Ocean spa

Local seawater as a source of fresh water and energy

A floating spa in Australia
Ocean spa: Local seawater as a source of fresh water and energy

_A floating spa in Australia_
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Preface

The oceans in the world hold an enormous quantity of resources, covering over 70% of the surface of the earth, which is hardly being utilized at the moment.

The different processes that are naturally present in the big oceans contain huge amounts of energy in different forms. For instance kinetic energy available in waves, tidal processes and winds. Thermal energy contains also a big part of the available energy potential, different ocean currents and natural temperature differences can provide this type of energy. These energy sources present in the ocean have been harvested in small scale for a very long time, even going back to the Middle Ages, where tidal mills were build to harvest the energy present in the rise and fall of the tides. In modern times the ocean energy is again gaining popularity, especially in the discussions about renewable energy sources, and are new techniques developed on a large scale.

Another great potential in the use of oceans, is the amount of water they hold. Of all earth’s water resources, 97% is saline water, and only 3% is fresh water. If you could use the water present in the oceans, this could solve a lot of existing and future drought problems. Very simple ways of extracting fresh water from salt water have been used for a long time. Simple solar stills warm the salt water and use evaporation to separate the fresh water from the salt water. By condensating the fresh water vapour clean drinking water can be produced. This very small scale technique for desalination is still being used and improved to maximise the output of fresh water. Other more complicated techniques have been developed in the last decades that can produce large amounts of fresh water in a small period of time. A negative side of these more developed techniques is the need for energy input.

It is clear that there is great potential in the use of oceans for energy generation and fresh water production. In big plants the different techniques are being implemented on a large scale ever more often. But there might also be a possibility to use these resources on a small scale, the scale of a building for instance. If a building would be located near or on the ocean water, the ocean might be able to supply the building of its neccessary energy demand and fresh water need. The techniques used in the building could also have a influence on the architecture of the building.

For this project there will be designed a building that is floating on the ocean, by using a floating concrete construction. The function of the building will be a spa. Housing pools, sauna’s, steam rooms and treatment rooms creating a place for quests to relax and be pampered. The building will be located in the harbour of Sydney, Australia.

The use of the ocean in this project will be the most important object. The ocean will have to supply the energy need of the different pools and other functions, but will also have to provide the building of its need for fresh water. This fresh water production will be the most important challenge in this project because of the drought problems Australia is facing at the moment and because of the excessive fresh water use this building has.

In the research of this project there will be focussed on the possibilities and potentials the oceans have. The exploration will begin by discovering the many different processes that are present in the oceans in the world. Thinking of these processes there will be a research to different available techniques to harvest the resources from the ocean and the properties they have. After finding the necessary information about the techniques there will be researched what demands a building with the function of a spa will have. Concluding this research there will be formulated different possibilities in which the techniques, dealt with in the first part of the research, can be implemented in the architecture of a floating spa building.
Research questions

Main research question:

How can local seawater at a site serve as a direct or an indirect source for the fresh water and energy demand of a building?

Sub questions:

1. What processes are present in the oceans?
2. What techniques are available to convert salt water to fresh water? And what are the specifics of these techniques?
3. What techniques are available to generate energy from the ocean? And what are the specifics of these techniques?
4. What techniques can be used for both purposes?
5. What is the typical demand of fresh water and energy of a spa building?
6. How can the techniques be implemented in the architecture of a spa building?
Problem definition

The climate in Australia has always been extremely variable. The climate has a direct correlation with the El Nino and the La Nina phenomenon. During the El Nino years, big droughts terrorize the continent and during La Nina years there is an occurrence of events with storms and flooding. Due to this variability of the climate in Australia, there have always been huge difficulties in maintaining a steady water supply. During the droughts there is not enough rainfall to supply the demand of water that arises and during the wet years the excessive rainwater will directly run off to the ocean.

In the early 20th century the Australian government started the execution of a major water catchment plan. In the south east of the continent they started with the construction of dams in the main rivers descending from the highlands of the Great Dividing Range. These dams allow the creation of big catchment areas further up the river. These lakes collect excessive rainwater during the wet years and supply the water demand during the dry years.

In the first three quarters of the 20th century there was a huge expansion of these catchment areas. Due to low constructions costs and a lack of environmental restrictions there was almost unlimited growth possible. The under pricing and great availability of water attracted a rapidly growing agricultural business in the Murray Darling Basin (located just west of the Great Dividing Range), which by now is the most important agricultural region, accounting for 39 percent of Australia's gross value in agricultural production.

This unlimited expansion of catchment lakes has resulted in a serious disruption of the natural ecosystem in the Great Dividing Range and in the lower Murray Darling Basin. The flooding of huge forests of gum trees has caused this natural storage of water in the ecosystem to die. The construction of dams and big irrigation projects in most of the rivers leading to the ocean has resulted in almost completely dried up rivers in the lower parts of the area. This means a huge degradation of the national parks present in this area.

In order to limit further damage and degradation of the national parks in this area there have been imposed numerous environmental restrictions in the last decades of the 20th century. These regulations seriously limited the expansion of the catchment areas. Nevertheless do the continuously growing population and the prolonged droughts (as a result of global climate change) cause an ever growing water demand.
Due to the chronic water shortages during the years of drought there have been imposed very strict restrictions for the use of water, these apply for agricultural business but also for inhabitants and businesses in the cities.

These water restrictions mostly involve the use of water outside, for instance watering gardens, car washing, and refilling of pools. The water restrictions influence the everyday life and have created a huge awareness in Australia for the (ab) use of water. People have become very cautious to use as little water as possible and fresh water has become a luxury good.

The construction of a spa, where water has to be available in abundance, in a location like this will be difficult. The water restrictions will limit the use of fresh water in the building enormously and on top of that will the public opinion, about excessive use of water, be determining for the popularity of the building.

[Department of Climate Change and Energy Efficiency]
[Sydney Catchment Authority]
[Sydney Water]
Natural processes in oceans
Tides

The process of the tides of the ocean refers to the rise and fall of the sea level in comparison to the land. The highest point of the rise is called high tide and the lowest is called low tide. Most places on the earth have two high tides and two low tides each day. These vertical movements are effected by the seasons, astral alignment, and other factors, including geomorphology.

The movement of the sea level is produced by the gravitational pull of the moon and sun. The moon has a much greater impact on tides than the sun because it is far closer to earth. The moon pulls water that is closest to it making a high tide on the side of the earth closest to the moon and there is a high tide on the opposite side of the earth too. Low tides happen in places between the high tides. Because of the rotation of the earth, the tides change over time.

The difference between high tide and low tide is called the tidal range. The tidal range can be as little as a few centimeters to as much as several meters depending on the shape of the ocean floor. (for characteristics of various sites on the world, see figure) The tidal range changes through the year as the location of the moon and sun in relation to earth changes. At times when the sun, earth, and moon are in line with each other (during full and new moons), the tidal range is larger because both the sun’s and moon’s gravitational pull create the tide. This is called a spring tide. At times when the moon and the sun are not in line with earth, when they are at right angles when viewed from earth, the tidal range is smaller. This is called a neap tide.

