

(RE)DESIGNING THE PIER

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### Abstract

The Pier of Scheveningen is closed. Exploiting it wasn't feasible, due to unclear functions and high maintenance costs, because of the extreme environment at the Dutch shore. This paper explores the potential of the pier in Scheveningen, as a self-sufficient valuable complex at the Dutch coast. An analysis of the location of the pier showed that especially wave, wind, thermal and solar energy provide opportunities for energy neutrality. A combination is needed, because most of these sources cannot be generated at any time of the day. It shows that Scheveningen is in need of more hotel accommodations and the conference possibilities fit the international ambitions of the municipality. The public function of the pier is related to the experience of Scheveningen as a seaside resort. Therefore, the continuity of this promenade and the presence of a lookout point are essential. The current structure is made out of concrete and demolishing this would mean a loss of material and a burden for the environment. It is best to work with the already existing structure, even with the challenge related to the high salt levels.

*Keywords:* Pier, Scheveningen, The Hague, Sustainability, Renewable Energy, Coastal Area, Extreme Environment, Redevelopment, Tourism, Self-Sufficient.

### Definitions

#### Pier

*-a structure sticking out from the land over the sea, where people can walk or boats can be tied, sometimes with restaurants and places of entertainment on it (Oxford Dictionary)*

*-sea protruding dam; resting on a pillar scaffolding (van Dale)*

#### Mare Liberum

*an almost poetic pamphlet of Hugo Grotius written in 1609. About freedom of trade under the lofty slogan: "freedom of the sea". Grotius states: the sea belongs to no one.*

#### North Sea

*Sea between The Netherlands, England and Norway.*

## (RE)DESIGNING THE PIER

Until a few years ago, one could take a stroll above the sea in the Netherlands. This was made possible by the Pier of Scheveningen, which is part of the city The Hague. In 2013, the pier was closed, but not because of a lack of visitors: In 2004 17.7 million people visited Scheveningen and the Pier had around 585.000 unique visitors (ZKA Consultants & Planners, 2006). However, the safety could not be guaranteed anymore. Since operation costs became higher and margins over profits smaller, maintenance was not or partly performed since the 1990s by the former owner. Since a few years the pier wasn't profitable anymore and the pier was put up for sale in 2012. Eventually the Pier B.V. went bankrupt in 2013 (Omroep West, 2013). At this moment, the pier is under ward, but there is a lack of interest. This is due to the high investment costs to make the pier save and operable for coming decades. So why not demolish the pier? It is possible to make the pier profitable again and give the city back what the pier was: a romantic attraction for all. Scheveningen and the Pier are undeniably linked together. The first Pier in Scheveningen was built in 1901. The original pier was built in front of 'Het Kurhaus' and was built of cast iron. After demolishing by the German occupiers in World War II, a new pier was built in 1959. Until the beginning of the 1970's the pier was visited by upper-class Dutch and German people who wanted to enjoy the seaside. But from late 60's on, tourism is changing. More people can afford cars and more and more 'regular' day-visitors are coming to Scheveningen. With a small nadir in the 70's, the pier has been the major attraction for Scheveningen, which is still the main seaside resort in the Netherlands. In the 90's the former owner bought the pier and transformed it to a big leisure attraction, as it looks nowadays. The pier has been the face of Scheveningen for more than a hundred years.

To make sure the pier will survive at least another hundred years, the durability of the materials, functions and structure should be optimal. However, the use of a building is time dependent and cannot be set for a long period of time. Therefore a certain adaptive capability has to be considered, so buildings can survive long periods of time and hence to be sustainable for the future (Beadle, 2008). The way of living in contemporary society creates a heavy burden on the environment. An example of this statement are the world CO2 emissions. These have never been so high and will be around 2035 raised by 28% (Ernst & Young LLP, 2014, p. 14; IPCC, 2014). This will cause a temperature rise of around 2 degrees Celsius, which will inevitable have effects

on the world's climate and behaviour. This is just one consequence of human behaviour. Further examples are depletion of natural resources, exploiting humans and animals, extinction of flora and fauna, etcetera. However, the biggest social problem is not climate change, but the depletion of our energy reserves. This is a social economic problem rather than a technical one. This paper therefore involves the sustainability of the (re)design of the pier and how to deal with its local footprint. As a principle the New Stepped Strategy (NSS) will be used, given the importance of immediate integration of sustainability in the design. This strategy involves three steps (see figure 1): Reduce consumption (using intelligent and bioclimatic design); Reuse waste energy streams; Use renewable energy sources and ensure that waste is reused as food (Tillie, 2009).

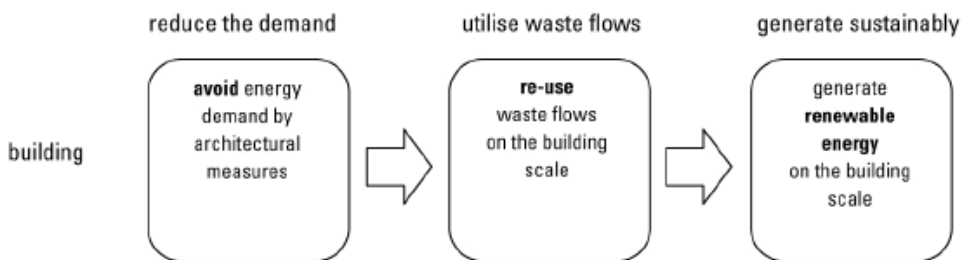


Figure 1/ the new stepped strategy (Tillie, 2009)

The importance of the Pier in Scheveningen is clear, as well as the relevance of responsible development for a sustainable future. The combination of these two aspects leads to the following research question: What is the potential of the pier in Scheveningen, as a self-sufficient valuable complex at the Dutch coast? To answer this question, a few sub questions have to be answered: What are the requirements for a (re)design of the pier in Scheveningen in order to be self-sufficient and to add to the seaside experience? What specific demands are required for materials that are used in coastal areas? These questions will be answered in order to, in the end, be able to (re)develop a pier that is at least energy neutral and has functions that add to its context.

As figure 2 shows, this part of the research can be reduced to four main themes: Location, context, structure and use (functions and appearance). A pier is closely related to its location, the coastal area. There is no single scientific way to define a coastal area. For a geophysicist the Dutch coast begins west of Utrecht, a painter will think of it from the sight of the dunes on, while a sailor

knows that he sails in coastal waters when he experiences shallows and land looms on the horizon. So a definition of 'coast' exists by the grace of interpretation. From this point of view coast is a perception of space: the perception of the transition from sea to land, in physical, social and mental terms (Bomans, 2003). In this research the coastal area will be defined by the space that reaches from the city district Scheveningen to one kilometre into open sea.<sup>1</sup> Closely related to the coastal area is the sea it is connected with. So for this paper the acquaintance of the North Sea is important. The first chapter, about location, defines the different potentials of the location with regard to energy potentials. Therefore, climate characteristics, environment behaviour and linked regulations, and also more global applicable properties like sea behaviour, will be discussed. Also, this chapter refers to the technical aspects of renewable and sustainable sources.

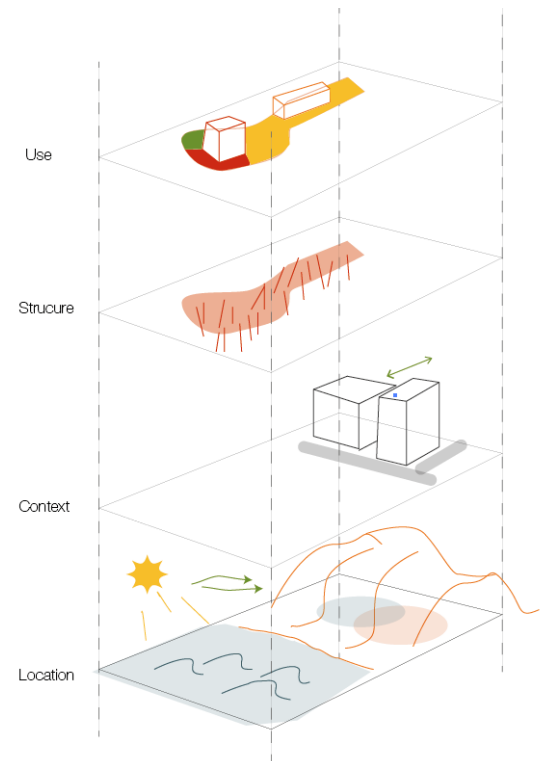


Figure 2| Build-up layers (IJsselstijn, 2014)

The context of the pier will be analysed in the second chapter. This context analysis shows the functioning of the area in multiple levels, from its economic relevance and to the wishes and regulations of the local administrations. Tourism is a very important part of this analysis, for several reasons. Tourism determines a large part of the economic opportunities and the ambiance in Scheveningen. For the experience of Scheveningen as a seaside resort, the continuity of the pier in relation to the beach and the boulevard of Scheveningen are of importance. The third chapter is closely related to this analysis, since different possibilities with regard to the function of the pier will be discussed. It shows for which different functions the pier can be used, and how and why these are needed or suitable for the pier. These functions are important, because it defines the estimated energy demand of the pier.

<sup>1</sup> This definition is based on administrative purposes: the powers of the provinces and municipalities situated on the coast extend to one kilometre from the coast. Further the national government is administrator.

