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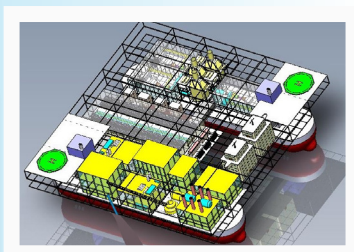


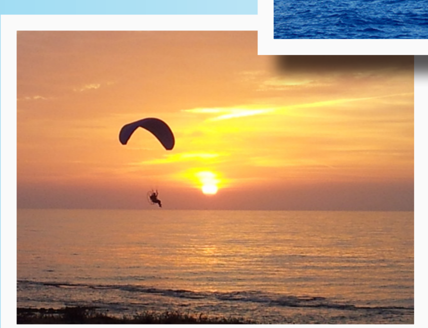
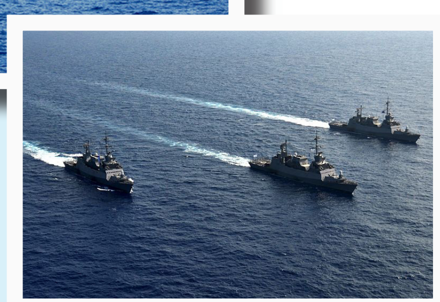

Chapter 12: Artificial Islands for Energy Infrastructure

Motti Klamer

Israel is one of the 20 most densely populated countries in the world.[1] The shortage of land is reflected in the prices of real estate and the difficulty encountered by planners in balancing between various land uses, such as residential, industrial and commercial, public space, military, public infrastructure, etc. Additional environmental challenges that result from the shortage of land are the dangerous proximity of residential areas to infrastructure facilities, the lack of open spaces for recreation and the need to preserve nature and heritage sites.

Finding this kind of balance is even more complex in the case of the sea coast. The length of Israel's Mediterranean coast is about 196 km of which only about 53 are natural open beach. Forty percent of the country's population lives within a 10-kilometer strip along the coast. Along the coast of Israel, there is competition between seaports and marinas, electricity plants, military bases (naval and for weapons testing), infrastructure facilities and of course citizens who want to live and relax near the coast.

Looking forward, Israel has the highest birthrate in the OECD countries. In addition to the allocation of land for residence, the growth of the population requires public infrastructures, some of which must be located on the on the water's edge (power plants and ports). In this context, it is worth mentioning that since the 1980s new piers have been constructed in the Ashdod and Haifa ports (the Yovel port, the western pier in Haifa and the *Hamifratz* port) which involved draining the sea since there are no other possibilities for expansion. In addition, it should be mentioned that following the major discoveries of natural gas in Israel's economic waters in 2009 a lively public discourse took place on where to locate the connection of the gas pipeline to the coast. None of the municipal authorities agreed that the connection facilities would be located within their boundaries. This illustrated the extent of the land shortage along the coast, even when we are talking about essential national industrial and utility infrastructures.

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1 Israel within the Green Line is in 29th place in population density; however, if one ignores city-states (such as the Vatican, Monaco and Hong Kong) or islands with small populations and territories (San Marino, Nauru, and Tobelo), Israel rises to 20th place.

One of the possible solutions to the shortage of land and one that is commonly implemented abroad is to transfer some land uses to the sea and onto artificial islands.

A number of comprehensive studies have been written about the creation of artificial islands in Israel, most of them already in the 1990s, within the framework of the Chaikin Chair for Geostrategy at Haifa University and the surveys carried out by various government ministries. The government of Israel has even made several decisions on the issue: Decision 2709 from November 10, 2002 regarding the establishment of a steering committee of ministry directors to examine the possibility of creating an artificial island for residence, recreation and tourism off the coast of Israel; and Decision 4776 from June 17, 2012 to investigate the feasibility of creating artificial islands for clusters of industrial and utility infrastructure. In addition, the Ministry of Energy published a policy paper in 2007 on artificial islands for industrial and utility infrastructure.[2]

It appears that the public and academic discourse has reached a basic consensus regarding the planning need and the technological feasibility of creating relatively small artificial islands (tens of dunams) to be used for industrial and utility infrastructure, while taking into careful consideration the issue of environmental protection. Indeed, in 2012, the government of Israel approved Decision 4776 regarding the "Investigation of the feasibility of creating artificial islands for clusters of industrial and utility infrastructure".[3]

The introduction to Decision 4776 makes clear that the motive for the feasibility study is the need—in view of the natural gas discoveries—to create facilities that will enable the receiving, processing and transmission of natural gas to the national distribution network.