The tidal range, that can have different values depending on the geographical location, contains a lot of potential energy. By trapping the incoming high tide, and slowly releasing this water when there is a low tide. Energy can be extracted by using the flowing water to rotate a mill or a turbine.

There are restrictions on this way of generating energy from the oceans. First this process only works in locations of at least a tidal range of more than 2 meters and there is a limitation because of the difference between the occurrence of tides and the need for power. By using multiple smaller ponds to store the high tide water, the energy can be generated at chosen times.

[Allaby, 2002]
Tidal currents

Tides are the vertical movement of the sea level (rise and fall), tidal currents are the horizontal flow, sometimes called “run”. The current experienced at any given time is usually a combination of tidal and non-tidal currents. The tidal current in the unimpeded open ocean is normally rotary, clockwise in the northern and counterclockwise in the southern hemisphere. Speed varies, with two maxima and two minima. It is reversing where flow is restricted. The movement away from shore (downstream) is the ebb, and toward shore (upstream) is the flood. The maximum speed is attained at high and low tide, with directions being opposite to one another. It is nil when the direction inversion occurs.

The energy existing in the tidal currents can be extracted by placing a turbine in the ocean, at a point which has the highest tidal speed. This speed is highest in places with a canal, but this location is problematic because the turbine would obstruct the shipping routes.

Both the rise and fall of the tide, and the flood and ebb of the reversing current can be harvested to produce mechanical and/or electrical power. Tidal currents are alternating and their maximum velocity occurs at high and low water. The motion is uniform from surface to bottom, except for wave interference at the surface and increases with distance. Because of superimposition by other currents, observation of tidal currents is difficult and requires extensive data.

[Pfafflin, 2006]
Marine winds and waves

Wind is the flow of gases on a large scale, and this is caused by differences in pressure that exist on earth. On the earth there are two major elements that can cause large scale winds (the atmospheric circulation see figure). These are the differential heating between the equator and the poles and the rotation of the planet.

Ocean winds are winds that exist on the big oceans and these winds are generally stronger than on land because there is less friction over water to slow the winds down, no hills or mountains to block the winds path.

Ocean winds can be harvested for energy the same way land winds can. By using a wind turbine with a propeller that powers a turbine.

Wind generated waves are surface waves that occur on the free surface of oceans, seas, lakes, rivers, and canals or even on small puddles and ponds. They usually result from the wind blowing over a vast enough stretch of fluid surface. Some waves in the oceans can travel thousands of kilometers before reaching land. Wind waves range in size from small ripples to enormous waves. After the wind ceases to blow, wind waves are called swell. Or, more generally, a swell consists of wind generated waves that are not, or hardly, affected by the local wind at the same moment. They have been generated elsewhere, or some time ago. Wind waves in the ocean are called ocean surface waves.

Waves on the open water have specific characteristics, for instance the wave height and wave length, but also the time interval between arrival of serial crests at a stationary point, called the period. Waves in a given area typically have a range of heights. For wind wave analysis the height of the waves, over a period of time is usually called the significant wave height.

Ocean surface waves are mechanical waves that exist along the interface between water and air; the force is provided by gravity, and so they are often referred to as surface gravity waves. As the wind blows, pressure and friction forces disturb the equilibrium of the water surface. These forces transfer energy from the air to the water, forming waves. In the case of waves in deep
water, particles near the surface move in circular paths, making wind waves a combination of longitudinal (back and forth) and transverse (up and down) wave motions. When waves are present in shallow water, (where the depth is less than half the wavelength) the particles are compressed into ellipses.

Ocean wave energy is form of the kinetic energy that exists in the moving waves of the ocean since waves are caused by blowing winds over the surface of the ocean. This energy can be used to power a turbine and there are many areas in the world where wind blows with sufficient consistency to provide continues waves. There is tremendous energy in wave power which gives this energy source gigantic energy potential. Wave energy is captured directly from surface waves or from different pressure fluctuations between the surfaces.

[Nelson, 2009]
[Pfafflin, 2006]
Evaporation

Evaporation is a type of vaporization of a liquid, that occurs only on the surface of that liquid. The other type of vaporization is boiling, that occurs on the entire mass of a liquid. Evaporation is also part of the natural water cycle present in the oceans.

Evaporation is a type of phase change; it is a process where molecules in a liquid state (for instance water) become gas (like water vapour). Evaporation can be seen as the disappearance of a liquid from a substance when exposed to a enough gas. In this process the evaporating vapour leaves all the dissolved molecules behind.

On average, the molecules in a glass of water do not have enough heat energy to escape from the liquid. With sufficient heat, the liquid would turn into vapor quickly. When the molecules collide, they transfer energy to each other in varying degrees, based on how they collide. Sometimes the transfer is so one-sided for a molecule near the surface that it ends up with enough energy to escape.

Evaporation is an essential part of the water cycle. Solar energy drives evaporation of water from oceans, lakes, moisture in the soil, and other sources of water. Evaporation is caused when water is exposed to air and the liquid molecules turn into water vapour which rises up and forms clouds.

The water cycle, also known as the hydrologic cycle or H2O cycle, describes the continuous movement of water on, above and below the surface of the Earth. Water can change states among liquid, vapour, and ice at various points in the water cycle.

The sun heats up the water in oceans and seas. Water evaporates as water vapour into the air that is connected to the surface of the sea. Rising air takes the vapour up into the atmosphere where, because of a cooler temperature, it to condenses into clouds. Air currents move water vapour all around the earth, water particles can fall out of the sky as precipitation. Most water falls back into the oceans or onto land as rain, where the water moves over the ground as surface water. A portion of this water enters rivers, where the stream moves the water the ocean. Water can also be stored as freshwater in lakes. Not all water flows into the rivers, much of it ends up into the ground as infiltration. Some groundwater can reach the surface again in the form of springs. Over time, the water returns to the ocean, where the water cycle started.

[Allaby, 2006]
Temperature differences in oceans

Temperature and density have an important relation. When a temperature increases the space between the individual molecules becomes bigger. So, when the temperature of a liquid decreases the density will increase. At a temperature of 0°C the water freezes and is has the highest density possible.

Between salinity and density there is also an important relation. When density increases, the amount of salts in the water increases. There are different ways in which the salinity of the sea can change. For instance by the melting of polar ice or by the freezing of this ice. The salinity can also change from an big addition of freshwater or a huge event of evaporation.

The ocean water is moving all the time underneath the surface. This brings nutrients to the top. The difference in density that cold water has compared to warmer water causes ocean currents and the upwelling of nutrients. The cold seawater will sink and warm seawater will float. This is why there are layers of different temperatures present in the ocean water. These temperatures can range from -2 degrees to 28 degrees.

If there is an area where the density or salinity of the different layers changes fast, this is called a thermocline (see figure). These clines in the sea layers are important because of the high amount of energy that they contain. These clines occur mostly in the areas around the equator because the heating of the surface water in these areas is much higher than in other places.

