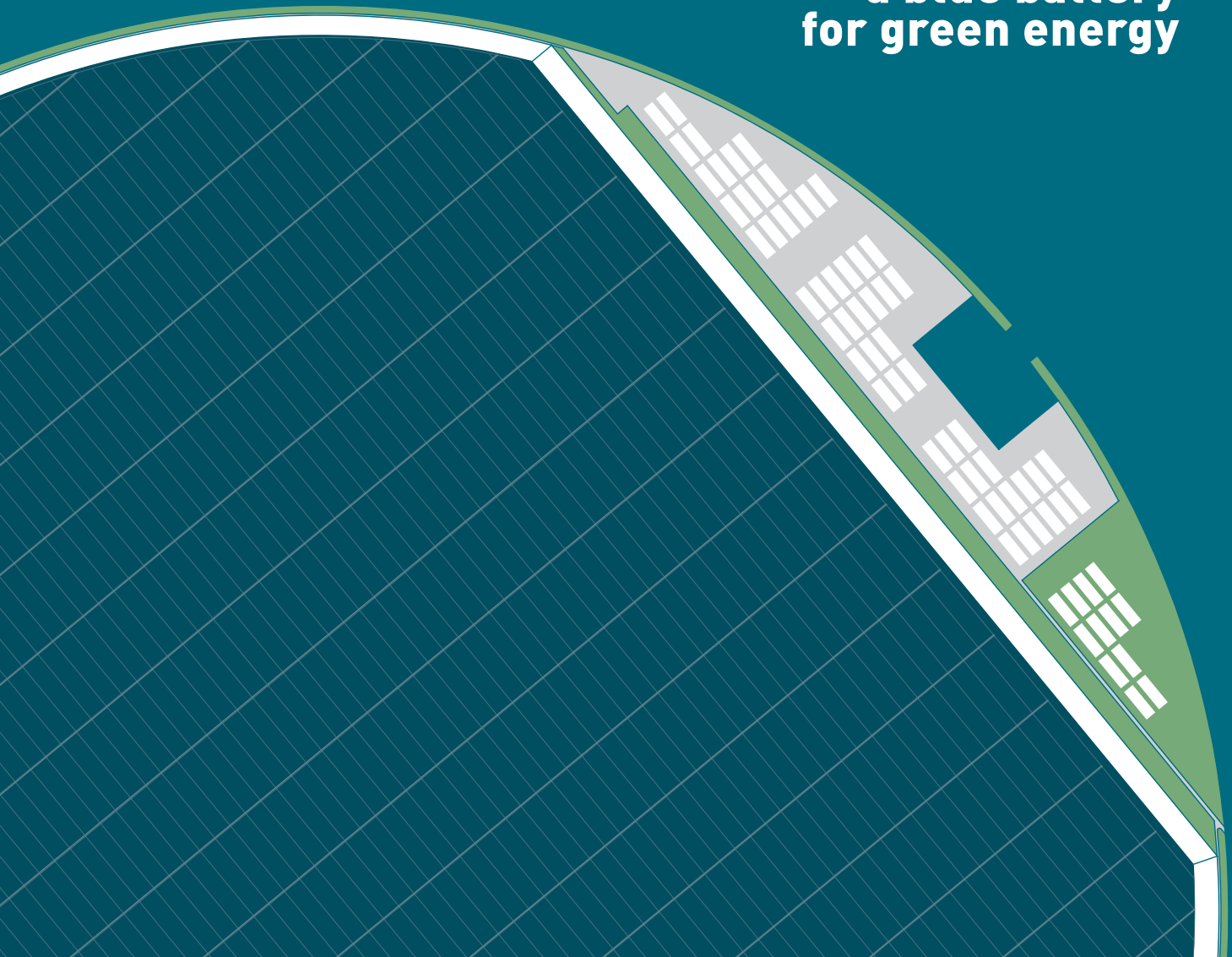
Gottlieb Paludan

GREEN POWER ISLAND

a blue battery for green energy



GREEN POWER ISLAND

Visionary ideas for the energy systems of tomorrow

Green Power Island was created by

Gottlieb Paludan Architects and the Risø National Laboratory for Sustainable Energy under the Technical University of Denmark, with support from Danish and international advisors. Green Power Island is a development project in its initial stages, and further research and development will include financial, technical, environmental and design studies.

