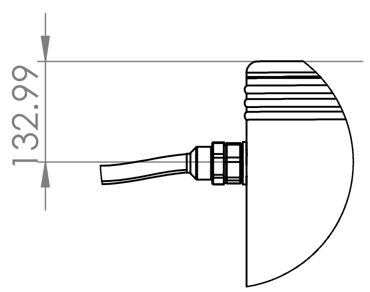
Appendix H - Blue Prints

General Blueprints generated with SolidWorks 2015.

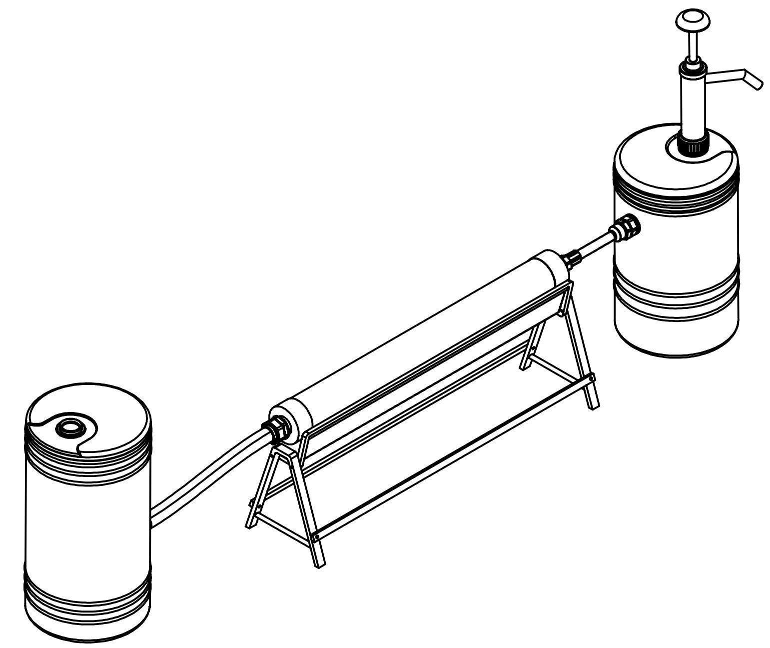




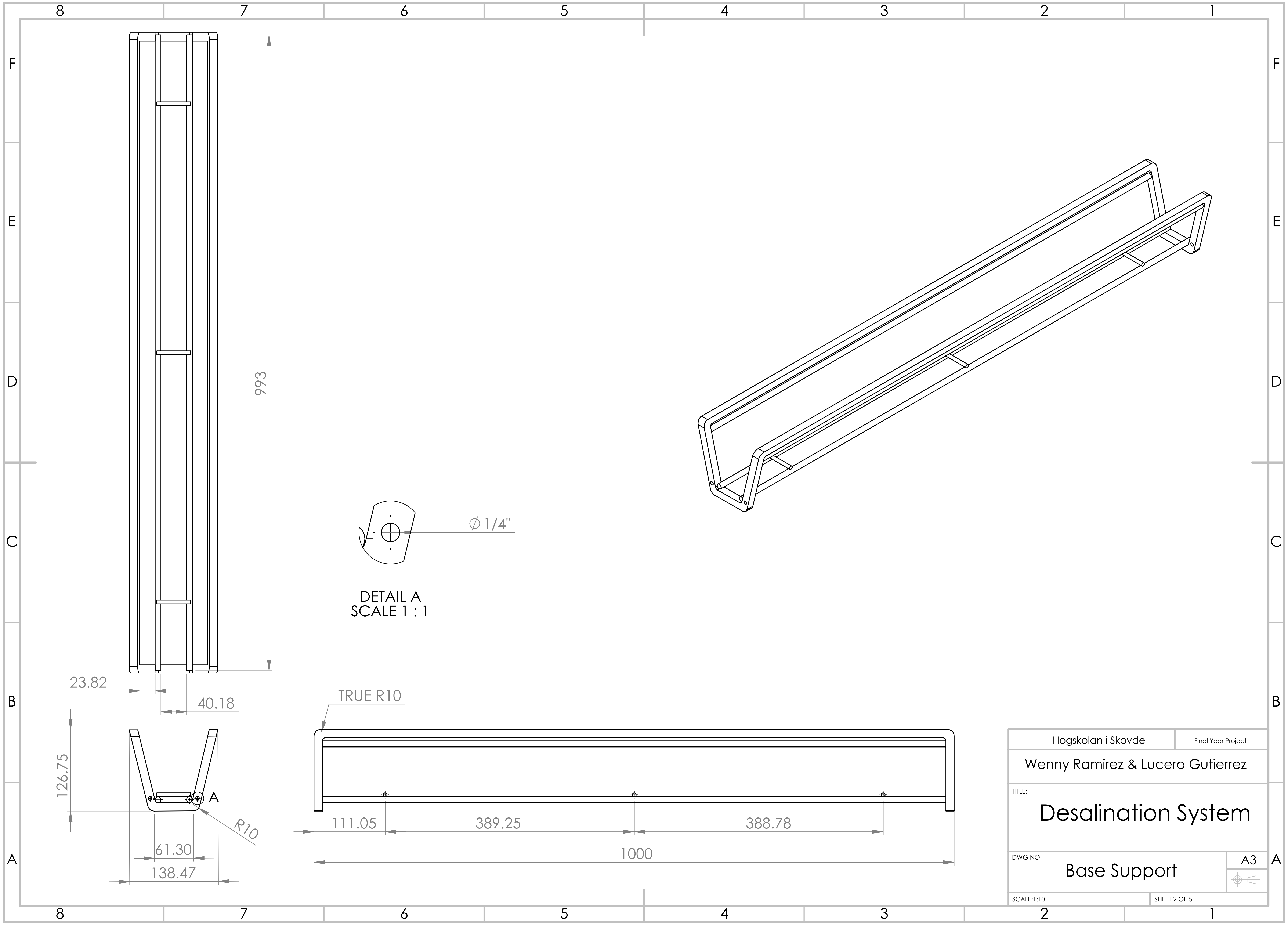
DETAIL E
SCALE 1 : 10