[Allaby, 2006]
Techniques for desalination
Desalination techniques

In the next pages there will be explained some of the most common desalination or distillation techniques that are being used in desalination plants all over the world. Also more experimental techniques, that are still in a research phase, will be explained. This to get a full view on the available techniques that might be interesting to use in floating buildings. The scale on which the following systems can be implemented are very different. Some techniques are only profitable in big installations, where others can also be manufactured in small modules that can produce fresh water on their own.

The different techniques will be assessed on a few topics that are most important when considering such a system for a project. The techniques will be assessed on the amount of fresh water they can produce and the amount and type of energy they require to produce this water. The square meters that the different techniques cover is also very important when you are dealing with a building that has limited space. The last topic that is assessed for every technique will be the visibility of the system. This is interesting for the architecture of the future design, systems that can work in a small tank might be very efficient fresh water producers but these are not able to influence the architecture in any way. When it comes to creating a sustainable building, it is also very important to show the visitors that the fresh water is being produced from a renewable source, and to explain to the public how these systems work.

For every system there are images indicating the quantities of the different topics from low (blue) to high (red):
2.1 Solar still

Process description:

A solar still is a very simple desalination technique that uses only sun as its energy source. And does not need any additional energy. A single basin solar still has a roof made of glass, with inside a basin which is covered with black material to improve the absorption of the sun. The basin is filled with salt water.

The glass roof allows the radiation of the sun to pass into the still, this is mostly absorbed by the black basin. This will make the water heat up and the water starts to evaporate. The roof construction traps the heat of the sun inside the still and creates a greenhouse effect.

The heated water vapour evaporates from the basin and condenses on the inside of the glass roof. In this process, the salts and bacteria that were in the seawater are left behind. Condensed water runs down the glass roof to a collection point and can be used as clean fresh water.

There is also a possibility for linking solar stills together. In this technique the condenser surface of the lowest basin will be the floor of the higher basin. This causes the heat of the condensing vapour to heat up the water of the basin on top.

[Cipollina, 2009]
[Kalogirou, 2004]
[Tzen, 2003]
2.2 Multi effect humidification (MEH)

Process description:

In this technique the sun passes through a double glazed dome that has more than 80% transparency. The solar absorber that is constructed in the middle of the dome absorbs this energy and becomes a large hot surface. This is the most important part of this desalination process.

Molecules in the air that touch the absorber are heated, this hot air expands and rises, this causes the fresh air and water vapour to be drawn in. This creates a convection current. Now water will evaporate from the surface of the salt water and passes through pipes in the absorber.

The air in the convection current is returned through pipes to just underneath the absorber. The outgoing clean water will transfer heat to incoming salt water in the heat exchanger.

The principle of MEH plants is desalination under atmospheric conditions by means of an air loop with water vapor. The air can be circulated by either natural or forced convection.

[Cipollina, 2009]
[Tzen, 2003]
2.3 Multiple effect desalination

Process description:

The effects are vertically oriented, one on top of the other. Preheated seawater feed is sprayed onto the outer surface of the evaporator tubes in the first effect at the top of the column, where a portion of seawater is evaporated by the heating steam.

The remaining seawater is collected at the bottom of the first effect and then sprayed onto the outer surfaces of the second effect where another portion of seawater is evaporated, being heated by the vapor generated in the first effect. The generated vapor is delivered through a mist eliminator section. The vapor itself condenses into fresh water in the side section.

The cycle is repeated in each successive effect up to the last one. Vapors generated in the last effect are condensed in a heat rejection condenser.

[Cipollina, 2009]
[Kalogirou, 2004]
[Tzen, 2003]

Fresh water production:
Small unit: 25 liter/m²/day
Big plant: 5000 m³/day

Required energy input:
Thermal 60 - 70 kWh/m³
Electrical 1.5 - 2 kWh/m³

Visibility

Square metres required:
Evacuated tube solar collector surface
Small unit: 2 m²; Big plant: 1862 m²
2.4 Vapor compression (MVC or TVC)

Process description:

Vapor compression processes work with pressure differences to stimulate evaporation. The heat for the evaporation is made by the compression of the vapour, either with a mechanical compressor (mechanical vapor compression, MVC), or a steam ejector (thermal vapor compression, TVC).

Incoming seawater feed is preheated in the heat-exchanger, by the produced freshwater and the blow down brine. The vapors released in the first stage are flashing to the second stage and so go on up to the 4th (or the nth stage). The vapor from the last stage is compressed in the compressor. Electric power is generated in a turbine to drive the compressor. Compressed steam is circulated through the tubes of the condenser, where it condenses, giving the heat to the evaporating seawater.

Released vapors are used as heating medium in the second stage, etc. The condensate, i.e., the produced freshwater, leaving the flashing chambers is collected after further cooling in the heat-exchanger and brine is rejected.

[Cipollina, 2009]
[Kalogirou, 2004]
[Tzen, 2003]
2.5 Multi-Stage-Flash distillation (MSF)

Process description:

MSF is a thermal distillation process that uses evaporation and condensation of water. The evaporation and condensation steps are coupled in MSF so that the left over heat of the evaporation is recovered for reuse by pre-heating the incoming water.

When saline water is heated to a temperature slightly below its boiling point at a given pressure and then introduced into a chamber where a sufficiently lower pressure exists, explosive boiling will occur. Bubbles are evolving from the whole mass of the liquid and part of the water will evaporate until equilibrium with its vapour at the prevailing pressure is reached.

This evaporation lowers the temperature of the remaining brine. The liquid may then be passed into another chamber at an even lower pressure, where it flashes again to vapour.

[Cipollina, 2009]
[Kalogirou, 2004]
[Tzen, 2003]
2.6 Freezing desalination

Process description:

Salt water has a specific critical temperature which is related to the salinity of the water, at this temperature the water will freeze. When salt water is reduced to this temperature, it will start a process that will form ice crystals made of fresh water. When these crystals have formed it is possible to separate these crystals from the remaining salt water. Is these crystals are separated and melted to form fresh water. This is principle is the basis where freezing desalination is based on.

There are different techniques available, a direct and indirect process. In a direct freezing process, the solution to freeze the salt water is mixed directly in it. In an indirect process, this solution is separated from the salt water by a surface that can transfer the heat.

There are a number of ways to separate the ice from the salt water including centrifugation. One of the more practical ways involves making the ice crystals flow upwards in a column. The brine is then drawn off. A counter current flow of freshwater is fed into the top of this column to wash any remaining brine from the ice. This washing can be done with the loss of only a few percent of the freshwater product. The ice is then fed to the melter where freshwater is formed.

[Abdul-Fattah, 1986]
2.7 Membrane distillation (MD)

Process description:

Membrane distillation is a technique that is both a membrane technique (like reverse osmosis) and at the same time it is a evaporation technique. In this system the vapour of the salt water is transported through pores of a membrane because of a temperature difference across the membrane. This system needs less energy than other membrane or evaporative techniques and is therefore a very good alternative for both. Also this system operates at low temperatures and at atmospheric pressure which makes this system very easy to apply.