The fourth chapter deals with the structural elements that support the building. Different support types and materials that fit function and location will be described, namely concrete, steel and wood. These materials are selected, because they are most common in constructions in marine environments. Three aspects will be highlighted, namely durability, flexibility and recycling. Durability refers to the lifespan of the material and what factors influence this lifespan. This is relevant, because the aim is to design a building that can last for 100 years. However, the function of a building might change in this period of time. Therefore, flexibility is also desirable, in particular with regard to the structures related to the function. Recycling of the materials is discussed, because environmental considerations should also play a role in the choice of materials.

### **Location**

Continuing concerns about the future of fossil fuels have been a major catalyst of growing interest in renewable energy sources. These concerns are well funded by scientific research. The most recent report of the International Energy Agency shows that the energy consumption and gaining of the Netherlands has to change dramatically in order to be prepared for a sustainable future.<sup>2</sup> Therefore, in this chapter, the options of using sustainable sources at the location of the Pier are explored. Ideally, a sustainable source is one that is not substantially depleted by continued use, does not entail significant pollutant emissions or other environmental problems, and does not involve the perpetuation of substantial health hazards or social injustices. In practise only a few energy sources come close to this ideal, especially renewable sources appear to be ideal (Boyle, 2004, p. 2). Therefore, the considered solutions to make the pier energy neutral only contain renewable sources.

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<sup>2</sup> The report of the IEA has a predominantly economic input. This reflects in the fact that the report is not ideologically in sustainable development. To read a more sustainable advice the Greenpeace 'Towards a fossil free energy future' report is of more interest.

## Renewables and economics

Although renewable sources are interesting because of environmental reasons, economic factors also play an important role. Multiple institutions from all over the world try to give insight in these costs. For this paper the FEEM Project by Cases is used, an European Union funded research program to get a full perspective of the total costs of a certain fuel. This also includes the environmental and social costs of a fuel, the so called external costs. This includes the costs for healthcare, cleaning of environmental damage and pollution, taxes and so on. Table 1 shows the private, standard and the external costs. The difference in the private and external costs for the conventional and renewable sources is interesting. The external costs for renewable sources do not

Table 1/

**Private and External Costs for Different Fuels in Eurocents/kWh** (Markandya, 2012)

Fuel	private	external	total
<i>Conventional Fossil Fuel</i>			
Heavy oil Condensing	6,66	2,40	8,97
Hard Coal Condensing	3,33	3,14	6,47
lignite Condensing	2,68	2,65	5,33
natural gas Combined Cycle	4,81	1,39	6,20
nuclear	3,10	0,21	3,31
<i>Renewables</i>			
Hydropower run of river	7,83	0,06	7,89
Hydropower Dam	11,04	0,08	11,12
Wind onshore	6,11	0,10	6,21
Wind offshore	6,36	0,09	6,45
Solar PV open Space	35,91	0,89	36,80
Solar Parabolic Trough	12,76	0,12	12,88

*Note: the difference between onshore and offshore is almost not noticeable in this table, but other researches are showing large differences between these two. Offshore costs are sometimes two to three times higher than onshore. This is mainly a result of higher construction and maintenance costs and conversion losses over transport (Hellings, 2010, p. 20).*

even come close to costs for conventional fossil based sources. Since the external costs are most of the time not borne by the energy producer, but by consumers, energy producers are still likely to use conventional sources. Thus, for the society, renewable sources are especially of interest. Another issue is the constant rate of energy, since demand and production are not always in balance when using renewable sources. By keeping production as local as possible, this problem can be solved partially, since the link between demand and production is very direct.

## Climate data

Data about energy demands underline the importance of this subject: the total energy use in The Netherlands in 2012 was 3.269 PJ (Compendium voor de leefomgeving, 2013). Only 4,5% of this energy use was produced by renewable sources (Compendium voor de leefomgeving, 2013b). The Hague has a total use of 53 PJ<sup>3</sup> and the pier had an estimated annual energy use of 0,00801 PJ<sup>4</sup>.

The coastal area location is interesting in terms of potential energy sources. Since it is on the transition zone from sea to land, energy derived from both situations can be used. In this chapter several sources will be explained that can be used in this transition zone in The Netherlands. Obviously, the typology pier can benefit from its location on this transition zone.

Data about wind and sun is derived from the Koninklijk Nederlands Meteorologisch Instituut(KNMI). To get the best average data, three coast stations are used for data analysis: Hoek van Holland, Valkenburg and IJmuiden. These stations are spread over the coastal line of the Netherlands. With regard to the wind conditions, the station of Ijmuiden and Hoek van Holland matches the situation in Scheveningen best. For sun data a combination of Hoek van Holland and Valkenburg is used, since these locations are close to Scheveningen. Analysing this data shows that the average numbers of the two datasets, wind and sun, gives almost equal numbers for the locations. Therefore, a combination of the data of all three places is used.



Figure 3| Monitoring stations. 1. Hoek van Holland 2. Valkenburg 3. IJmuiden. Map source: (National Geographic, 2014)

<sup>3</sup> Rough estimation based on the total energy use of the Netherlands divided by ratio of total CO2 emission of the Netherlands and CO2 emissions of The Hague. This number is just for visualisation and cannot be taken for granted, since too many variables are not scientific calculated.

<sup>4</sup> Based on amount of square meters multiplied by energy demand per floor area. This is all energy combined, where it is more efficient to calculate energy for heating and electrical energy separate, so losses can be minimized and different sources calculated.

## Tidal Energy

Tidal energy is the result of the interaction of the gravitational pull of the moon and, to a lesser extent, the sun, on the seas. However, the North Sea has certain characteristics that make tidal energy production not feasible. The sea has three amphidromic points, which is a natural phenomenon of places where no tide occurs. When a ship lies at anchor there, it remains level, while the sea goes up and down. As figure 4 shows, the maximum tide in front of the Dutch coast is relatively low (a maximum

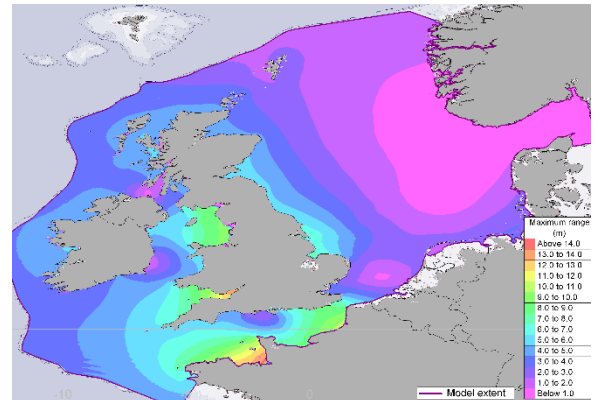


Figure 4| Maximum tidal range Atlas produced by the Coarse Continental Shelf Model (innovation & research focus, 2010)

of 2 meters at the shore of Scheveningen). This is due to an amphidromic point between The Netherlands and England. Parts of England and especially France are more suitable for tidal energy, where much more energy can be produced. Tidal energy is not considered as a good energy source for the Dutch coastal area, but might become interesting again if energy prices will rise and even the small yields make it feasible.

## Wind

Wind action is one of the oldest energy sources that provides mankind with mechanical power. In the Netherlands, windmills were used to shape the land to its current state. By pumping the water to higher levels, polders were created. Furthermore, wind power was used for and other mechanical applications, like milling grain. Since the 1980's wind action is used for energy production with so called wind turbines (Boyle, 2004, p. 244).

Coastal locations always have to deal with wind. Sea breezes occur because of different heat capacities of sea and land (Boyle, 2004, p. 247). These breezes are always present, in theory. Stronger winds on a bigger scale are created due to high and low pressure zones. In coastal areas these winds are stronger than on land. This is a result of the open character of coastal areas. The more land inwards, the energy of the wind decrease because of buildings, trees and other obstacles.

Data shows that the average annual wind speed of Hoek van Holland is 7.0m/s and IJmuiden 7.2m/s. With an average of 7.1m/s, this is a lot more than for instance Valkenburg, which is more land inwards, with an average of 4.8m/s. This knowledge, together with the fact that wind is always present in the coastal area (see figure 5), shows that it would be foolish not to use wind power as an energy source. The wind direction is more than 50% of the time from South West orientation. The remaining 50% of the times, it is equally spread over the remaining orientations (KNMI, 2014).

Large wind turbines are, compared to the cost for production and maintenance, one of the most economical attractive renewable sources if placed on shore. Wind turbines have some environmental impacts that have to be considered: Noise, electromagnetic interference and visual impact. It is very important to deal with these problems in a good way, since the object will be placed on or near the beach and the energy production shouldn't interfere with the beach-experience.

As an example of a suitable application for the pier, a relative small wind turbine of 5,5m<sup>2</sup> is selected. Because of its small size, there will be less noise<sup>5</sup>, the visual impact is smaller and it can be installed on or under the pier. The annual production with an average wind speed of 7.1m/s is around 17600 kWh a year including (0.00006336 PJ).

## Wave Energy

Wave energy is energy caused by the action of wind over water. The North Sea doesn't have very high waves, with an average of 0,5 meters and a frequency of 4,4 seconds. However, it still has a constant wind action that gives an average of 100 kWh per meter crest length per day and 36500 kWh yearly (Boyle, 2004, p. 307) (Baal, 2011). A wave turbine of one meter can produce around 0,0001314 PJ on a yearly basis. This doesn't include losses by transmission and conversion. The efficiency of end to end transmission is around 30%, which means a production of 0,00004 PJ a year for one meter crest length. The cost of this system are around 0,08 Eurocents per kWh for contemporary systems, which is comparable to other power systems (see table 1) (Centre for Renewable Energy Sources (CRES), 2002). This system has some great advantages.