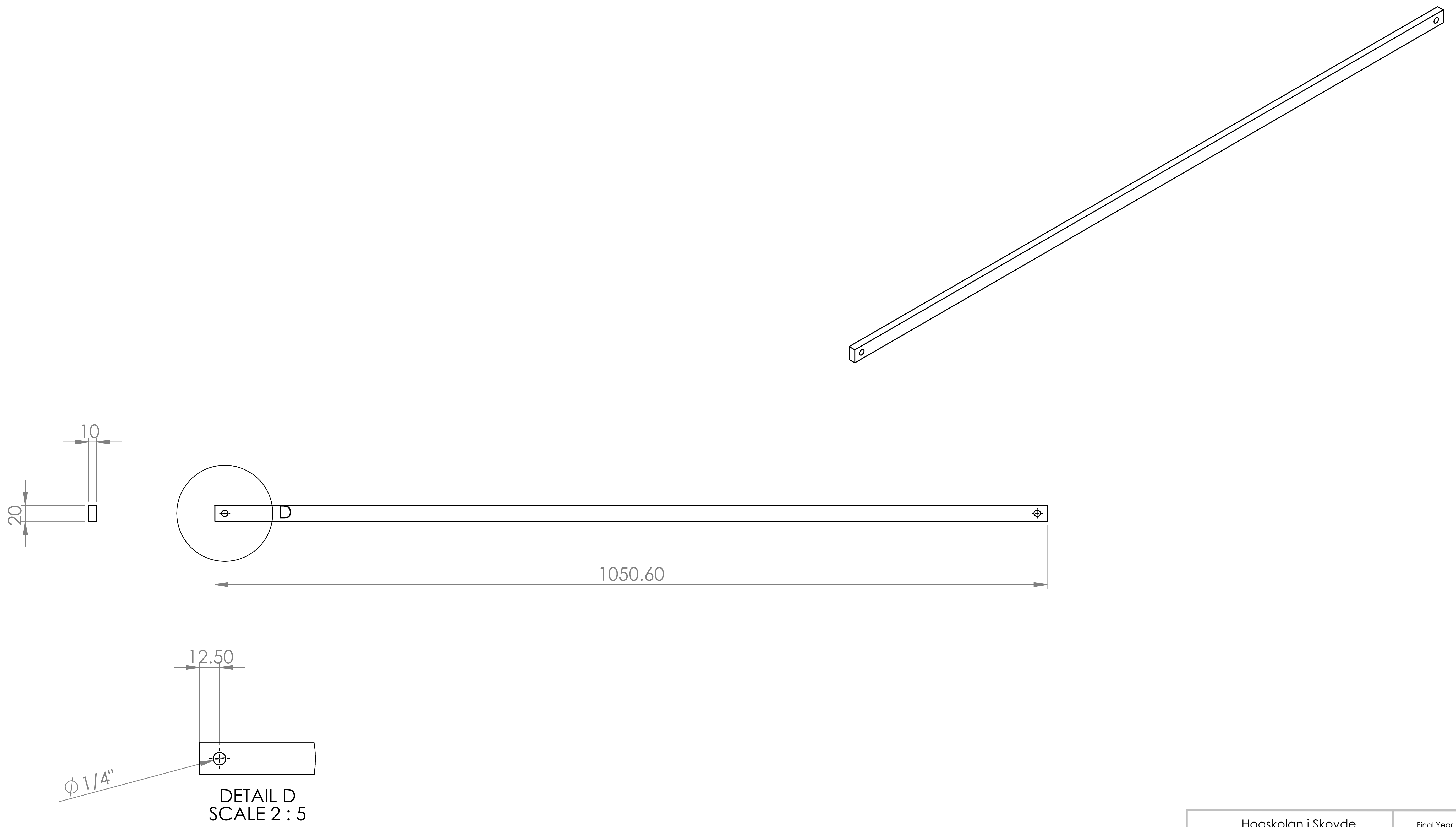


DETAIL F
SCALE 1 : 10

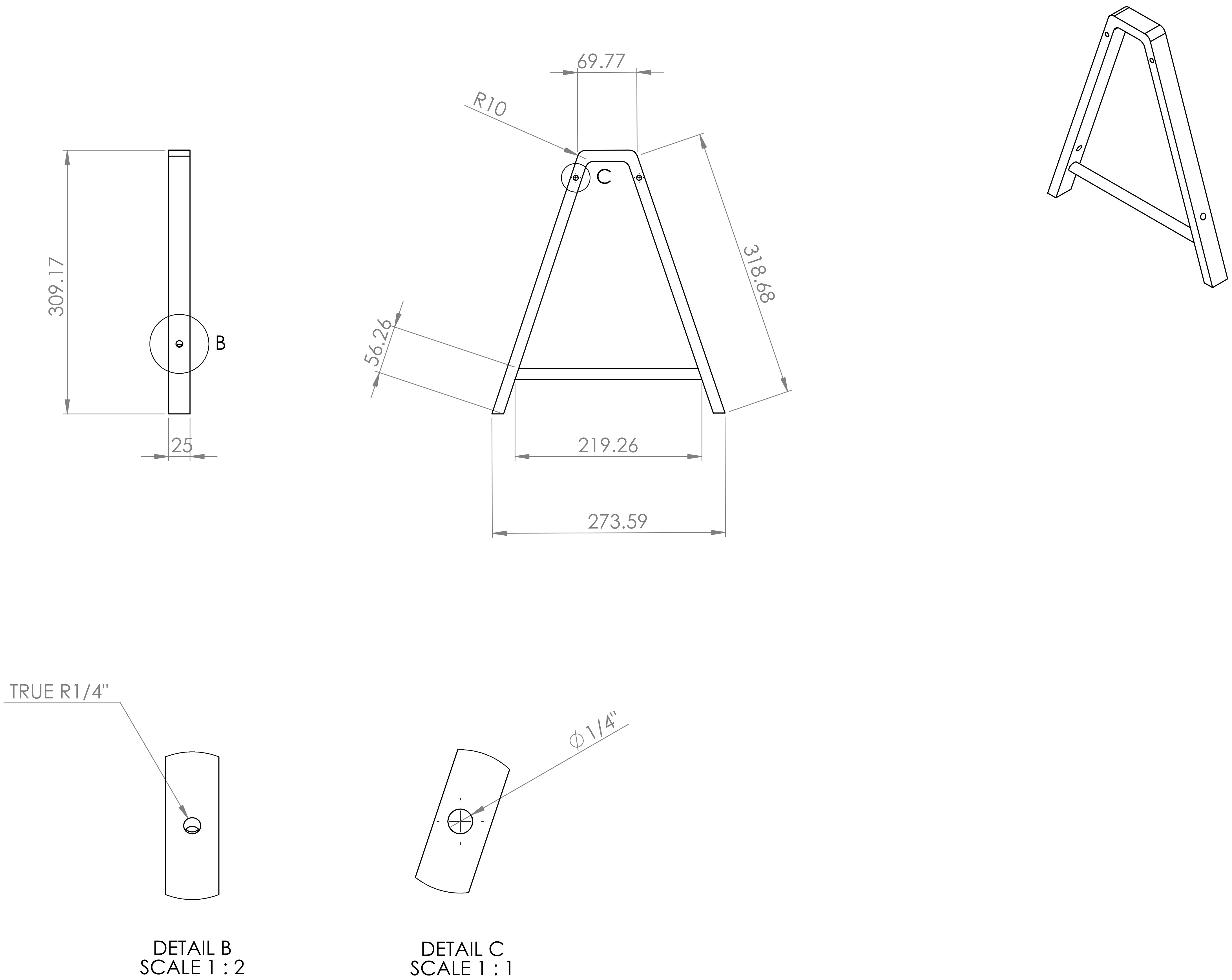


Hogskolan i Skovde	Final Year Project
Wenny Ramirez & Lucero Gutierrez	
TITLE: Desalination System	
DWG NO. General Measurements	A3
SCALE:1:50	SHEET 1 OF 5


993
23.82
40.18
126.75
61.30
138.47
R10
A
DETAIL A
SCALE 1 : 1
∅ 1/4"
TRUE R10
111.05
389.25
388.78
1000
Hogskolan i Skovde
Final Year Project
Wenny Ramirez & Lucero Gutierrez
TITLE:
Desalination System
DWG NO.
Base Support
A3
SCALE:1:10
SHEET 2 OF 5



Hogskolan i Skovde	Final Year Project
Wenny Ramirez & Lucero Gutierrez	
TITLE: Desalination System	
DWG NO. Base Crossbar	A3
SCALE:1:10	SHEET 3 OF 5



Hogskolan i Skovde | Final Year Project

Wenny Ramirez & Lucero Gutierrez

TITLE:

Desalination System

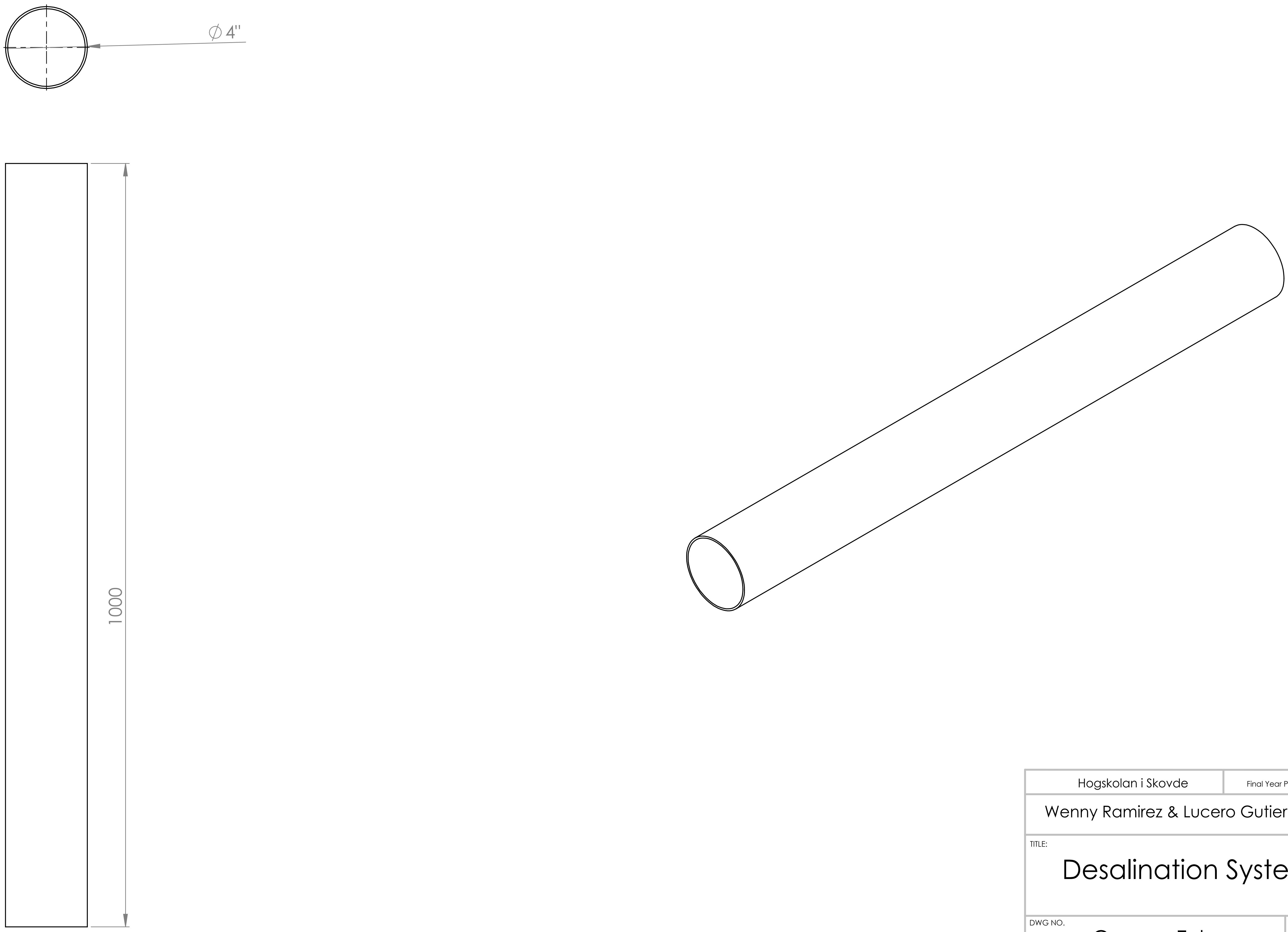
DWG NO.