www.greenpowerisland.dk

Contents

Quote

"To cap greenhouse gas emissions, the leaders of the world must cooperate on, and pump money into, projects that in terms of cost and scale are comparable to a lunar landing" as Danish Prime Minister Lars Løkke Rasmussen put it at a climate conference in Brussels.

"Let us each, in our own field, pursue new Apollo-scale projects, so that we can realize the full potential of technology" he urged. In his speech the Prime Minister also set the stage for Denmark to increase its percentage of wind power for electricity production, from today's 20% to 27% in the year 2020. This will, however, necessitate the ability to control production.

"Proportionally to the considerable share of wind-generated electricity we achieve, we are forced to solve the problem of storage and peak demand."

www.ingenioren.dk 18 June 2009

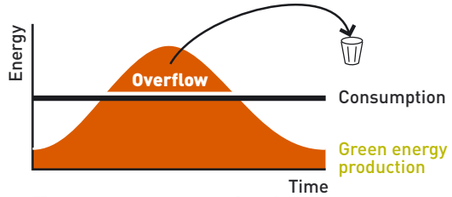
Green Power Island stores excess green energy in seawater when demand is low and supplies energy instantly when demand rises.

WHY ?

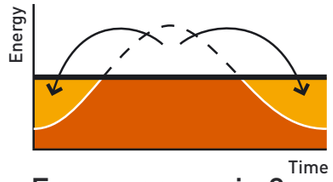
Renewable energy sources, like the sun and wind that we increasingly rely on for future worldwide emission-free energy, are unpredictable and uncontrollable. Fluctuations in solar and wind-based power production are inevitable and cannot be calibrated to match variations in energy consumption. As a result, wind turbines and solar plants are bound to produce power at times when no one needs it – and to *not* produce at times of peak demand. A minor problem today, perhaps, but one that will grow with our increasing reliance on wind and solar power.

In order to make the necessary transitions and move towards a renewables-based energy system, even while maintaining an efficient, stable and secure power supply, we must find ways to store excess wind and solar energy to prevent it from simply going to waste.

In some of the world's mountainous regions, pumped hydro is used to balance the power system. Water is pumped back into the high reservoirs of hydro plants to generate power in later periods of high demand. For the world's many low-lying, flat coastal regions, this is not an option. Such areas are often ideally suited for wind farms, both on land and offshore – yet today they lack methods for storing large quantities of energy.



Energy scenario 1
without storage options



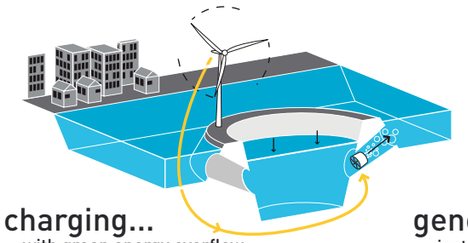
Energy scenario 2
with storage options

How ?

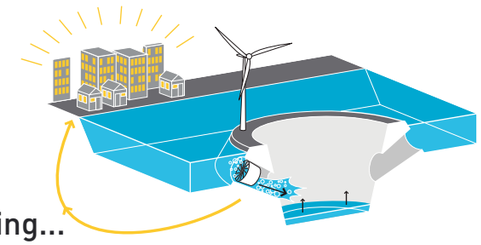
Green Power Island is a visionary concept for constructing artificial islands that store energy by means of seawater. Each island encloses a lagoon-like reservoir, which is emptied using pumps driven by excess wind and solar power produced while demand is low.

As consumption rises, seawater is allowed back into the reservoir, driving turbines that generate new power. In this way it is possible to regenerate up to 75% of the energy that went into the process of pumping the reservoir empty.