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<sup>5</sup> Sound pressure levels of the wind turbine: L<sub>p,20m</sub>=52 dB; L<sub>p,50m</sub>=45 dB;L<sub>p,90m</sub>=35dB (with wind speeds of 7m/s). The airborne sound levels of waves are: L<sub>p,40m</sub>=62dB; L<sub>p,75m</sub>=58 dB;L<sub>p,150m</sub>= 53 dB (Bolin & Åbom, 2010). According to these numbers the waves transcend the sound of the turbine. In practise a lot more variables are of influence, like wind direction, tide, and so on.

The environmental impact of wave energy devices is very low, since it doesn't produce sound, has relative little materials (which are non-toxic) and doesn't influence the local sea habitat. If a system can be designed and integrated on every column of the pier that is located in the sea, a total of 120 poles can be used. This means that a gain of 0,0048 PJ a year is theoretically feasible. The previous paragraph showed that wind energy is almost always available, with fluctuations though. This means that wave energy is also always there, thus making this another great potential energy source.

### **Thermal solar energy**

The sun is the most powerful and infinite energy source on earth. To put its potential in perspective, the amount of energy that the whole earth uses in a year, radiates down in one hour. Almost all sources that are discussed in this chapter, with exception of tidal- and geothermal energy, are (in)direct derived from the power of the sun. There are different concepts that can collect the heat of the sun. The most well-known is the greenhouse system, where transportation of heat goes mainly through air. If a building or house contains glass windows, this effect can be achieved, since the incoming radiation has a different frequency than outgoing frequencies. This is why heat is 'captured' inside, which can also be a disadvantage in summer, since there is a potential risk of overheating. Secondly, solar collectors can be used. By exchanging the heated water with a heat exchanger, hot tap water or central heating can be heated with renewable energy. Central heating can reach 45 degrees Celsius, while hot tap water is set to 60 degrees Celsius, as a protection against the formation of salmonella. The most common system, the so called indirect active system, consist of two parts. First, heated water from the solar collector is transported to a tank. By a heat exchanger the water in the tank is heated to a certain temperature. Either the tap water or heating system can use this water for its purpose. For design purposes, it is important to consider the water tank, because size, weight and capacity have to be defined.

The latitude of The Hague is a little more than 52 degrees north. This means that the sun rays reach the horizontal surface in an angle. To achieve maximum yield, the solar energy collectors have to be in a tilt. Research has shown that for The Netherlands an angle of 42 degrees and an orientation between 60 degrees from south are optimal (Bokel, 2013).

## **Photovoltaics**

Photovoltaics are a direct method to generate electrical energy by solar radiation. PV cells in its most common form are made of silicon, which is the most abundant element on earth, after oxygen. It doesn't contain moving parts and is therefore in principle wearing proof. Since the system almost doesn't need maintenance, the lifetime costs are relatively low. The environmental impact of the system is also very low. The main materials used for the panel are galore around the world thus no exploitation to nature or human beings is needed. For the manufacturing of the PV cells some toxic chemicals are used, but recent technics will make this process superfluous (Boyle, 2004). The visual impact can be considered as harm to the environment, but since it is only a human disadvantage, one can choose to take this for granted.

As can be seen in figure 8, solar radiation in Hoek van Holland has especially high values in spring and summer. With an annual average of 235 kWh/m<sup>2</sup> (0,000000846 PJ), electrical energy can be produced. If for instance only half of the roof of the promenade of the pier is covered, around 2500m<sup>2</sup>, a yield of 590000 kWh (0,0021 PJ) a year can be reached.

The ideal tilt for photovoltaic panels differs from the ideal tilt for solar collectors (42 degrees). They have an ideal tilt angle of 30 degrees and an ideal orientation up to 30 degrees from south (Bree, 2013).

## Geothermal Energy

There are two different methods that use the ground as an energy source. One can be seen as temporary storage of energy in an earth layer to around 100 metres deep (open well), while the other system only exploits heat. The first system is enhanced geothermal energy: from a deep source hot water is pumped. In the Netherlands, this is from a depth of three to five kilometres. Through an extra pipe, cold water is pumped into the well to let the water heat-up before extracting (see figure 5). Due to the functioning of the system, the source can't be used unlimited. The location of the well is permanent and because of

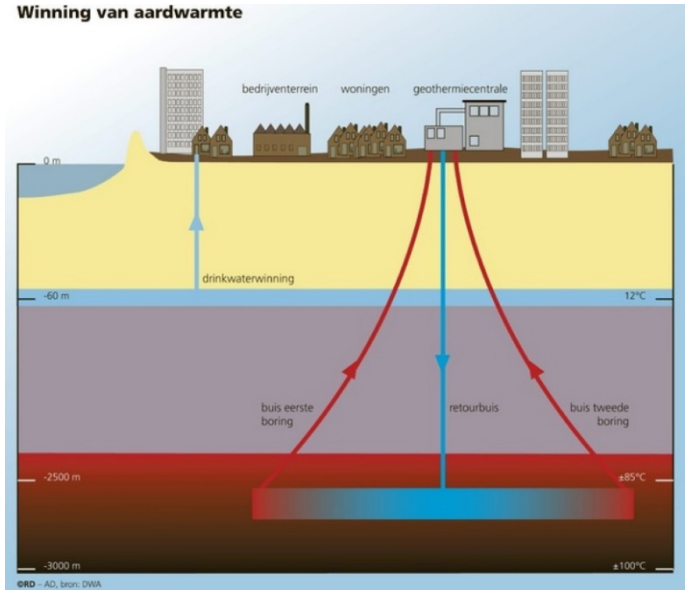


Figure 5| To extract geothermal energy from the ground at least two wells are needed, called a doublet: a production well and an injection well (Buitenhuis, 2008)

the law of conservation of energy, the thermal energy of the location will decrease. In The Hague such a system is already built, but it has not been profitable yet. This is due to the high investment costs and limited decrease by energy clients. The system is mainly suitable for large energy demands. When taking into account the small scale of the pier, this method is not feasible.

However, a different method is also available, which combines a heat pump with heat and cold storage. This means that in summer 'warm' water is pumped into an aquifer in the ground. In winter, this water is pumped up to heat the building (see figure 6). This process works both ways, so in summer 'cold' water can be used to cool the building. Two wells are needed in this case, one with 'cold' water and one with 'hot' water.

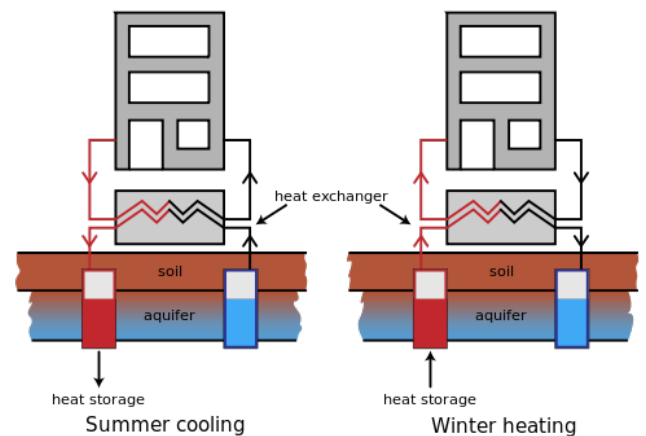


Figure 6| A heat pump in combination with heat and cold storage (Oyster, 2010)

The environmental impact is relatively low, if the installation is powered by renewable source. Given the location of the pier, in the dune landscape, it's advisable to be careful with the

integration of this system. The dunes in this location are used to filter water for the Dutch drinking water supply (see figure 7). To avoid pollution, research is needed about water flows in the surrounding.

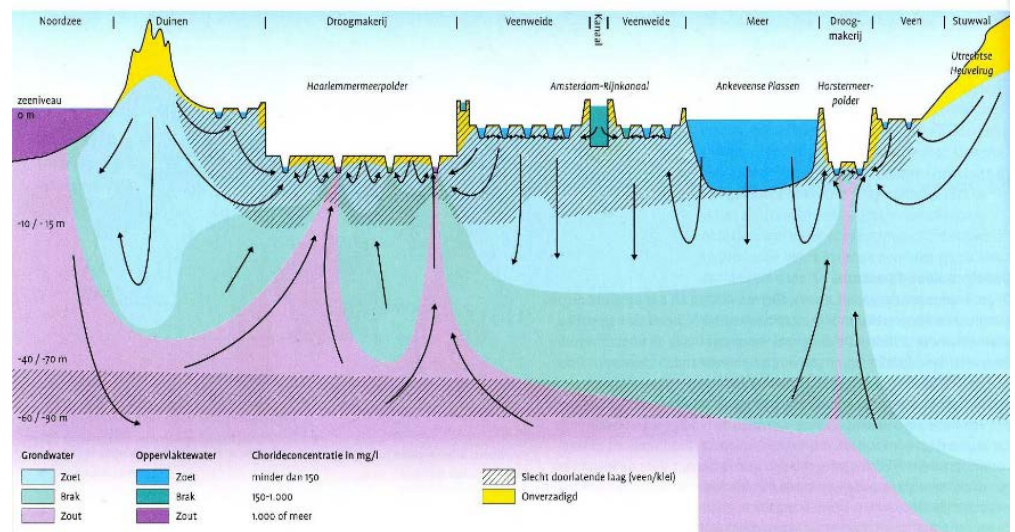


Figure 7 | Water system Netherlands (Smits, 2013)