[Cipollina, 2009]
[Koschikowski, 2003]

Fresh water production: 0.15 - 10 m³/day
Required energy input:
Total energy: 100-200 kWh/m³ distillate, Thermal: 100 kWh/m³, Electric: 1.2-3.2 kWh/m³
Visibility
Square metres required: Membrane area, for small MD modules is 7 - 12 m² plus area of solar collectors
2.8 Reverse Osmosis (RO)

Process description:

Reverse osmosis is based on a natural process that occurs in cells. This process works with a semi-permeable membrane that separates two solutions with different concentrations. Osmotic pressure will drive water through the membrane to the more concentrated solution. At the end there will be an equilibrium.

In desalination systems a hydraulic pressure is applied to the concentrated solution which will reverse the osmotic pressure. This way fresh water is driven through the membrane from the salt water solution.

Reverse osmosis will produce fresh water from salt water and at the same time excluded all other molecules from the water as well, this means that the solution that is produced will be pure water. If the water will be used for drinking water some minerals will have to be added again.

[Cipollina, 2009]
[Koschikowski, 2005]
2.9 Electro dialysis (ED)

Process description:

Electrodialysis is the transport of ions through ion-selective membranes as a result of an electrical driving force. The process takes advantage of the ability of these membranes to discriminate between differently charged ions, allowing for free passage to either cations or anions and being impermeable to ions of the opposite charge. Electrodialysis is a desalination process of brackish water and, under certain circumstances for seawater as well. The electrical mechanism of ion removal is much more complicated, and much cheaper, than chemical equivalence to replace the two ionic changes of a molecule salt, since an electric current assists greatly the dialysis or movement of the ions through membranes permeable to the positive ions and to the negative ions, respectively. A membrane which is permeable to sodium ions forms the wall on the side of a channel of flowing saline water and a membrane permeable to chlorine ions forms the wall on the other side. The deionized water flows between the two membranes, and the electric current may be regarded as flowing at right angles. The other aqueous streams on the other side of the respective membranes may flow out counter-currently in the other direction.

[Cipollina, 2009]
Techniques for energy
Energy techniques

The energy present in the oceans is enormous, and for centuries people have been trying to harvest this huge amount of energy. Modern versions of these century-old techniques and complete new techniques to capture the energy from the ocean are being explained in the next pages.

The techniques use the natural processes that are present in the oceans, as explained in chapter 1, to generate either electrical, thermal or mechanical energy. The techniques will be assessed on some important points that will be interesting to decide on a specific system for a floating building. The amount of energy that a specific technique can produce is dependent on a number of factors and is therefore very hard to name. This is why in the assessment there is only a potential energy production mentioned, this together with the other points of assessment will be enough to compare the individual techniques and find the most suitable for the situation. Another topic that will be assessed for every energy system is degree of location specificness. Some energy sources are available all over the world, where other are only available in high enough amounts in very specific places in the world. The materials that need to be used to harvest the energy from the ocean differs for every energy technique too, this will be assessed as well.

The last topic to be assessed is the visibility of the system in the architecture of a building. Some techniques do not have any influence on the building that they are implemented in, and other have a very big influence on the architecture and even the shape of the building.

The same system for indicating the quantities of the systems is being used as the previous chapter.
3.1 Tide mill

Process description:

The tides discussed in an earlier chapter, cause the seawater to rise and fall twice a day. A way to capture some of the energy present in this movement of the ocean is to use a tide mill. A tide mill is a type of water mill that uses the rise and fall of the tides to turn the wheel of the mill. The mills are usually located near the sea, sometimes in rivers. A dam with a sluice is created across a suitable tidal inlet, which possesses some kind of reservoir to store water, the mill pond. As the tide comes in, it enters the mill pond through a one way gate, and this gate closes automatically when the tide begins to fall. When the tide is low enough, the stored water can be released to turn a water wheel, and in that way generating energy.

This type of water mill has existed since the Middle Ages, a modern version of this tide mill is the tidal barrage or tidal power plant. The first method of extracting tidal energy involves building a barrage across a bay or river, similar to the creation of the mill pond. Inside the wall of the barrage there will be turbines installed that generate power as water flows in and out of the basin. Just like the tide mill, the barrage is also only capable of producing energy when the water level outside the basin changes relative to the water level inside. This makes this type of energy generation not continually, which can be a problem if there is a continues need of energy.

[Charlier, 2009]

Fig. 2.1 Operation of a medieval tide mill

Energy potential:
3000 GW of tidal energy is estimated to be available worldwide

Location specific:
Only 3 percent of the locations is suitable tidal energy generation

Visibility

Materials required
3.2 Tidal turbines

*Process description:*

In stead of using the vertical movement that tides cause there is also a way to capture energy from the tidal movement by utilizing the horizontal movement of the tides. Tidal turbines draw energy from the tidal currents in a similar way to windmills that use winds. The turbines can be connected to the sea floor or to floating constructions. The turbines can profit from both the tidal rise and the fall, so they can turn four times a day. The turbines work best close to shore, because the tidal current speed is highest in these places. A tidal turbine can generate four times as much energy per rotor swept area as a similarly rated power wind turbine.

[Charlier, 2009]
3.3 Marine wind turbines

Process description:

As discussed in the previous chapter, the ocean winds have a higher velocity and more power than land winds. They also have a more stable direction. This makes it very beneficial to use wind turbines on the ocean to generate electricity from the wind. The propellers of the turbines will be moved by the wind and will turn a generator that will produce electricity. The turbines can be placed on floating platforms that can even be moved when needed, or on a foundation on the sea floor. Generally the turbines have 3 blades that rotate.

[Nelson, 2009]
3.4 Floating moored device

Process description:

This is a technique to capture energy from ocean waves. The device floats on the surface or just below the surface of the ocean and is moored to the sea floor. One of the devices that can be used is called the Nodding Duck after a design of the University of Edinburgh. It works by rotating independently on a long link. The Duck rotates with a nodding motion as a wave passes. This way there can be generated electricity. Another device in this same category is called the Pelamis. This device generates energy by the rotating joints of a floating element.

[Cruz, 2008]
3.5 Oscillating water column

Process description:

The oscillating water column is a technique that can capture the energy existing in the ocean waves. The columns can either float in the water or be fixed to the shore or sea floor. By the motion of the wave a air pocket inside the column is being compressed up and down, which powers a turbine inside the column that generates electricity from rotation. The turbine inside the column is a so called Wells turbine, which can rotate in the same direction even though the compression is up and down.

Source: Novel ocean energy permanent magnet linear generator buoy; Rhine-frank K.
3.6 Solar pond

Process description:

A solar pond is a pool of saltwater that collects the energy from the sun and at the same time stores this energy. The saltwater automatically forms different salinity layers in the pond. In the top layer there will be low salinity water and in the lower layers will be high salinity water. So the salinity and the density increases with the depth of the pond.