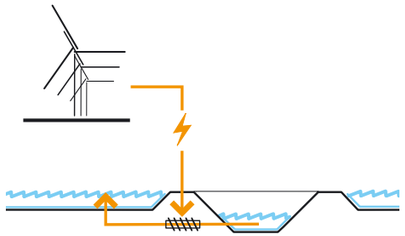
To even out the imbalance between demand and capacity, existing and future solar plants and wind farms can be combined with a number of Green Power Islands. This creates the potential to store renewable



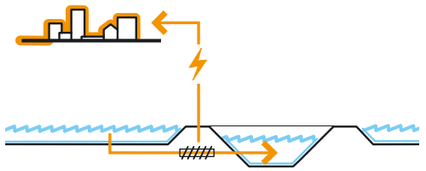
charging...
with green energy overflow



generating...
instant hydropower



Storing wind power when demand is low
by emptying the reservoir.



Regenerating power when demand is high
using hydroturbines.

energy on a massive scale and rapidly regenerate it at peak hours, even in the absence of sun and wind – thus matching supply to demand.

Interacting with emerging technologies - such as power storage in electric car batteries, electric heat pumps and a more intelligent distribution system - Green Power Islands offer a large scale and low tech answer to the growing problem of green energy overflow.

The large-scale introduction of a flexible technology like pumped hydro into the energy market will also allow for traditional power plants to run at constant load, as the Green Power Islands are much better equipped to handle short term fluctuations in energy consumption.

Synergy

A Green Power Island is effectively a man-made atoll that fills with seawater to produce energy using hydropower techniques when demand is up. In times of energy overflow from wind turbines or solar plants, the island utilizes surplus energy to empty its reservoir – and is ready to produce again.

Such islands are suitable for a variety of locations: around wind farms out at sea, near large infrastructure projects like bridges, as reclaimed land near major cities. Islands may vary in size from about 1.5 to 65 sq km with storage capacities ranging from approximately 400 MWh to 50,000 MWh.

A crucial factor when integrating such large facilities into an existing environment is that they possess qualities over and above their mere ability to store energy. In functionality and design they must serve to enhance the existing values of a site, or add new ones. Depending on their location and size, the islands can fulfil additional and synergetic functions that fall into different categories and focus areas.

What is more, when building these large structures it is possible to incorporate ideas that can generate additional income – that is, financial benefits unrelated to the energy storage itself. Such functional synergies can help to optimize the financial equation in a Green Power Island project.

Location, size and function

Context

Business

Living

Leisure

Energy

Context

For centuries, in coastal areas across the globe, reclaiming new land has been a way to expand one's territory and adapt to new challenges. Green Power Island carries on these traditions – only this time the challenge lies in imminent climate change.

The size and configuration of a given island depend entirely upon the context into which it will be integrated. The context also decides which additional and synergetic functions the island will ultimately fulfil. The Green Power Island project has identified four distinct contexts where integrating such an island is meaningful:

Open Sea – Because there are no neighbours, a location out to sea obviously provides some degree of freedom when it comes to size and configuration. At the same time, the open sea offers a good opportunity to maximise the island's wind-power potential.

City – The elevated areas of an island located next to a major city can be incorporated into urban development projects and add high-quality space to the city as a whole, even while helping to finance the construction work they require.

Bridge – Integrating a Green Power Island into major infrastructure projects like bridges and tunnels makes the most of the vast earth-moving works that such projects require in all events. Often they involve artificial islands at strategic transition points, for instance where a bridge links to a tunnel. In other cases there is simply a need to dispose of excess earth from other projects.

Power Plant – Locating a Green Power Island near a power plant can yield several positive synergies, such as easy link-up to the grid, potential growth of energy crops and smoke scrubbing.

Business

Depending on the location and context of each individual island, there may be various types of business activities that can contribute to financing the project and integrating the island into its own particular context.