## Thermal energy seawater

To use thermal energy, the same system as geothermal can be used, only instead of groundwater seawater is used. The heat pump system works more efficient than regular water heating system. The efficiency of a heat pump is defined by the coefficient of performance (COP), what is the ratio of heating or cooling provided to the electrical energy consumed. Heat pumps nowadays have a COP of around 4.5, what means that for every unit of energy consumed 4.5 units of heat is provided. A new neighbourhood in Scheveningen, Duindorp, has the world's first seawater heat plant, where this heat pump system is applied. The idea of using seawater for cooling is not new. The Opera House in Sidney and many datacentres all over the world use this concept. Closer to home, the high-rise buildings in Rotterdam use the water of the Maas to cool the buildings. The temperature of the North Sea flows between 4 and 20 degrees, depending on the currents and the season. The advantage of a heating or cooling system by seawater is the amount of CO<sub>2</sub> emissions that are saved compared to conventional systems. The system can be carbon neutral if the whole installation is powered by a renewable energy source. The system fits the temperature-demand graph partly (figure 8), since a time delay of the sea temperature is extant. Especially in spring and autumn the system can be used for corresponding cooling and heating. The main

disadvantage of using seawater are the high maintenance costs of the system, as it needs to be withstanding seawater with high salt and other polluting content. Since the pier is close to the source from which energy is extracted, it might be a worthy energy source.

### Constant Rate

The disadvantage of the renewable sources is the gap between the moment energy is demanded and produced. As figure 8 shows, there are a lot of fluctuation in the availability of sources. For example, solar power is only available during the day, so energy has to come from a different source during the night. However wind energy is almost always available in coastal areas. To achieve at least a minimal constant rate that covers the demand of the pier (chapter function), to make it energy neutral or even autarky, a combination of different sources is needed. Consideration of the different potential energy sources leads to the conclusion that wave, wind, geothermal and solar energy are interesting methods for the specific situation of the Pier.

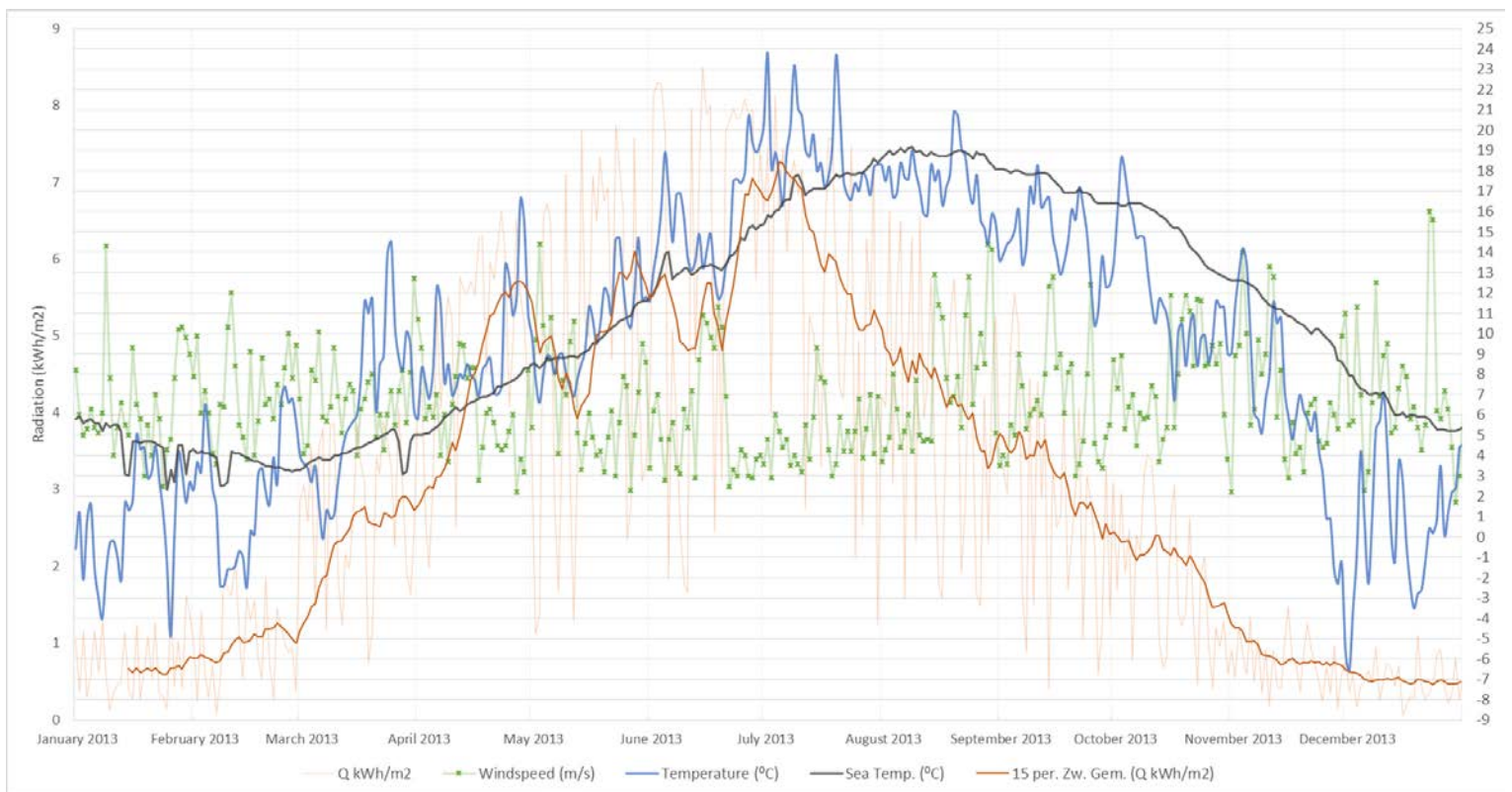


Figure 8| Plotted annual radiation (+average) (kWh/m<sup>2</sup>), wind speed (m/s) and temperature of air and sea water (°C) for Hoek van Holland (KNMI, 2014; Data-ICT-Dienst Rijkswaterstaat, 2014)

## Context

The function of the pier is of great importance for the functioning of the pier itself and also for its surrounding. Therefore, the pier is not an object in itself, but rather an extension to its surrounding and should be analysed in this way.

### Economical relevance of tourism

Tourism in the seaside resort Scheveningen is of major economic relevance. There are major differences between the economic prospects of Scheveningen and other coastal places in the Netherlands. Table 2 shows that Scheveningen has less beds, but has a relative high number of daily visitors. In Scheveningen, tourism has by far the biggest economic significance compared to the other cities. This is partly a result of its big cultural offer it, for example cinemas, casinos and theatres.

Table 2/

<i>Summary benchmark coastal cities</i> (ZKA Consultants & Planners, 2006)					
	IJmuiden	Katwijk	Zandvoort	Scheveningen	Noordwijk
Available beds	1667	4153	13931	2675	3040
Marina berths	550	370	-	350	-
Overnight stays	98000	162600	896000	350000-375000	533000
Visits watersports	13000	27600	-	8750	-
Daily visits, annual (million)	0,8	2,1	2,9	17,7	3,1
Economic significance (million Euro)	23,3	28,6	160	290-325	140

The importance of the tourism industry also shows in the big offer of hospitality industry in Scheveningen. The part of Scheveningen around the pier has 21000m<sup>2</sup> of hospitality industry, used by bars, restaurants and fast food restaurants. This is the same amount as the whole industry of Zandvoort or 1.5 times the whole industry of Katwijk. In summer an extra 50 beach pavilions are added to this number, which have a total combined area of 12000m<sup>2</sup>. Scheveningen has 43 hotels with 1344 rooms. The pier can be a catalyst for the welfare of Scheveningen and in bigger extend for the city of The Hague. It has the potential to attract people and therefore boost the hospitality industry and small shop keepers.

The Ministry of Economic Affairs and the Ministry of Infrastructure and Environment have studied why people go to the beach (ZKA, Consultants & Planners, 2013). There are five main motives for people to go to the coast. These are respectively: Getting breath of fresh air/being outside, relaxing, enjoy sea view, being together with family/friends and atmosphere of the coast (figure 9). There is a noticeable distinction between the people that visit for one day and people that stay longer. People who stay longer care more about the view and atmosphere of the beach. The daily visitors go to the beach to spend time outdoors.

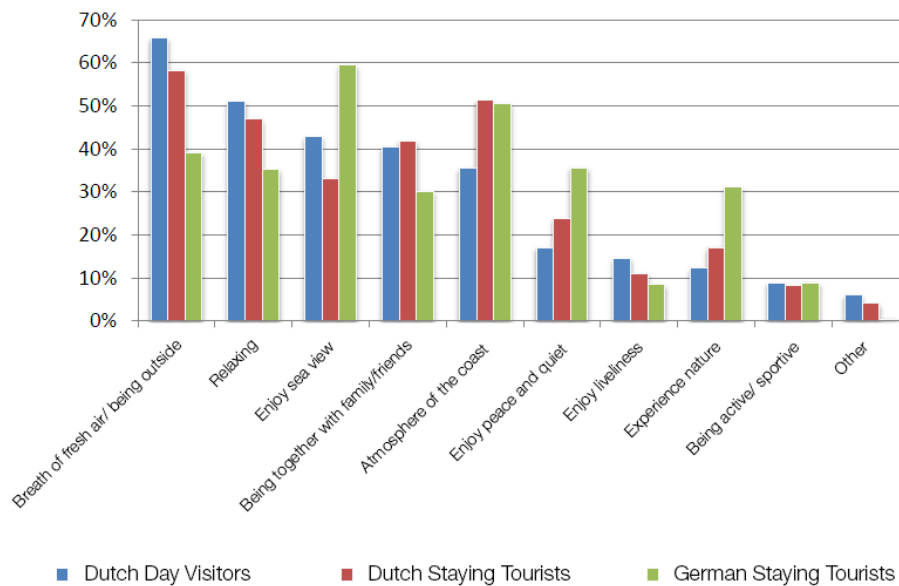


Figure 9| Visit motives (%), (ZKA, Consultants & Planners, 2013)

When relating these motives to the situation of the pier, it is clear that for both groups the outdoor quality and the sea view is of great importance. Therefore, when redesigning the pier, the experience of the beach should be one of the main aspects to consider.