The position of the writers of the Maritime Assessment for Israel is that the government should adopt the solution of floating islands for industrial and utility infrastructure and should choose a multipurpose solution from among the variety of possible engineering options, one that will combine elements that are already in use or in the stage of active planning in other parts of the world, while giving careful consideration to the issue of environmental protection, from the perspective of possible pollution and the movement of sand along Israel's coast.

2 Policy paper on artificial islands for infrastructure http://moin.gov.il/SubjectDocuments/Chof27.pdf

3 Government Decision 4776 from June 17, 2012 http://www.pmo.gov.il/Secretary/GovDecisions/2012/Pages/des7446.aspx

The advantages of artificial islands for infrastructure:

- Saving of expensive and sought-after coastal land.
- Distancing of hazards and sources of pollution from residential concentrations.
- Release of land that is today taken up by infrastructure or essential facilities, in order to make room for future urban development.

The technology of building artificial islands

It is not the intention of the document to present a full survey of all the existing technologies, but rather to mention the main ones and to assess their suitability for our region. In general artificial islands can be divided into a number of categories:

Artificial islands near the coast (the territory becomes the new shoreline or the islands are have a permanent connection to the shore)

- The draining of land: This is the oldest method/technology and has existed for centuries. In general, the use of this method requires the closing in of the drained area by means of a rigid structure such as a breakwater made of stones and filling of the internal area. The use of this method is possible in shallow water and requires a major quantity of appropriate filling material (with the appropriate compression so as not to dissolve in seawater).
- Use of caissons: This is a new technology based on the casting of concrete pools/compartments that are placed one on top of or beside the other and then filled with filling material or with seawater, sunk and anchored to the sea floor. This method is already in use in the construction of piers the new ports of Haifa and Ashdod. This method is also feasible only in shallow water and requires, in addition to the filling material, facilities for producing the caissons.

Facilities on pillars

- This is an existing technology that puts down pillars ("feet") on the seabed. The platform is positioned on these "feet" and is raised or lowered hydraulically or is even floating. Most of the oil and gas drilling and production facilities that are close to shore use this technology. Its advantage is the speed with which it can be built and the extensive experience that exists in the building of similar structures. Its disadvantage is its dependency on water depth and the limited area that is available for activity. Due to the limit of water depth, most of the platforms are located under the horizon line and are visible from the shore and therefore it can be assumed that there will be public opposition to their construction.

Islands that are not dependent on location and are not limited by water depth

- Floating islands: This is a new/old technology based on existing technologies and their specific modification to each task. It mainly requires planning and conceptual flexibility and makes use of existing and proven elements, such as the construction of huge ships, the laying of underwater electricity cables, etc.

Suitability of the technology to the situation in Israel

Islands created by draining the sea are not practical in Israel since it does not have the quantity nor the quality of material needed in order to build artificial islands in the open sea on a scale that will support industrial plants. The only deposits of sand in the region that can be used as filling material are located in northern Sinai and would require the import of sand from Egypt. It is difficult to imagine this happening in view of the internal political opposition that it would arouse in Egypt against the sale of "Egyptian soil" to Israel. An instructive example is the experience of Singapore which has been importing filling material for an ambitious draining project for several decades. The filling material is brought from Malaysia and Indonesia. Whole mountains have "disappeared" from the Malay peninsula and the northern islands of the Indonesian archipelago, which have then been used to drain the sea in Singapore. Even though there are neighborly relations between the countries, the issue from time to time becomes a source of tension.