The storage function of the pond works with these density differences. The highest layer is called the uppermost layer and has the lowest temperature and density. The second layer is the stable gradient layer and is the most important layer, this layer cannot rise or sink because of the density differences and therefor becomes an insulator for the lowest layer, the thermal layer. This lowest layer is the storage layer, this water can be pumped out and the heat can be used to produce energy. Or the thermal energy of this hot water (temperatures of 50 to 90 degrees) can be used directly.

[Huanmin, 2000]
3.7 Ocean thermal energy conversion (OTEC)

Process description:

The desalination technique OTEC uses the temperature difference that exists between shallow and deep waters in the ocean to generate energy (see chapter 1.5). The system can produce the most energy where the temperature difference is the highest.

The OTEC uses a heat engine to generate energy from this temperature difference, this engine is placed between a high tank with high temperature water and a tank with low temperature water. When heat flows from one tank to another, the engine converts this heat energy to mechanical energy. This is the same principle used in steam engines.

The OTEC installation can be placed near or on shore, or can be a floating platform in the ocean. Large pipes will be used to collect cold water from the deep ocean layers to be used in the system. This cold water can also be used directly for passively cooling buildings.

[Pfafflin, 2006]
3.8 Marine Biomass Conversion

Process description:

Another way to utilize the ocean is by growing algae and using the biomass that these plants contain to generate energy. At offshore marine farms algae or seaweed plants can be fragmented to produce methane, this biogas can be used to fuel a power cell or a turbine. A positive side effect of this method is the expansion of the natural ecosystem of the ocean. The marine farms form submarine forests that serve as habitats for fish and shellfish.

[Yokoyama, 2007]
Hybrid techniques
Combinations of energy and desalination systems

When designing a sustainable building it is very important to concentrate on utilizing all the local resources that are available around the building site. This opens up the possibility of using renewable energy for desalination. If at a building site you could couple two of the systems described in the previous chapters, you could make a complete renewable and sustainable cycle of energy production and fresh water production. This will make the building self-supporting for the energy production as well as the fresh water need.

There has already been done a number of research and experimental projects on how to combine these two systems. In the table on this page there is a visualization of the most common (and proven to be successful) combinations.

The main division between the different couples is the kind of energy that the desalination systems needs to perform. The systems that need electrical energy can be combined with energy systems providing an electrical current. For instance a reverse osmosis system can be combined with pv, wind turbines or electrical water energy systems, like an OWC system.

The desalination techniques that need thermal energy for producing fresh water can be best combined with warm water producing energy systems. This could be a solar pond or thermal collectors. An exception in this case it the Multi Stage Flash desalination system, this system only functions well with water on an extremely high temperature, so a special thermal collector type should be used.

A point of interest that has to be taken into account when combining desalination systems with renewable energy sources is the unpredictability and non regular energy supply that these systems provide. If there in a need for a regular, day and night, supply of fresh water, there will have to be found a way to store the energy so it can be used when the renewable energy source is not producing.

Selecting the right combination of systems depends on a number of factors. These can be amount of water and energy needed for the function of the building, the salinity of the salt water at the location and the type and potential of the local renewable energy resources.

In this chapter there will be shown a few combinations of systems.

<table>
<thead>
<tr>
<th>Energy System</th>
<th>Solar</th>
<th>Wind</th>
<th>Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar still</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi effect distillation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi effect distillation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multi stage flash distillation</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vapor compression</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Freezing desalination</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Membrane distillation</td>
<td>X</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Reverse osmosis</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Electrodialysis</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table showing successful combinations of renewable energy and desalination techniques. Source: Roadmap for the development of desalination powered by renewable energy; Michael Papapetrou; Prodes
4.1 Electrical and mechanical energy

Desalination systems that run on electrical energy can be combined easily with renewable energy systems that produce electrical energy or mechanical energy. Examples of systems that produce electrical energy are PV and wind turbines. Mechanical energy can be produced by wave energy systems and tidal energy systems. This type of energy needs to be converted into an electrical current before it can be used by a desalination system.

Examples of combination that are being used:

**PV and Reverse Osmosis**
This very popular combination collects energy from a photovoltaic field, near the Reverse Osmosis plant and uses the energy to desalinate salt water. This system needs a battery to store the energy generated during the day, to be able to run the system at night. This system can be used best for small applications, in bigger desalination plant the PV field would get to big. In this case wind energy would be more suitable.

**Wind energy and Reverse Osmosis**
Wind energy technology can be used easier than PV for bigger scale plants. The electrical current produced by the wind turbines is not very continuous, it depends on the amount and speed of the wind present. Therefore also in this combination a battery for back up power is needed.

**Wind energy and Vapour Compression**
The Vapour compression desalination system uses a mechanical compressor to compress vapour, which generates heat. This heat is used for evaporation (see chapter 2). The problem that occurs when coupling wind power with vapour compression is that the desalination system can only work at a certain, quit precise temperature which has to be continuously maintained that way. This is problematic because of the unreliable energy being offered from the wind turbines.

**Wave energy and Reverse Osmosis**
Desalination with wave energy as a source of electrical energy is a popular combination. This because waves and salt water, the main ingredients are...
available at the same location in most cases. This type of hybrid system can be used for small scale as well as large scale plants. A way of storing the energy generated by the waves in case of a calm sea day, is illustrated in the picture on the right. In this system they use the wave generated power to transport water up an elevation. In this storage tank the water can stay till the need for energy requires the water to be released again. In this process a turbine can extract the energy that was put in the rising of the water and provide the necessary electrical energy.

**Wave energy and Vapour Compression**

This combination works in the same way as described before. The wave energy can supply the mechanical compressor of the desalination system of its energy demand.

**Tidal energy and desalination**

Tidal energy is not yet researched a lot in combination with desalination. In theory it works the same coupled with a desalination system as wind turbines do, because of the similarity of the rotating blades. The negative point on using this type of energy is the location specificness of the system. There are only a few places on the earth where tidal energy has enough energy generation to support a desalination plant.

[Koschikowski, 2003]
[Papapetrou, 2009]
4.2 Thermal energy

The sun is a perfect energy generating element that can be used in almost all locations in the world as a renewable energy source. In the chapter about desalination we already discussed the use of solar energy as a direct source of energy for the desalination in a solar still (see chapter 2.1). But the sun can also be very beneficial in the combination of energy and desalination techniques in an indirect way. In this case the solar energy will be captured by use of for instance solar thermal collectors, that supply the desalination system with its need for thermal energy.

Next we will discuss some possible and used combinations of desalination systems that work with an input of thermal energy.

Solar thermal collectors and Multi Effect Humidification
The multiple evaporation and condensation cycles that this type of desalination system offers require input water of temperatures between 70 and 85 degrees. When using solar thermal collectors the process will go faster and the system will deliver more fresh water per m² of area.

Solar thermal collectors and Multi Effect Desalination
This type of desalination can be easily combined with solar thermal collectors, because it needs water of a temperature of 60 - 90 degrees to start the process of the different effects. Water of this temperature can be supplied by solar thermal collectors during the day and needs to be stored in water tanks during the night, as to have a 24 hour desalination cycle.