Base Legs

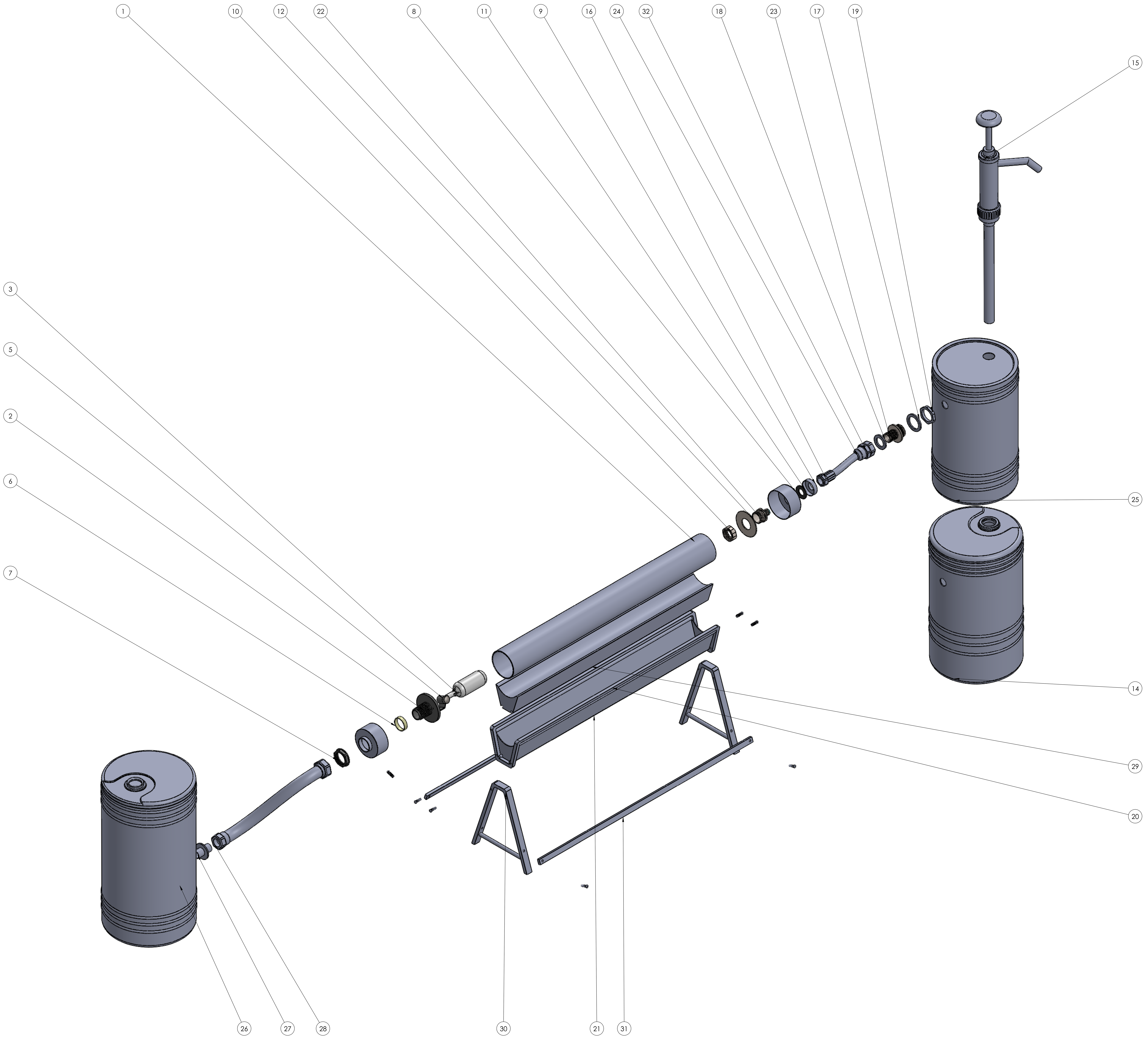
A3

SCALE:1:5

SHEET 4 OF 5



Hogskolan i Skovde	Final Year Project
Wenny Ramirez & Lucero Gutierrez	
TITLE: Desalination System	
DWG NO. Copper Tube	A3
SCALE:1:10	SHEET 5 OF 5



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Copper Tube		1
2	Tank Nipple 1		1
3	Float Valve Bottle		1
4	Carriage Bolt		1
5	Pivoting Lever Arm		1
6	Neo Washer		1
7	NN-13-BK		1
8	Reductor 4"-2"		2
9	Reductor 2"-1/2"		1
10	NippleG-1		1
11	NippleG-4		1
12	NippleG-5		1
13	NippleG-6		1
14	Output inner Water Tank		1
15	Hand pump		1
16	Gasconnector		1
17	Neo Washer 2		1
18	Neo Washer 3		1
19	Nut		1
20	Base		1
21	Woven container		1
22	NippleG-2		1
23	NippleO-2		1
24	Gas Connector 2		1
25	Output outer Water Tank		1
26	Input Water Tank		1
27	Output nipple		1
28	Hose		1
29	Sand		1
30	Base support		2
31	Base crossbar		2
32	Nipple		1
33	Bolts		8

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBURR AND BREAK SHARP EDGES

Högskolan i Skövde

REVISION

Wenny Ramirez and Lucero Gutierrez

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Desalination System

MATERIAL:

DWG NO.

Exploited View

A0

WEIGHT:

SCALE:1:20

SHEET 1 OF 1