Floating artificial islands for energy infrastructures

The idea of a floating island was first raised as a solution near the coastline for a specific engineering problem. The first "islands" were barges that were used as jetties for loading and loading of ships at anchorages where there was no harbor. These rafts quickly became storage facilities for liquids (such as water and fuel) or goods. The installation of various machines on these barges, such as pumps, cranes, winches and drilling machines, transformed them into work areas or small factories. With the increasing manpower and scale of operations of these "factories", along with the allocation of residential areas for the manpower, the barges became "islands", which grew according to changing needs. The current oil and gas rigs grew to significant proportions, from several dunams (3,000–5,000 square meters) to tens of dunams (10,000-20,000 square meters) and even more. Thus, they can certainly be called islands, without quotation marks.

The discovery of offshore oil and the need to extract it, first at shallow depths and later in deep water, led to the development of offshore technology, which involved the finding of technological solutions to problems such as anchorage and tying down of heavy equipment in deep water, maintaining a stationary position at sea, use of appropriate standards during construction, deciding on appropriate ecological standards, etc.

At the same time, the size of ships was also growing. Today, ships that are 300–350 meters long, with a displacement of hundreds of thousands of tons are not a rare sight, whether they be oil tankers or some other kind of ship. Furthermore, there is a revival in passenger ships for recreation, which have grown to displacements of hundreds of thousands of tons and which sometimes carry infrastructures that can maintain a whole city. They can perhaps be considered to be inhabited floating islands.

The planning concept to build an artificial island for energy infrastructure

The most prominent characteristic of any floating island that has already been planned (whether or not it remained on the drawing table) is their design for one defined task. There are artificial islands (platforms) that are designed for the drilling of oil or gas, islands for power plants, islands for the storage of liquids and islands for the handling of natural gas. But as far as we know, and even though the parts of the engineering puzzle are used separately, there is currently no island with a variety of industries, which include an entire energy system.

The reason may be the price of a single island and/or the cost of planning. Without a specific and defined request from the customer, there are currently no companies that possess an "off-the-shelf" integrated solution, since the customer is in general a company in a specific field. A producer of natural gas, for example, will order an island with facilities for the production of gas while an electricity producer will order an island with a power plant, and so on.

We claim that from an engineering perspective, all parts of the puzzle in building an artificial island for energy infrastructures already exist and have been implemented in numerous locations around the world (such as in giant ships, in facilities for electricity transmission by means of underwater cables, in facilities for the production of gas, etc.), such that the concept of a floating artificial island for infrastructure opposite the coast of Israel is certainly worthy of serious consideration.

Examples of plans for floating infrastructure islands

One of the characteristics common to the planned facilities is their enormous size, which in some cases exceeds 500,000 tons.

The island appearing in the illustration serves as a gas handling facility near the production field and as a loading facility onto an LGT ship. The island essentially serves as a hub for the production network from the various wells dispersed throughout the field and it has the ability to regulate production.

The first island of this type was built in China by PETROBRAS, the national fuel company of Brazil.

Status: active
Diameter: about 110 meters
Displacement of 230,000 tons.

Figure 12.1 The planner: The ASA Sevan Marine Company from Norway.

There are various versions based on the same basic plan including power plants run that burn natural gas, tanks for storing natural gas and fuels, etc. Nonetheless, there is still no plan for a multipurpose island.

The island in the illustration is an example of a planned floating island for the storage of gas.

Figure 12.2 Ship/island for the processing of natural gas, including liquefaction facilities and loading onto natural gas tankers.

The following illustrations are examples of the planning of a floating "island" that includes a facility for gas production and a facility for liquefaction and loading onto LNG tankers. This island was meant to be the largest of its kind in the world. Ordered by Shell International which is under Anglo/Dutch ownership in a consortium with the Korean Samsung Industries, which was also meant to build it.

Length: 480 meters
Width: 74 meters
Displacement: 500,000 tons

Figure 12.3 Facility for gas production and a facility for liquefaction and loading onto LNG tankers.

Intended to exploit the Prelude gas fields in northwestern Australia. Planned annual production when the facility is fully operational would be 3.6 million tons of LNG annually.

Advantages:

The plan enables the exploitation and production of gas fields in distant locations on a very large scale, regardless of the water depth.