Solar thermal collectors and Membrane Distillation
Membrane distillation is the only membrane desalination system that instead of electricity, thermal energy uses. The thermal energy is used to increase the vapour pressure on one side of the membrane. The temperature of the input water is required to be 60 - 80 degrees. This makes this system very well suited for a combination with solar thermal collectors.

Ocean Thermal Energy Conversion (OTEC)
This technique of generating energy from the temperature difference between different layers in the oceans, is very easy to combine with desali-
nation. In this case there is no need for assisting a desalination plant, the desalination system can be implemented in the OTEC system itself. In this hybrid version of the OTEC plant the warm seawater, of the upper layer of the sea, enters a chamber where the water is evaporated into vapour. The vapour can then generate energy by turning a turbine. The vapour then moves to a new chamber where it will condensate by coming into contact with the cold seawater of the lower layer of the sea. This way fresh water is produced. This system is very well suitable as a combined system because the fresh water can even be considered as a side product of the OTEC system, this means that there is only a small change necessary in the system to make it a hybrid system. At the same time will the OTEC system keep producing energy which can be used for other functions too. The only limitation in using this system is the limited amount of suitable locations that can use OTEC. Only the areas around the equator are suitable for this type of energy generation, because at that location is a big enough temperature difference.

Solar pond and desalination
Thermal desalination by salinity gradient solar ponds is a very promising solar assisted desalination technology. Compared with other solar desalination technologies, solar ponds provide also a very good heat storage. It is very important that if a renewable energy system that is supporting the desalination can deliver energy 24 hours a day. The heat storage of solar ponds allows them to power desalination during cloudy days and nighttime. Another important benefit of using this method to support desalination is that the system can utilize, what is often considered a waste product, namely reject brine, as a basis to build the solar pond. The best desalination system to use in combination with a solar pond is the MED systems (Multi Effect Desalination; see chapter 1.3) because this system requires an input of warm water of about 80 degrees.

[Papapetrou, 2009]
Demands of a spa building
5.1 Spa building type

Spa buildings are most commonly focused on nonmedical physical, spiritual, and therapeutic treatment and relaxation. Therapies range from the traditional massage, also in numerous variations, to facials, wraps, pedicures, manicures, and a variety of other pampering treatments. They also facilitate recreational water use, like swimming, and different types of baths. Saunas and steam rooms are also an important part of a spa. Spas may be day spas, resort spas, or destination spas. Day spas offer a menu of treatments oriented to the person coming from home. Resort spas are a part of or affiliated with a hotel or resort, but they are not normally dedicated to an exercise or nutritional regimen. A destination spa caters to at least a weekly commitment by the guest to a program of physical exercise, a nutritional menu, spiritually uplifting programs, and pampering treatments.

The main feature a spa has to project is a high level of luxury and tranquil atmosphere. When the guests enter the spa they should be able to leave the hectic and stressful life behind. In the spa the staff will take care of all the guest’s needs.

A guest at the spa first arrives at the reception desk. The desk consists of, at least, two workstations for staff to handle check-in, phone reservations, and spa appointments. Some situations use the main desk as a cash-wrap for handling retail transactions or payment for treatments. Service orientation of some spas demands a staff person to personally escort the guest to the next step in the process. In some cases there will be a division at the reception desk between different areas of the complex. Some maybe family areas, where swim wear is required and other areas maybe single gender areas.

Following check-in, the guest is directed or escorted to the women’s or men’s reception area and waiting lounge. At this point, the user is assigned a keyed locker and oriented to the locker room and rest rooms. Amenities like steam rooms, saunas or swimming may be part of the guest’s regimen prior to a treatment. Nearing the appointment time, the user retires to the waiting lounge to be met by the therapist. Lockers are day lockers, a fresh robe is placed in every locker, or handed at the reception desk, which is keyed to protect the user’s clothes and valuables. The locker rooms attendant provides slippers in the guest’s size. Locker rooms also include a hamper to collect used robes, towels and slippers.

Wet areas are opportunities to project the spa facility’s degree of luxury. In addition to different kinds of swimming pools, spa wet areas include a number of shower areas with all kinds of soap and scrubs, steam rooms, saunas, jacuzzis, hamam areas and herbal baths.

To complete the experience of luxury most spas also provide a restaurant. The menu will mostly consist of healthy and cleansing food and drinks and the interior and waitering should again express the pampering atmosphere of the spa.
When investing a lot in finding suitable systems to utilize renewable and sustainable sources of energy and fresh water in the design of a spa, it is also mandatory to make sure that the building does not waste the energy and fresh water that is generated. To limit the loss of energy and fresh water it is important to design the building in such a way that the transmission, convection, vaporization and radiation losses of the different parts of the program are minimized as much as possible.

By making smart decisions in the use of materials and systems the amount of energy lost can be reduced noticeably. Working with the principles of a bioclimatic design will even limit the need for more energy and at the same time create an inside environment that is more healthy and pleasant for the guests.

To limit the loss of fresh water the most important area to focus on will be the waste water from the different pools and the large amount of showers. If the so called “grey water” is lead directly to the sewage the amount of new fresh water needed every day will be enormous. For this reason it is required to find a way to clean the grey water so it can be used again. There are a lot of options for cleaning grey water on site, for instance the use of constructive wetlands. The wetlands can clean the grey water by using specific plants, like reets. This way the amount of new fresh water needed will decrease substantially.

In the next chapters the different parts of the program of the spa are being explained together with the energy and fresh water use of these programmatic parts. Also the ways of saving energy and fresh water will be discussed.
5.3 Pools

In a spa different types of pools may be present. Some might be actual swimming pools with a depth of about 1.5 - 1.7 meters; others might be salt water pools. Plunge pools are used to cool off fast after a sauna visit. Herbal baths help relax the muscles and the herbs can soothe the skin and stimulate blood circulation. Jacuzzis offer a relaxing bath experience because of massaging jet streams. All of them have a specific energy use and a fresh water use. Only salt pools are excluded from fresh water use.

Energy use:
The energy use in pools is divided in electrical energy use and thermal energy use. Thermal energy is used for keeping the pool water at the right temperature and space heating or cooling. Electrical energy is used for the water purification of the pool water, for the ventilation and humidity and for the lighting and other services surrounding the pool.

To calculate the energy use for the heating of the pool water there is a general rule of thumb that applies. This rule says that the heating requirements of a pool are 0.45 - 0.65 kW/m³.

Most of the electrical energy for the water purification is consumed by the pool pump. This pump has to transport the water that has been purified back to the pool. This means that the pump has to transport the water the amount of metres that the pool is deep. This will indicate the amount of energy the pump uses, as shown in figure for energy use of pumps. Important for the use of energy of the pump is also the flow of filtration system. This is part of the turn over of a pool, which is the number of hours it takes to circulate the pool volume through the filtration system.

Energy loss:
The pool itself is the heat storage medium of a swimming pool system. The usefulness of the system lies in the storage. The solar heating system must compensate only for the storage losses, i.e. the losses of the pool. The pool losses consist of convection losses, radiation losses, vaporization losses and transmission losses.