Harbour – The intergration of harbour and port facilities is mainly meaningful for islands located near major infrastructure projects.

Aquaculture – Growing shellfish or seaweed for human consumption can be a viable undertaking, as the upper layer of the reservoir offers better and more controlled growth conditions than those found in open waters.

Industry – Islands can serve as a base for industries which, for various reasons, are best located away from populated areas.They can also host businesses naturally linked to other functions on the island, such as the processing of aquaculture crops.

Logistics – A strategic location and excellent accessibility to the regional infrastructure can make the island a site of choice for transport and logistics facilities.

Business – An island located near a major city or business area may be ideal for development as new commercial or industrial properties.

Living

Depending on their location and shape, Green Power Island areas can also be used for a variety of residential purposes, ranging from extensive, co-financed urban projects to alternative types of permanent and recreational dwellings.

Houseboats – An island can be designed to harbour alternative communities based on houseboats. Alternatively, and rather more radically, houseboat colonies could freely float on the rising and falling surface of its lagoon-like reservoir.

Housing – Islands near major cities have an obvious potential as residential areas; part of urban development schemes; and a means of co-financing their construction.

Allotment Gardens – The large surface of the reservoir can be used for barge-based floating kitchen gardens, which make a valuable contribution to urban households and create new recreational opportunities.

Leisure

Establishing leisure facilities on the islands can help to integrate the new areas into the community, and augment the quality of life.

Natural Resort – Notably in the open sea or in remote locations, man-made islands and coastlines can serve as protected areas for birds and other marine fauna and flora.

Sports – The elevated portions of islands near urban areas can be used for sports facilities, to become a natural part of local daily life.

Beach – Establishing a public beach on the coastline of a new island is one obvious way to add quality, for local beach-goers and for visiting holiday-makers.

Water sports – Like public beaches, facilities for water sports will add quality to the area and root the island within the local context.

Biking – Whether the new island is used for industrial, residential or recreational purposes, the incorporation of public bicycle trails and footpaths can promote the area's integration into the local community.

Marina – Whether located near an urban or recreational development, a Green Power Island is the ideal place for a marina that accommodates sailing and boating activities.

Energy

Green Power Islands offer a variety of options for actual energy production in connection with energy storage.

Turbine Base – The conditions for wind power on these islands are excellent, and quite unique, pairing the benefits of land-based wind turbines with the power of the open-sea wind. In short, offshore wind farms with onshore conditions – meaning high efficiency, low construction costs, and easier maintenance.

Solar Energy – The large surface areas of the reservoirs readily lend themselves to the idea of solar power plants, based on barges or other floating structures and moving up and down with the water level.

Biomass – In configurations linked to power plants and in other contexts, a Green Power Island provides superior conditions for growing biomass, on land or in the water. Elevated areas can grow high-energy willow, and the reservoir can be used to cultivate algae – either for biofuel production or for use as fuel in biomass-fired power plants.

Green Power Islands

The following pages outline a number of Green Power Islands located in different parts of the world.

The central premise of the Green Power Island project is that to avert destructive climate changes, the world must move away from the use of fossil fuels to fulfil its energy needs. This challenge is shared by all nations and by people across the globe – which is why the concept of Green Power Islands is a solution with global potential.

The locations have been selected based on their context, topography, energy profile and existing traditions for large-scale construction projects. At this stage conditions in the seabed and marine environment have not yet been studied.

The chief aim of the initial studies has been to show the wealth and diversity that the concept of the Green Power Island embodies in terms of size and design, context and functionality.

DENMARK

Green Power Island

Denmark
Green Power Island Kattegat

The conversion of the Danish energy system to accommodate renewable energy sources is well on its way. While exploiting the synergies of a future infrastructure project, this island helps solve the outstanding problem of how to feasibly store the growing amounts of green energy from Denmark's ever-increasing wind power capacity.