Disadvantages:

Since the "island" is meant to operate in the open sea, it must survive and function in a storm with high waves. The standard for such an "island" is a level 6 typhoon. This requirement, together with the requirement to produce 3.6 million tons of LNG, has determined the size of the "island". This in turn determined its price, which was estimated at $12 billion. It is no surprise that execution of the project is highly dependent on the global price of oil/gas.

Status: The project was halted due to the steep drop in global oil/energy prices during the last two years.

Transmission of electricity by underwater cables

The connection of the island to the shore and the national transmission system will be accomplished by means of existing and proven technologies. The technology for the transmission of electricity by means of underwater cables already exists and is becoming increasingly popular. Following are several examples of existing cables and of cables in the planning stages or are being laid:

Table 12.1 List of main underwater cables for transmission of electricity (in use and planned)

Name of cable and its point of connection	Voltage	Length of cable	Status
Westernlink UK. Scotland/England	600 kV DC	400 km	Being laid
Romulo between continental Spain and the ilsnad of Majorca		250 km	Being laid
SA.PE.I. (Italy) Sardinia/Italy Mainland	500 kV DC	434 km	Active
TransBay Cable USA San Francisco, California	200kV DC	85 km	Active
Messina Straits Crossing Italy, Sicily/Italy Mainland	380 kV AC	43.5 km	Active
Phu Quoc Island connection, Phu Quoc/Vietnam Mainland	110 kV AC	58 km	Active
Basslink (Australia), Victoria/Tasmania	400 kV DC	300 km	Active

Integrated multipurpose and multitask solution

Artificial Floating Mega Platform AFloMeP – We propose the consideration of a floating mega platform, which will include a combination of existing elements that have been shown to work successfully in other countries (although not in an integrated manner as proposed here).

This artificial floating island will bear an entire energy complex. Rather than transporting the natural gas from the new fields northwest of Haifa to onshore processing facilities and from there to the national gas network, as is currently planned, the gas could be transported directly to an artificial island near the field. The island will be used both as a processing facility and as a hub for the various wells. On the island, there will be a power plant that burns natural gas. The electricity can be transmitted to shore by underwater cable, which will be connected to the national grid or to the European grid by way of Cyprus. In addition, the island can also include a desalination plant that will use the excess energy produced by the two energy facilities for gas production and electricity production. The following illustrations depict the floating multipurpose artificial island for national energy infrastructures:

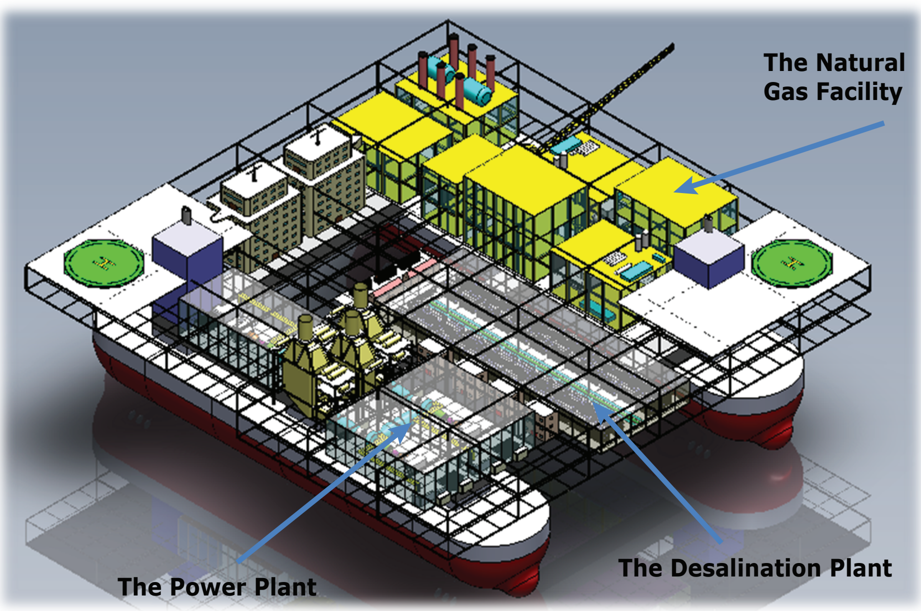

Figure 12.4 Artificial Floating Mega Platform AFloMeP*

The island will include the following:

- Three integrated power plants, each of them producing 350MW for a total of 1050MW.
- A desalination plant with annual capacity of 15 Mm^3.
- Gas processing plant.