### Vision of the municipality

The municipality of The Hague has a development plan for the region. This plan is developed to give assistance to plan developers and gives a red line that should lead to more economic welfare in the city, give tourism and culture a better platform and protect the environment from harm.

The principles of the municipality are very clear: They want to make The Hague *'een Wéreldstad aan Zee'* (Eng: a world city at Sea). Two main themes in their vision are The Hague as a seaside resort and The Hague as an international city. On the regional scale The Hague should be the seaside city of the metropolitan region The Hague-Rotterdam. In the previous paragraphs, attention is already paid to the importance of the tourist sector. Also, the ambitions for the local scale focuses on a combination of the relationship between city and sea, space for living, working and recreation (Gemeente Den Haag, 2005).

On (inter)national scale, the municipality wants The Hague to be the Capital of Justice and administrative centre of the Randstad. This policy connects with the history of The Hague. The Hague has always been the legal city of The Netherlands and even in international context the city is seen as the legal capital. It is the city where the famous Hugo Grotius once wrote his *Mare Liberum* (*free sea*) and the city that seats the famous Peace Palace. The Hague wants to build on to this image of the city, by allocating the area around the pier as the international coastal area, where international institutions are located. For example, the international court of justice gets a new office in this international zone. The international nuclear security summit of 2014, which took place in The Hague, also underlines the importance of The Hague as an international city. The city is suitable for a big event like this, but the costs were enormous. The pier offers great benefits, since the highest security levels can be easily met and both land and the sea can be used as gateways.

### **Interconnections**

In addition to the economic and political analysis, a more social input is also valuable. Local businesses and organisations are already complaining for years that the interconnections between pier, beach and boulevard are not sufficient. A hospitality consultancy firm studied problems related to the pier and concludes the following: There is no organic and logic connection to the landside, the entrance of the promenade is not attractive, provisioning is a weak point and the Pier has a dead end (Van Spronsen en Partners, 2013).

The committee *'De toekomst van Scheveningen-Bad'* states for the seaside resort in general that there is a poor appearance, chaos of functions, no interconnection between the boulevard and

the beach, no need to stay at the empty ‘arrival’ squares and no clear entrances (Comité Toekomst Scheveningen Bad, 2013). The opinion of this committee concerning the pier matches the opinion of the Van Spronsen en Partners: There is no clear function, a too long and boring walk, no clear connection between promenade and boulevard, and the pier relies on spontaneous visits (Van Spronsen en Partners, 2013).

Because of the physical appearance of the pier, the beaches at both sides are visually disconnected, humanness and the natural look are missing completely. Next to that, the connection from the beach to the boulevard is missing. The beach can be reached by small stairs, which are especially in summer indistinctive, because of the big number of beach pavilions. Improvement of these connections are key to a viable future. All the different problems statements are showed in figure 10.

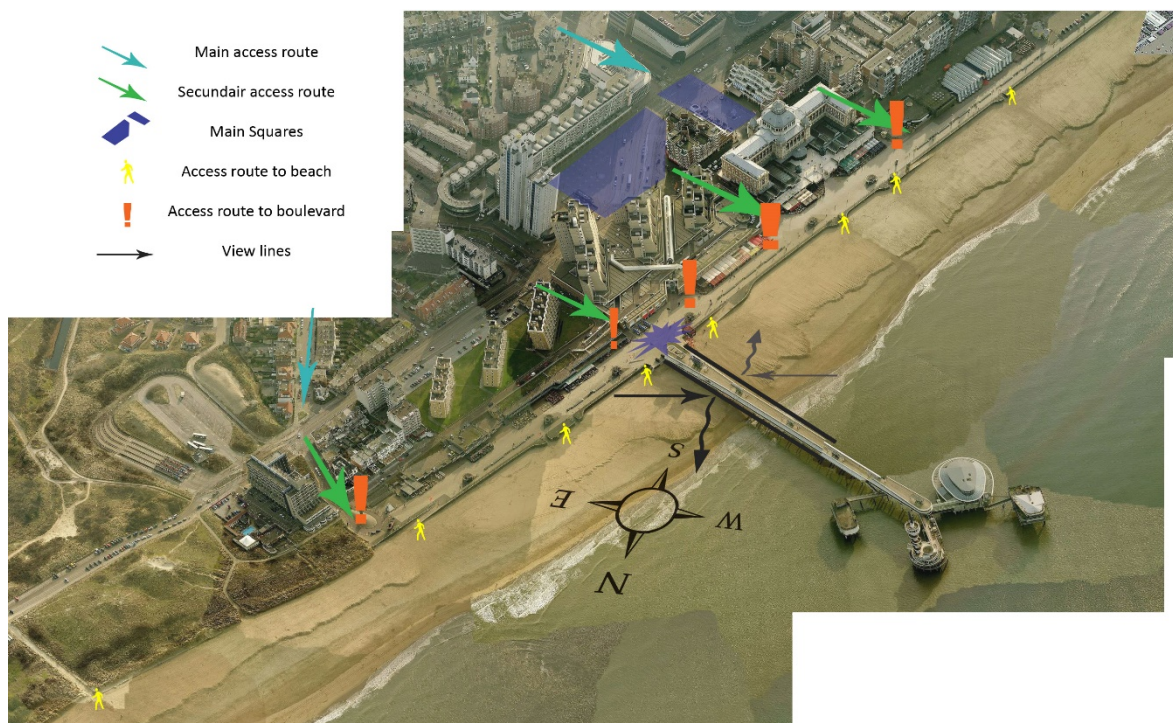


Figure 10| Visualisation of problems Scheveningen-Bad (IJsselstijn, 2014)

An argument for a certain function of the pier can be made from different perspectives. However, it is clear that the functions of the pier should at least add to the tourist sector, which is essential for this area. Also, the international ambitions of the municipality can be taken into account.

### Function and energy demand

A pier is a sea protruding dam, resting on a pillar scaffolding. This is the meaning in essential, but in practise the function of a pier is widespread and extends from simple jetty to advance leisure islands. Research shows that Scheveningen lacks one important thing compared to the amount of visitors, namely hotels. Furthermore the seaside resort needs secure and flexible meeting spaces for events. However, the function of the pier is in essence recreation, people walking over the beach or promenade, enjoying the view of the infinite sea. With this knowledge in mind a couple suitable functions can be proposed.

### Flexible set-up

As stated before, the pursuit of a flexible layout is key for a durable building that can last for decades. Right now, the pier doesn't have a function anymore. It is important to learn from the history of the pier. However, not reflecting on future events in the design phase and probable effects of the extreme conditions of the area on the used

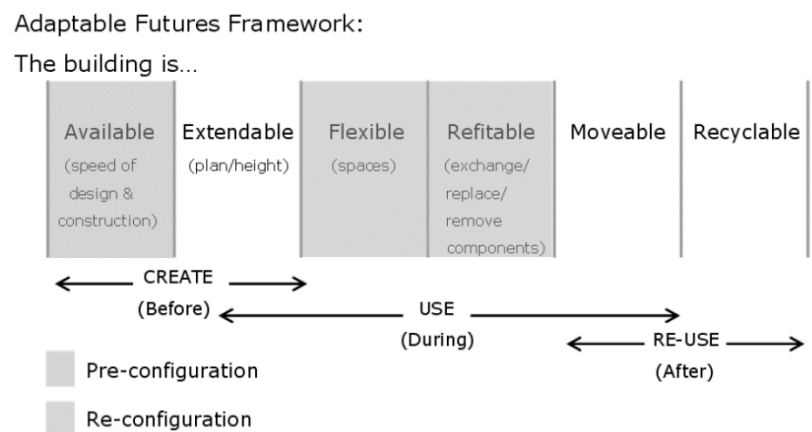


Figure 11| Adaptable Futures Framework (Beadle, 2008)

materials, can also be fatal for the exploitation in the longer term. Figure 10 shows a framework that helps guiding the development of a structure in different scenarios, where pre-configuration deals with initial design choices and re-configuration looks at subsequent changes in use. Beadle (2008) shows that in the case of an already existing structure the adaptability lays in flexibility and refitability. This is also the case for the pier in Scheveningen, where in case of refitting the pier *extendibility* is applicable, since the pier has an evident division of function and structure. It also shows the need to think of the re-usability of the whole. This framework doesn't give a decisive answer to the lifespan of the use, so in the development stage possible scenarios should be considered.