The transmission losses of a pool are heat losses that are transferred from the pool water to the construction or earth around the pool. The construction of the pool building plays a big part in the quantity of these losses. Determining of the value of this loss is the thermal transmittance coefficient of the building materials used. The convection losses consists of heat loss from the pool water surface in contact with the surrounding air. Elements that influence this loss is the difference between the air temperature and the water temperature, the water surface area and the presence of wind above the water surface.

The radiation exchange between the swimming pool surface and the sky causes radiation losses, by the transfer of heat energy through empty space by electromagnetic waves.
Ways to reduce the energy demand:
There are a lot of design interventions that can reduce the amount of energy that a pool will use. It is very important to look into the material use in the foundation of the pool building, this will influence the transmission losses of the pool. This can also be solved by using a insulating material around the pool volume. It is also necessary to increase the insulation of the other parts of the pool building, like the main walls and roof structure. In the material use of the facades it is important to avoid using too much glazing. Large areas of glazing can increase pool hall heat losses up to one third.

Another important part to take into account is the ventilation of the pool hall, when reducing the loss of radiation and convection losses. The ventilation should be lower during the night to reduce heat loss of the inside air, also during the day there should be heat recovery from the outgoing air to preheat the incoming fresh air. During the night it is also required to cover the pool surface to limit the losses because of evaporation.

Fresh water loss:
The fresh losses of pools depends on different factors. The most important way a pool losses fresh water is by evaporation. The amount of evaporation depends mostly on the temperature difference between the pool water and the air surrounding the pool. The higher the difference the more water will vaporize from the pool surface. Also the humidity plays an important role. When the humidity is very low, there will be more evaporation.

Ways to reduce the fresh water demand:
There are several ways to reduce the demand for fresh water, the most important measure is to prevent water evaporating from the pool. During the night the easiest way to accomplish this is to cover the pool surface. During the day, when the pool is in use, measures can be maintaining a high humidity level in the air inside the pool hall or a higher air temperature and air circulation.

[Dawes, 1979]
[Hoogstraten, 2010]
5.4 Saunas

The saunas in spa nowadays are mostly Finnish saunas. The consist of a wooden space with wooden benches for sitting or lying down. The temperature of a sauna can vary from 70 to 100 degrees, with a very low relative humidity of 10 to 20 %. Because of this dry type of air it is possible for the body to endure these high temperatures.

The main advantage of taking a sauna is because of its cleaning function. In the sauna the body will try to cool of the body by sweating a lot, this will open up the pores in the skin and will clean the body from toxins. Cooling down after taking a sauna is very important. Therefor there should always be a cold plunge pool or a cold shower available close to a sauna.

Energy use:
There are different methods of heating a sauna. The main heating device is the sauna stove, this can be heated with firewood or electricity. It can also be heated with oil, bottled or natural gas. The heater heats up hot stones that need to be present in the stove. The stones in their turn heat up the room by producing hot vapour and thermal radiation. When water is trown on the stones the temperature of the room usually goes down, although the opposite is felt by the bather because of the increase in humidity.

There are two main types of stoves used in the sauna. The first is a heat-storage stove, where the stones are heated to the desired temperature before bathing. And there is no additional heating during the actual bathing. The second type is a continuous burning stove, which is heated prior to bathing and during it. This last type of stove is used in most modern saunas because these can be electrically heated.

In the electrical stove the stones are heated by elements placed beneath, among and around the stones. The sauna gains its heat from air passing through the stove. The temperature is regulated by an element control unit and a thermostat. The electrical energy that this stove uses it dependent of the volume of the room. (see table)

<table>
<thead>
<tr>
<th>Dimensions of sauna</th>
<th>Electrical energy use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small; 6 - 8 people</td>
<td>4.3 kW</td>
</tr>
<tr>
<td>Medium; 8 - 10 people</td>
<td>5.4 kW</td>
</tr>
<tr>
<td>Large; 10 - 14 people</td>
<td>7.6 kW</td>
</tr>
</tbody>
</table>

Table energy use of sauna types; after MLSEISP

Ways to reduce energy demand:
Sauna consume a lot of energy, especially the ones that are located in a spa, and need to be heated continuously. An important factor that causes a lot of heat loss is the ventilation system that is used to provide the sauna with fresh air. Preheating the incoming fresh air with the heat of the outgoing air is a simple but very rewarding measure. The properties of the materials used for the walls, ceiling and floor of the sauna are also very important to limit the loss of heat from the sauna. All the surfaces in the sauna have to be thermally fully insulated.

[Dawes, 1979], [Hoogstraten, 2010], [Rakennustieto, 2008]
5.5 Steam rooms

A steam room is like a sauna, an enclosed room with benches to sit on. The main difference from the sauna is the highly humid environment. The space is saturated with large amounts of high temperature steam. The steam rooms generally have a temperature of 41 degrees or above, with a high humidity of around 100%.

Guests can stay in the steam room for about 10 to 20 minutes cleaning the pores of their skin and stimulate blood circulation. Another benefit of using the steam room is that it can clear up the respiratory system. People have indulged in steam baths for centuries, going back to the old Turkish and Roman reign. Like a sauna it is important to cool off after using the steam room, by means of a plunge pool or a cold shower.

Energy use:
There are two different ways of heating the steam room. The first one is generating steam by heating water. The hot water vapour will be lead into the room, or the hot water will be lead directly into the room, where the water vapour can fill the room. More modern ways of heating the steam room is using a electrical steam generator.

Electrical energy use of a steam generator differences with the dimensions of the steam room. (see table)

<table>
<thead>
<tr>
<th>Dimensions of steam room</th>
<th>Electrical energy use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam room medium</td>
<td>11.2 kW</td>
</tr>
<tr>
<td>Steam room large</td>
<td>16.6 kW</td>
</tr>
</tbody>
</table>

Table energy use of steam room types; after MLSEISP

Ways to reduce energy demand:
The ways to control the loss of heat, and in that way the loss of energy, from the steam room are the same as the ones of the sauna.

[Dawes, 1979]
[Hoogstraten, 2010]
5.6 Showers

A function in a spa that is often underestimated in its use of energy and water is the showers. In a spa it is normal to shower many times, the first time before you enter the spa, after the changing rooms. After that visitors will take a shower after every sauna or steam room visit, to cool off and wash the sweat off before going in a pool. Also a visitor will shower just before leaving the spa and after a massage or beauty treatment.

Energy and fresh water use: 
The previous means that the average visitor in a spa takes about 4 - 6 shower during his or her visit. Considering the fact that one shower per person consumes 2.9 kW of thermal energy and about 40 - 50 liters of fresh water, this will add up to a value that will influence the total energy and fresh water use of the spa enormously.

Ways to reduce the energy and fresh water use: 
It will be inevitable for a spa to use a big amount of energy and fresh water for its showers. There are some small ways on how to reduce the energy use, by re-using the heat of the water with heat exchangers. Also there are a number of water saving shower heads available that can reduce the amount of water used.