Advantages:

- Saving of land, primarily in the coastal area.
- Distancing of safety hazards from population centers.
- Optimal location of the island which will facilitate the export of electricity to Cyprus and from there to the European grid.
- Shortening of transmission lines for the gas.
- Cheaper energy prices to the consumer: Location of energy facilities on a single platform lowers the cost of production per unit of energy, thanks to the reduced losses from transmission of the gas and the elimination of the need for a liquefaction/gasification plant. In this model, the issue of cooling, which is essential for both the power plant and the desalination plant, can be dealt with on the spot. This eliminates the need for an intake pipe and diffusion pipe for the desalination plant and the regulation of electricity production according to consumption – the desalination plant can serve as a reserve for periods of high consumption on land.
- Planning flexibility: In a different version of the AFloMeP, petrochemical refineries can be located on the island, which in the future will make it possible to free up land in Haifa Bay, which is currently used for essential but polluting petrochemical industries, for urban use.

Location of the AFloMeP at sea

In principle, there is no technical constraint on the location of the proposed platform, since it is floating and its height is planned to be that of a significant wave[4] (9.5 meters). Any location with a water depth of 35–40 meters is suitable from the perspective of displacement. The platform includes a self-positioning mechanism so that it is not dependent on water depth for anchoring.

4 Significant wave: mean height of the highest one-third of waves.

The location of the platform has economic, political, security and also social/ employment significance and therefore its geographic location must balance between the following factors:

- Proximity to gas field – shortening of gas transmission pipeline.
- Proximity to coast – shortening of electricity transmission cable and easier transport of desalinized water.
- Proximity to an existing port – to create continuity of supply and for techno logistic support.
- Proximity to a naval force or alternatively the possibility of anchoring near the naval force that will guard the platform.
- It is desirable that the platform be located beyond the horizon line from the viewpoint of an observer on the shore (in order not to disrupt the sea view).
- Existence of enough space for additional platforms for the building of an energy archipelago in the future.
- Proximity to countries with export potential for the platform's output.
- Preference for location in Israel's territorial waters and of course in Israel's economic waters.

It appears that the location of the platform on the boundary of Israel's territorial waters—about 20 km northwest of Haifa or about 20 km west of the Ashdod-Ashkelon line, satisfies most of the criteria.

Floating platforms and terminals for natural gas near the coast of Israel

Israel Natural Gas Lines Ltd. is responsible for the unloading and transmission of natural gas to customers in Israel. The company currently has three unloading terminals, two of which are on land (Ashkelon and Ashdod) and one of which is offshore with a floating terminal (Hadera).

The two terminals in Ashkelon and Ashdod are modified for natural gas and are connected to the gas pipelines from the nearby fields, from Egypt and from the Thetis fields (Ashkelon) and the Tamar fields (Ashdod).

Receiving terminal for liquefied natural gas opposite Hadera

This is a floating platform connected by a flexible pipe to the national gas supply line, with gas brought in by a rigid underwater pipeline of about 8 km in length. The floating platform is anchored to the sea floor by means of eight chains and anchors. The length of the chains allows the movement of the platform on a vertical axis and also within a certain diameter on the horizontal axis. A special ship for transporting the gas is connected to the platform by means of an opening in its hull. The gas flows through the opening and the terminal and undergoes heating/gasification (since the gas is stored on the ship in liquid form). It then flows into the national transmission system and from there to the various customers (primarily the Israel Electric Company).

The facility was built by Micoperi, an Italian Company for APL, a Norwegian company. There are two additional floating platforms of this type in use worldwide. The system is operational.

Advantages:

- The facility is relatively distant from the shore although it is under the horizon line.
- The unloading of the gas is done underwater, which increases safety.

Disadvantages:

- The system needs a particular type of natural gas ship that is equipped with an opening in its hull.
- The system provides a solution for one problem only: the unloading of natural gas.