## Proposed functions

Given the points discussed in the previous chapter, the main function of the pier will be a hotel with conference possibilities. A hotel can generate stable turn-over over the year. The conference possibilities can give the pier allure for the (inter)national intentions of the municipality. Next to this, incorporating hospitality services and small shops are proposed, to make the pier attractive for tourists as well. To strengthen the attractiveness of the pier even more, an art exhibition or museum will be built. Since this pier is built on the beach and has a good overview on the beach and the sea, a part of the pier should be organised for lifeguard, coastguard and/or police. The promenade remains the main attraction of the pier and should be treated this way, with extra possibilities for public events, like beach cinemas or the famous firework shows of Scheveningen. In the proposed function table also extra space for installations is mentioned, since the installations for renewable energy likely need more space.

## Energy demands

The different functions all have their corresponding energy demand. Dutch average numbers are used to calculate the amount of energy needed, electrical and heat separated, since these can be covered by different energy sources. Table 3 shows different functions with their corresponding gross internal area and energy demands. Because these numbers are average numbers, smart and bioclimatic designs with their numbers are not included. By smart design the demands can go down a lot. When design is in a further stage this table should be updated to always get understanding of the energy use.

Table 3/

<b>Functions with floor area (m<sup>2</sup>), total demand (MJ, PJ, kWh) (Ijsselstijn, 2014)</b>				
<b>Proposed Functions</b>	<b>% time used</b>	<b>m<sup>2</sup></b>	<b>Total Heating/cooling</b>	<b>Total Electrical</b>
<b>Sundeck</b>	100%	3600	0	576000
<b>Safety and Research</b>				
Police, KNRM	70%	400	110880	147280
Coast Guard	70%	400	110880	147280
Research Facility/Rijkswaterstaat	70%	400	110880	151480
Public events	20%	510	0	7140
<b>Noordeiland</b>				
Technical Facility	100%	1500	16500	259500
Restaurant/bar	80%	500	318000	308000
<b>Promenade</b>				

Bar	80%	600	381600	350400		
Small shops	60%	200	60720	47760		
Small museum	60%	200	69120	66480		
promenade	100%	2800	0	644000		
<b>Hotel @ Sea</b>	100%		997500	1125000		
Forum @ Sea	40%	3500	532000	600000		
Restaurant	80%	1000	588000	600000		
<b>Total</b>		<b>15610</b>	<b>3296080</b>	<b>5030320</b>	<b>MJ</b>	<b>MJ</b>
			<b>0,00330</b>	<b>1397311,11</b>	<b>PJ</b>	<b>kWh</b>

### Self Sufficient

When comparing the results of the energy demands and the possible energy potential of the area, the efficiency of the building can be calculated. Table 4 shows the total amount of renewable energy that in this specific scenario can be gained. Compared to table 3 it shows that the pier can be energy neutral in use<sup>6</sup>. Although these tables are both rough estimations, a clear statement can be made that energy neutrality for the pier is possible. Further design steps should be improve the energy gains and lower energy demands.

Table 4/

<i>Annual energy potential for different renewable sources for Dutch coast (MJ, kWh) (IJsselstijn, 2014)</i>								
Energy	Type	Eff/COP	Amount	m2	MJ/unit	kWh/unit	Total MJ	Total kWh
Wind	turbine		10			17877		178770
Wave	turbine	30%	120			36500		1314000
Solar	PV panels			2500		236		590000
	Collectors			500	849,6		424800	
Thermal	Sea	4,5	1		500000	-111111	500000	-111111
	Ground	4,5	1		2400000	-533333	2400000	-533333
<b>Total</b>							<b>3324800</b>	<b>1438326</b>
							<b>MJ</b>	<b>kWh</b>

<sup>6</sup> This paper doesn't include the embodied energy of the materials used, because the materials are not yet set.

## **Structure and Materials**

The coast location is an interesting location to develop, because it has some challenging characteristics. Most importantly, there are extreme climate conditions it has to deal with. One of the most critical parts, and therefore the most expensive in terms of maintenance and constructing, are the structural elements. To keep maintenance costs and the environmental impact low, a structure has to be realized that is durable, so it doesn't exploit the environment for its existence.

The specific challenges of the seaside area influence the materials used. One important challenge are the high salt levels. This is not only a source of erosion in its liquid form, but even in the form of water vapour blown with winds. Winds also create erosion in another way, namely sandblasting. In this chapter, the main types of structural materials will be analysed to create understanding of the materials and their behaviour in coastal environments, namely concrete, steel and wood. As said, the pier structure will remain and will only be improved for further use. This means that the discussion about materials is rather generic, but can be used for understanding materials for the function, so a measured decision can be made for the materials used.

### **Concrete**

#### **Durability**

Concrete is a relative cheap and often used structural material and is able to last for many years if built correctly. However, concrete has some potential trends, depending on its location on water or land, like the saltiness of the water, winds, climate and powerful waves. Most of the knowledge about concrete in long term exposure to sea environments is based on practice experience (CUR-VB, 1981, p. 9), since these structures are not built with standardisation and therefore difficult to predict (for instance in comparison with steel).

There are several causes of weathering in concrete, but for this paper the focus is on the coastal area so only these causes are taken into account. As seen in figure 12 concrete in marine structures in tidal, splash and spray zones above the water get the highest environmental class, XS3. This means this location on a structure is affected the heaviest by coastal influences. This is due to the high salt levels in seawater, around 35 grams per litre (CUR-VB, 1981, p.

10). Regarding the durability of concrete structures a distinction can be made into deterioration of the concrete itself and deterioration of the reinforcement. To ensure the long term durability of concrete a few measurements need to be taken to protect it for the following influences: salts and winds.

Salts are probably the most important threat for the concrete part of the structure. For cement calcium- and magnesium sulphates are of great danger. Although law demands low levels of tricalcium aluminate for maritime structures, it can bound to the crystal ettringite with sulphates. This crystal will cause expansion and might damage the cement stone. If water reaches the crystal it might dissolve, and thereby will weaken the structure.

For the reinforcement of the steel chlorides and carbonation is also a real danger. Normally the steel in the concrete is protected for rust by the high alkaline environment (pH of 12-13), consequently a thin protective layer is formed around the steel, the so called passivation layer. This passivation layer may be lost due to lower pH levels and is caused by two phenomena: carbonation and exceeding a maximum chloride content. Carbonation happens through air. As long as the depth of the carbonation front is within the concrete outer layer, this will not cause problems. Although literature is inconclusive about how thick this layer should be, a minimal thickness of 35mm is advised (Toorn, 2014).

Chlorides can penetrate through the concrete by prolonged contact with seawater, sea breezes and de-icing salts. At the moisture phase, the concrete at the surface gets saturated by

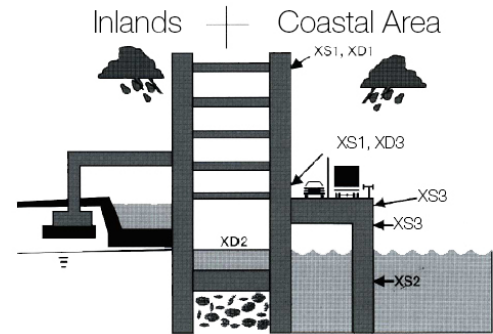


Figure 12| location environmental class XD, XS (Cement & Beton centrum, 2014)

capillary suction with a chloride solute. In the dehydration phase, the water evaporates and the chlorides remain in the dehydration front from where they can further penetrate by means of diffusion into the concrete. At the next moisten phase the pores are filled again with seawater, because dissolving chlorides remain in the pores an increased concentration is created. There is also the tides splash zone from an influx of chlorides by capillary effect. The extent to which chlorides are drawn by capillary effect is closely related to the capillary porosity of the cement and the evaporation of moisture from the concrete surface. In any event, the penetration of chlorides by capillary suction is much faster than by diffusion. Below the wet/dry transition zone, the type of concrete has a major influence on the penetration rate. Under these circumstances, a lot of oxygen is available, and there is a considerable risk of corrosion of reinforcement. The erosion of the steel or the formation of ettringite will cause expansion and can create extra cracks that will strengthen the vicious circle of damaging.

There are two types of concrete: Portland cement (Pc) and blast furnace cement (bfc). The first one is most commonly used, since it is cheap and easy to use. It dries relatively fast compared to bfc. Blast furnace cement is denser than Pc and needs to dry relatively long and a careful after-treatment. Therefore bfc is mostly made prefab to ensure the high quality of the concrete. Bfc is able to make chemical binding of chloride ions with the cement stone and this absorption also creates higher resistance, since reinforcement steel can only be affected by bounding of free moving chlorides. Therefore this concrete is mostly used in seaside areas (Cement & Beton centrum, 2014).

At the shore, sanding is another aspect that is important to consider. However, it is difficult to protect the structure against it. An extra protection layer can be added to ensure resistance against sanding by wind or water that contains sand, this can be concrete or another wearing proof material. It is really important to have a thick protection layer of (blast furnace) concrete of at least 35mm. Also cracks should be avoided, since this means free rein for water, chlorides and carbons. Once the process of erosion is started it will strengthen itself, so preventing this is key.

### Flexibility

Concrete is difficult to reshape. New concrete can be cast if the concrete is cleaned with high water pressure or parts of the concrete are cut out so reinforcement can be connected to each other, but it remains hard to perform. Despite the lack of easy adaptability concrete can be shaped in many ways if new casted.

### Recycling

Concrete with a normal strength can be recycled, whereby the crushed concrete can be used as a filler. Currently only 20% of the used concrete is recycled as gravel (source). Therefore concrete will always downgrade, in terms of speaking, since it quality wise never remains equal or even upgrades to a new material. However, the steel reinforcement bars can 100% be recycled.