The most important thing to think about when trying to make the showers in a spa sustainable is the re-use of the water. The water will not be very dirty in most cases so if the spa uses biodegradable soaps, it will be very beneficial for the fresh water consumption to treat the water with reet filters and use the water again after being treated.

[Dawes, 1979]
[Hoogstraten, 2010]
Implementation of techniques in the architecture
Conclusion

After looking into all kinds of different techniques for energy and desalination and successful combinations of the both of them, in this chapter there will be made some recommendations for solutions on how to implement the different systems in the architecture of a building.

The recommendations have to be seen as simple suggestions, with the information provided in the previous chapters it should be possible to find a suitable system, or combination of systems, that will fit the specific project. As mentioned before it is almost impossible to give one simple answer for every program a building could have. The type and amount of resources of renewable energy available in the direct surroundings determine for the biggest part the energy system that should be used. This together with the specific brief of the building will have to determine the scale and type of desalination can be linked to the energy system. After that has been decided it is up to the architect to dream about possible implementations of the combination he or she has found. It is possible to find hundreds of great implementations that bring the best out of the sustainable architecture and can provide the building of all its energy and fresh water need.

In the appendix after this chapter there is a more extended summary of possible solutions implemented in floating buildings.
Tidal energy

When the location provides a big enough tidal range, it might be interesting to use tidal energy to power the building and the desalination system. In this case a possible implementation could be the construction of a tide pond next to the floating building. Naturally the building would move up and down with the tides and the tide pond would stay in one position, so to collect the water at high tide and releasing it at low tide.

Another option to profit from the tidal energy is using the tidal current that exists in some locations. This solution will not have a big impact on the architecture because of the construction of the tidal generators underneath the floating building.
Wind energy

In most locations on the water there is enough wind to allow the use of wind turbines. These turbine will be very visible in the building, but it might be hard to find a way in which they can contribute to the architecture of the building.

The wind can also be used in a passive way to provide the building of cooling. This way the building will use less energy, which can also be very interesting. To profit optimally of the cooling by the wind, the building should be designed to allow most of the wind to enter.
Wave energy

If the building is floating in a location that has enough waves it might be interesting to use a system to collect the waves, different systems have different ways of implementation in or around the building. A example of a wave system could be a OWC system. This system can be constructed on the edge of the building that receives the most waves.

Another option of harvesting the wave energy is the wave dragon. This system collects energy from incoming waves and has as extra advantage that the water behind the wave dragon will be free of waves. This is positive for floating buildings because this will reduce the need for stability construction to protect the building from rocking with the waves.
Solar energy

Solar energy is available in all the locations in the world and will be an option for a lot of floating buildings. A way to profit from the energy from the sun can be to construct a solar pond next to the floating building. The pond needs to float to avoid contamination with seawater during high tide. This might be too expensive. Another option is to construct the solar pond on the shore near the floating building.

If the location is near the equator the building could use an OTEC installation to generated energy as well as produce fresh water. The OTEC systems have the negative point of not being visible in the building.
Solar desalination

A solar still, possibly assisted by solar thermal collectors, is a very good way to demonstrate the production of fresh water in a building. The ponds required for this system can be placed along the sides or in the middle of the building.
Multi effect humidification

This type of desalination is very suitable to be implemented in the architecture of a building. The system can be installed as a roof or facade around a pool or another function of the building. This way the system can profit from the incoming sun and at the same time protect parts of the building from the sun.
Multiple effect desalination

This type of desalination can be implemented in the architecture in a number of ways. One option is to install the different effects (chambers) on top of each other in a wall. The roof in this case can be covered with solar thermal collectors and provide the system of hot water. The seawater can be sprayed on top of the pipes with hot water and turn into vapour. This system could even be constructed of transparent materials to make the process visible in the building.
Appendix
<table>
<thead>
<tr>
<th>Ankoring</th>
<th>Solar energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram 1" /></td>
<td><img src="image2.png" alt="Diagram 2" /></td>
</tr>
<tr>
<td><strong>Poles</strong></td>
<td><strong>Spring</strong></td>
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<tr>
<td><img src="image3.png" alt="Diagram 3" /></td>
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</tr>
<tr>
<td><img src="image5.png" alt="Diagram 5" /></td>
<td><img src="image6.png" alt="Diagram 6" /></td>
</tr>
</tbody>
</table>

A solar pond producing thermal energy on the floating foundation.

A solar pond producing thermal energy next to the floating building.

An OTEC installation inside the floating foundation can produce electrical energy.

An algue farm grows algue next to the building which can produce electrical energy from biomass.
<table>
<thead>
<tr>
<th>Ankoring</th>
<th>Wind energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
<tr>
<td><img src="image3" alt="Diagram" /></td>
<td><img src="image4" alt="Diagram" /></td>
</tr>
</tbody>
</table>

Wind turbines are placed on the floating foundation to generate energy from the ocean winds. Wind blowing over the ocean can cool the building passive. Wind blowing over a pond on the floating foundation and partially inside the building can passively cool the building.
<table>
<thead>
<tr>
<th>Ankoring</th>
<th>Wave energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Poles</strong></td>
<td><img src="image1" alt="Diagram" /></td>
</tr>
<tr>
<td><strong>Spring</strong></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

A wave dragon catches the waves and produces electrical energy, it is placed in front of the building as to function as a breakwater for incoming waves.

A nodding duck produces electrical energy from the waves and also blocks the waves for the building.

An OWC installation is placed in front of the building to generate electrical energy from the waves.
<table>
<thead>
<tr>
<th>Ankoring</th>
<th>Tidal energy</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Diagram" /></td>
<td><img src="image2" alt="Diagram" /></td>
</tr>
</tbody>
</table>

**Poles Spring**

A tide pond is placed in front of the building, this construction will not rise and fall with the tidal movement. This way it can store water during high tide and release it during low tide, generating energy.

**Tidal energy**

The rise and fall of the building and the floating foundation can also generate energy from the connections with the anchors.

Tidal turbines are placed underneath the foundation generating energy from the tidal currents.
<table>
<thead>
<tr>
<th>Scale</th>
<th>Desalination</th>
</tr>
</thead>
<tbody>
<tr>
<td>Detail</td>
<td><img src="image1" alt="Diagram" /> <img src="image2" alt="Diagram" /> Inside the walls of the building there can be an integrated visible system of multi effect distillation. Warm water from solar collectors will be led through the pipes and salt water will be sprayed on it, which will vaporize the water, this will condensate in the room next to it and create fresh water.</td>
</tr>
<tr>
<td>Building</td>
<td><img src="image3" alt="Diagram" /> <img src="image4" alt="Diagram" /> Surrounding the building envelop there can be system of multi effect humidification be placed. It will create fresh water and also block the sun from the pool, as to limit the fresh water loses from evaporation. On both sides of the building there can be ponds with salt water, these will evaporate the water and create fresh water. The design makes it possible to look outside over the pond. The roof is build to function as a solar still, and at the same time catch the evaporation water of the pool.</td>
</tr>
</tbody>
</table>