### Concrete analysis Pier of Scheveningen

In the 1980's the CUR-VB did inspections and research on 60 Dutch maritime structures, including the Pier in Scheveningen. Back then the pier was around 19 years old and especially the prefab part of the pier was still in good condition. The in situ concrete was already slightly deteriorating, mainly corrosion and cracks around the reinforcement. The concrete covering of the prefab parts are between 50-55 mm and the in situ concrete 30-35 mm. In 1992 the former owner of the pier did a total transformation of the pier and improved the structural parts that were in bad condition. This included all concrete piles under the promenade, which received, after cleaning with fresh water, a glass fibre reinforced polyester jacket. Between the existing concrete and the jacket, mortar was injected. This system was already used at the New Jersey Pier and the Chesapeake Bay Bridge (Wijk, Breukelen, & Baks, 1995). Nowadays these columns are still in good condition, besides aesthetic degradations. As Van der Toorn (2014) states, maritime structures are mostly in good condition, but there are a few places where degradation is taking place in a bigger extend (see figure 13). The worst location is underneath a maritime structure. Seawater mist and wash hits the structure where salts will remain after water vaporised. This phenomenon happens in principle on

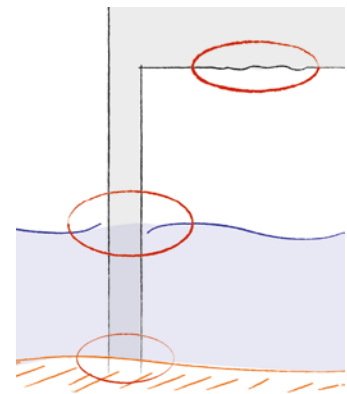


Figure 13| Most damaged location marine construction (IJsselstijn, 2014)

all parts of marine structures, but rain and seawater cleans most places (Toorn, 2014). Recent study by TNO and Royal Haskoning (2012) showed that the pier in Scheveningen has big problems with corrosion at the first part of the pier where in situ concrete is used (see figure 14). As a result a safe structure cannot be guaranteed and the pier is closed until further notice.

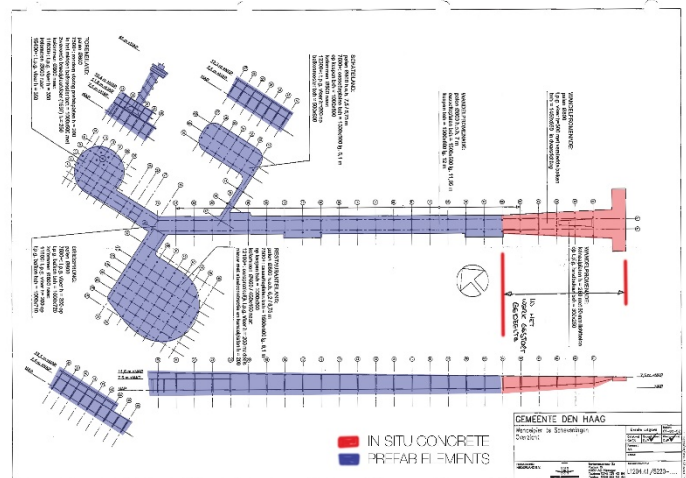


Figure 14| Concrete analysis Pier of Scheveningen (IJsselstijn, 2014)

## Steel

### Durability

To protect steel against the heavy environments a few measurements can be taken. The use of paint or galvanic material is common used, both will protect the steel from erosion by cathodic protection. This erosion will mainly occur of potential differences with another material. Therefore steel is always protected by galvanic materials in marine environments. These are usually blocks of aluminium. Considering the waste of this sacrificial metal, a different material, with better sustainable characteristics, should be considered. Another way to protect steel against erosion is anodic protection. By creating a electrical current through the steel, potential differences are wiped out and the steel can last much longer. This can also be applied to reinforcement steel in concrete, but first the steel needs to be revealed, what can be a difficult and complex task (Toorn, 2014).

### Flexibility

Steel is easy adaptable. It can be bolted or welded to other of steel elements. In case of welding or drilling the steel needs to be protected again, since the worked location is unprotected for erosion.

## Recycling

Although it is possible to recycle almost 100% of the steel, it is difficult to separate all scrap from waste. But steel prices are so high that it becomes more and more interesting to recycle. As table 5 shows the lifespan of steel is around 50 years. This means that the steel produced today can be recycled in around 50 years.

Table 5/

<i>Recycling rates &amp; Lifespan</i> (Arcelor Mittal, 2013)		
	RECYCLING RATES	LIFESPAN
	(%)	(Years)
Cladding	85	40
Reinforced steel	50	50
Structural steel	97	50

## Wood

### Durability

Timber is an environmentally responsible material option if recycled or obtained from a sustainably managed resource. It is particularly attractive since it has low embodied energy and is virtually ‘carbon neutral’ (apart from transport and processing) (Crossman & Simm, 2004, p. 6). However, using wood as structural element is often difficult: strengths are difficult to calculate and lengths of timber are around 12 meter maximum. With laminated wood bigger lengths can be achieved, but the natural endure against extreme conditions will be lost.

For maritime structures different types of wood are suitable. The denser the wood is, the better protected against extreme conditions, in this case a high salty environment. Wood in this instance acts like a bundle of straws, wicking salt water into the wood structure. As the wood surface is exposed to heat and drying (as from direct sunlight), the water evaporates and salt crystals form in the wood cells. Over time, the physical forces applied by the salt crystals push the fibers of the wood apart, causing the “fuzzy” appearance. Salt damage can be observed on untreated wood or wood treated with waterborne preservatives, such as CCA (copper chromated arsenate) and ACQ (alkaline copper quat). It usually does not occur on wood treated with oily preservatives, such as creosote, because the oil forms a barrier to the salt movement. Although salt damage can be unattractive, the fuzzy wood need not be a cause for alarm. The gradual sloughing off of the wood surface proceeds slowly, and the wood beneath the affected area remains sound.

Salt damage has been observed on poles and piles that are still in service after 25–30 years (Kirker, 2011).

### **Flexibility**

Wood is one of the most flexible materials for construction. It can be edited on site and can easily be fixed to other wood or other materials. However, since timber species used in the marine environment are frequently dense, heavy and difficult to work, adaptability can be a problem. Often combinations between steel and wood are created to combine the most efficient characteristics of both worlds.

### **Recycling**

At a certain point a timber structure will have to be replaced or dismantled and reconstructed, usually because it presents a significant safety hazard or maintenance becomes increasingly uneconomic. The life expired structure should be carefully dismantled rather than demolished, with any opportunities to recycle materials carefully. Waste timber can normally be recycled in some form (after treatment) or used for energy recovery, but great care must be taken with preservative-treated timber components. It should be noted that preservative-treated timber is now classified as hazardous waste and therefore cannot be burned.

Generally, timber should be machined so that worn, weathered and damaged surfaces are removed to expose the underlying timber. This will inevitably result in a loss of section. In addition to naturally occurring strength-reducing features such as knots and slope of grain, the timber may have been significantly affected by man-made defects such as holes for fixings and notches. In practical terms, where high volumes of timber are being recycled, heavily notched timbers should be machined so that these areas are removed. Mechanical damage may affect the strength of recycled timber significantly. If there are visible signs of impact, there may be a risk of compression failure within the timber. Therefore it may not be advisable to place the recycled member in a critical part of any structure (Crossman & Simm, 2004, p. 64). Recycled timber considered to be unsuitable for further structural work should be made available for other uses (including landscape or decorative features) rather than disposal to landfill sites or burned for energy.

## **Inference**

Since concrete is already used as main structural element in Scheveningen, in terms of sustainability it would be best not to replace these, but improve them. As the lifespan of the structure has to be at least another 100 years it would be advised to make these fit to this demand. The functions on top of the main structure can be more lightweight. In this case a low footprint can be achieved and a less long durability is possible, since functions will change over time.

The main difference between concrete, steel and wood, are obvious, the appearances. Where concrete looks massive and durable, steel looks industrial and wood gives a more natural look. Although all materials can withstand the extreme environment of the coastal area, security measures need to be taken to ensure a long lifespan. All the materials have an average lifespan, based on experience, and should be chosen in a way that they will fit the lifespan and esthetical demands of the function.

Wood is the most (eco) friendly looking material, but this is underlining the downside of the material as well. Its structural characteristics are difficult to state. Also the load bearing capacities of wood are in a total different order of magnitude that heavy beams are needed to have the same effect as steel or concrete. Even if it was responsible to use wood, the problem lies more in the maximum lengths of the beams. The timber comes in lengths of maximum 12 meters (Crossman & Simm, 2004, p. Appendix I). For all materials it is difficult to state the lifespan, since the influences of the environment are harsh and difficult to predict, but a combination of these is not inconceivable to get the best solution for a durable structure.

## Conclusion

When redesigning the pier, a balance has to be found between the private and public functions of the pier. As main private functions of the pier, a hotel with conference possibilities is proposed. Scheveningen is in need of more hotel accommodations and the conference possibilities fit the international ambitions of the municipality. The public function of the pier is related to the experience of Scheveningen as a seaside resort. In this function, taking a stroll over the promenade is an important aspect. Therefore, the continuity of this promenade and the presence of a lookout point are essential. Studies have also shown that it is necessary to improve the connection between the beach and the entrance of the pier. Also, certain functions can increase the attractiveness of the pier for tourist, namely bars, shops and an exhibition space.

The ambition is to make the pier a self-sufficient complex. In order to do so, several renewable energy sources can be used. An analysis of the location of the pier showed that especially wave, wind, thermal and solar energy provide opportunities for energy production. A combination is needed, because most of these sources cannot be generated at any time of the day. A comparison between an estimation of the energy demand of the pier (with the proposed functions) and an estimation of the potential energy production shows that is theoretically feasible to develop a self-sufficient pier.

The current structure is made out of concrete and demolishing this would mean a loss of material and a burden for the environment. Therefore, it is best to work with the already existing structure, even though there are quite some challenges. These challenges are mostly related to the salt water levels. Steel and wood also have their disadvantages and difficulties with the sea environment. In order to be able to contain the concrete for several decades, one possible solution is to wrap the existing structure with protective material, as has been done before.

## References

- Arcelor Mittal. (2013). *Recycling steel and lifecycle analysis*. Retrieved May 27, 2014, from Arcelor Mittal: <http://corporate.arcelormittal.com/corporate-responsibility/making-steel-more-sustainable/recycling-steel>
- Baal, M. v. (2011, 08 09). *Kunnen we overschakelen op duurzame energie? Deel 9 - golfenergie*. Retrieved June 03, 2014, from Technisch Weekblad: <http://www.technischweekblad.nl/rubrieken/energieserie-1/kunnen-we-overschakelen-op-duurzame-energie-deel.143236.lynkx>
- Beadle, K. G. (2008, September 1-3). Adaptable futures: sustainable aspects. *Dainty, A (Ed) Procs 24th Annual ARCOM Conference*, 1125-1134.
- Beadle, K. G. (2008). Adaptable futures: sustainable aspects of adaptable buildings. *Dainty, A (Ed) Procs 24th Annual ARCOM Conference* (pp. 1125-1134). Cardiff, UK: Association of Researchers in Construction Management.
- Bokel, R. (2013). *AR2AE035-D1\_oktober2012\_English\_3\_BB\_for students - The Sun*. Delft: Bouwfisica, TU Delft.
- Bolin, A., & Åbom, M. (2010). Air-borne sound generated by sea waves. *The Journal of the Acoustical Society of America*, 127 (5) (pp. 2771–2779). Stockholm, Sweden: The Marcus Wallenberg Laboratory/Linné Flow Centre, KTH - Royal Institute of Technology.
- Bomans, B. (2003). *Naar zee! : ontwerpen aan de kust*. Rotterdam: NAI Uitgevers.
- Boyle, G. (2004). *Renewable Energy: Power for a Sustainable Future* (Second Edition ed.). Oxford, UK: Oxford University Press.

Bree, R. d. (2013). *De Ideale Hellingshoek - Zoektocht naar de beste opstelling voor zonnestroom*.

Retrieved May 30, 2014, from Siderea:  
<http://www.siderea.nl/artikelen/hellingshoek2/hellingshoek2.html>

Bruins Slot, R., & Blokzijl, M. (2013). *Parel aan de Noordzee*. Retrieved August 27, 2013, from

Geschiedenis 24: <http://www.geschiedenis24.nl/andere-tijden/afleveringen/2013-2014/Parel-aan-de-Noordzee.html>

Buitenhuis, J. (2008). *Diepe Geothermie, een onontgonnen warmtebron*. Bodegraven: VV+.

Cement & Beton centrum. (2014). *Wapeningscorrosie door chloriden*. Retrieved March 17, 2014,

from <http://www.cementenbeton.nl>: <http://www.cementenbeton.nl/technologie-en-uitvoering/441-wapeningscorrosie-door-chloriden>

Centre for Renewable Energy Sources (CRES). (2002). *Wave energy Utilization in Europe -*

*Current Status and Perspectives*. Pikermi, GR: Centre for Renewable Energy Sources (CRES).

Comité Toekomst Scheveningen Bad. (2013). *Communicatiebewoners - visie scheveningen 2020*.

Den Haag: Comité Toekomst Scheveningen Bad.

Compendium voor de leefomgeving. (2013). *Stroomdiagram energie voor Nederland, 2012*.

Retrieved May 29, 2014, from Compendium voor de leefomgeving:  
<http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl020117-Energiebalans-Nederland-%28stroomdiagram%29.html?i=6-40>

Compendium voor de leefomgeving. (2013b). *Verbruik van hernieuwbare energie 1990-2012*.

Retrieved May 29, 2014, from compendium voor de leefomgeving:  
<http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0385-Verbruik-van-hernieuwbare-energie.html?i=9-53>

- Crossman, M., & Simm, J. (2004). *Manual on the use of timber in coastal and river engineering*. London: Thomas Telford Publishing.
- CUR-VB. (1981). *Duurzaamheid Maritieme Constructies - CUR rapport 100*. Zoetermeer: Betonvereniging.
- Data-ICT-Dienst Rijkswaterstaat. (2014). *Temperatuur in oC in oppervlaktewater*. Retrieved June 03, 2014, from live.waterbase.nl: [http://live.waterbase.nl/waterbase\\_wns.cfm?taal=nl](http://live.waterbase.nl/waterbase_wns.cfm?taal=nl)
- Ernst & Young LLP . (2014). *Sustainability Review 2013 - BP*. London: Corporate reporting BP.
- Gemeente Den Haag, D. S. (2005). *Wéreldstad aan Zee - Structuurvisie Den Haag 2020*. Den Haag: Gemeente Den Haag.
- Hellinga, C. (2010). De energievoorziening van Nederland - Vandaag (en morgen?). *KIVI NIRIA 'Duurzaam omgaan met energie'* (pp. 1-34). Delft: KIVI NIRIA, TU Delft .
- IJsselstijn, D. (2014). *Own work*. Den Haag.
- innovation & research focus. (2010). *SMARTtide: a unique tidal energy modelling tool*. Retrieved May 29, 2014, from innovation & research focus: [http://www.innovationresearchfocus.org.uk/Issues/94/IRF94\\_HR2.html](http://www.innovationresearchfocus.org.uk/Issues/94/IRF94_HR2.html)
- IPCC. (2014). *Fifth Assessment Report*. Geneva: C/O World Meteorological Organization.
- Kirker, G. (2011). *Salt Damage To Wood*. Madison, US: Forest Products Laboratory.
- KNMI. (2014). *KNMI DataCentrum - Waarnemingen & rekenmodellen*. Retrieved May 13, 2014, from KNMI DataCentrum: <https://data.knmi.nl/portal/KNMI-DataCentre.html>
- Markandya, A. (2012). Externalities from electricity generation and renewable energy. *Cuadernos económicos de ice n.º 83*, 85-99.
- Meijer, P., & Verweij, R. (2008). *Energieverbruik per functie voor SenterNovem*. Den Haag: Meijer Energie- & Milieumanagement BV.

- National Geographic. (2014). *MapMaker Interactive*. Retrieved May 21, 2014, from <http://education.nationalgeographic.com>:  
[http://education.nationalgeographic.com/education/mapping/interactive-map/?ar\\_a=1](http://education.nationalgeographic.com/education/mapping/interactive-map/?ar_a=1)
- Omroep West. (2013, Februari 02). Scheveningse Pier vraagt faillissement aan. *omroepwest.nl*.
- Oyster, F. (2010, April 1). *HeatAndColdStorageWithHeatPump*. Retrieved June 03, 2014, from wikipedia:  
[https://en.wikipedia.org/wiki/Geothermal\\_heat\\_pump#mediaviewer/File:HeatAndColdStorageWithHeatPump.svg](https://en.wikipedia.org/wiki/Geothermal_heat_pump#mediaviewer/File:HeatAndColdStorageWithHeatPump.svg)
- Royal Haskoning . (2012). *Vervolgonderzoek constructieve veiligheid Pier van Scheveningen*. Rotterdam: Royal Haskoning .
- Smits, F. (2013, September 30). Concise introduction to the Dutch watermanagement and the Amsterdam Water Supply Dunes. Amsterdam.
- Tillie, e. a. (2009). Towards CO2 neutral urban planning. *45th ISOCARP Congress 2009*. Rotterdam: dS+V.
- Toorn, A. v. (2014, april 3th). Hydraulic Structures. (D. IJsselstijn, Interviewer)
- Van Spronsen en Partners. (2013). *A new future for the De Pier – Scheveningen*. Warmond: Van Spronsen en Partners.
- Wijk, M. v., Breukelen, H. v., & Baks, F. (1995). Renovatie palen scheveningse pier - unieke reparatiemethode verhoogt ook de constructieve waarde. *Cement*, 6-10.
- Wikipedia. (2014, May 28). *Hardwood*. Retrieved from Wikipedia:  
[https://en.wikipedia.org/wiki/File:Hard\\_Soft\\_Wood.jpg](https://en.wikipedia.org/wiki/File:Hard_Soft_Wood.jpg)
- Wikipedia. (2014, April 13). *Noordzee*. Retrieved from Wikipedia:  
<https://nl.wikipedia.org/wiki/Noordzee>

ZKA Consultants & Planners. (2006). *Scheveningen 2020: Levende badplaats - Economische visie Scheveningen-Kuststrook*. Breda: ZKA Consultants & Planners.

ZKA, Consultants & Planners. (2013). *Onderzoek effecten Wind op Zee op recreatie en toerisme*. Waalwijk: ZKA Consultants & Planners.