Denmark
Green Power Island Kattegat

Energy storage and regeneration

The island's main function is to store excess energy from wind power production. The reservoir of 3.3 sq km has a volume of 31,350,000 cu m, with a generation potential of 2.75 GWh of electricity. This equals the total electricity consumption of all households in Copenhagen for a 24-hour* period.

Wind power

The south-western rim of the island holds 25 wind turbines of 5 MW each – which brings total installed capacity to 125 MW.

Marine biomass

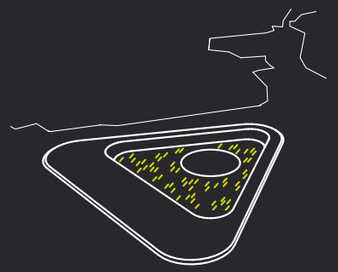
The 31,350,000 cu m of seawater in the reservoir is utilized for growing marine biomass by way of macroalgae for biofuel and for food ingredients. The algae grow in the upper 10 m of water in a floating grid of buoys and gangways that move up and down as water levels change.

Infrastructure

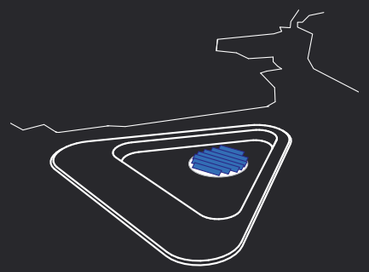
The island is designed as a part of a future traffic link stretching between the island of Zealand and the peninsula of Jutland, and spanning the waters of the Kattegat.

The Green Power Island lies directly south of Samsø – the world-renowned Danish Renewable Energy Island – at the point where the bridge layout changes from high to low and links up with Samsø's own transport infrastructure.

** Based on a daily consumption of 10 kWh / household*



Marine biomass



Solar power

Energy crops

Recreation

Denmark
Green Power Island Copenhagen

Linked to the Avedøre Power Plant (APP) and located near the capital, Green Power Island Copenhagen will enable a gradual transformation of APP from a conventional energy production plant into an integrated and sustainable energy centre with

- hydro storage
- algae-production for biomass/biofuel, CO_2-cleansing and food ingredients
- bio fuel crops
- the largest, most efficient solar power station in Scandinavia.

Green Power Island Copenhagen covers a total area of 4.9 sq km, including a water reservoir with a capacity of 22,000,000 cu m and a generation potential of 2.3 GWh of electricity – roughly corresponding to the electricity consumption of all the households in Copenhagen for a period of 24 hours*.

Architecture & Planning

For centuries the reclamation of new land has been a way to expand territory and adapt to a changing world. In fact, large portions of the city of Copenhagen and its surrounding fortifications have developed in this manner.

Green Power Island Copenhagen is situated on the outer rim of Avedøre Holme, which is itself an artificial island that is home to the Avedøre Power Plant and other facilities.

Green Power Island Copenhagen will become a hub for producing and storing renewable energy, and be a cornerstone in the system providing power to the Copenhagen area.

The island is designed to adapt and fit into its surroundings – the waves, currents and winds, and the flat landscapes that lie further off to the south.

** Based on a daily consumption of 10 kWh / household*


Tampa
Gulf of Mexico
0
20 km


USA
Green Power Island Florida

USA
Green Power Island Florida

An energy island off the west coast of Florida, located near the city of Tampa, will help this state achieve its ambitions to become the solar locomotive of the United States. It will also contribute to solving the overarching American challenge of making a secure transition from existing energy models and moving towards carbon-neutral energy systems.

USA
Green Power Island Florida

Energy storage and regeneration

The island's main function is to store excess energy from wind and solar power production.

The water reservoir of 9.4 sq km and a volume of 89,300,000 cu m has a generation potential of 7.8 GWh of electricity. This equals the total electricity consumption of all households in the city of Tampa for about 48 hours*.

Energy production

The island's perimeter serves as a base for 33 wind turbines, and the surface of the reservoir is utilized for 8 large floating Concentrated Solar Power plants with a combined installed capacity of 253 MW.

Residential

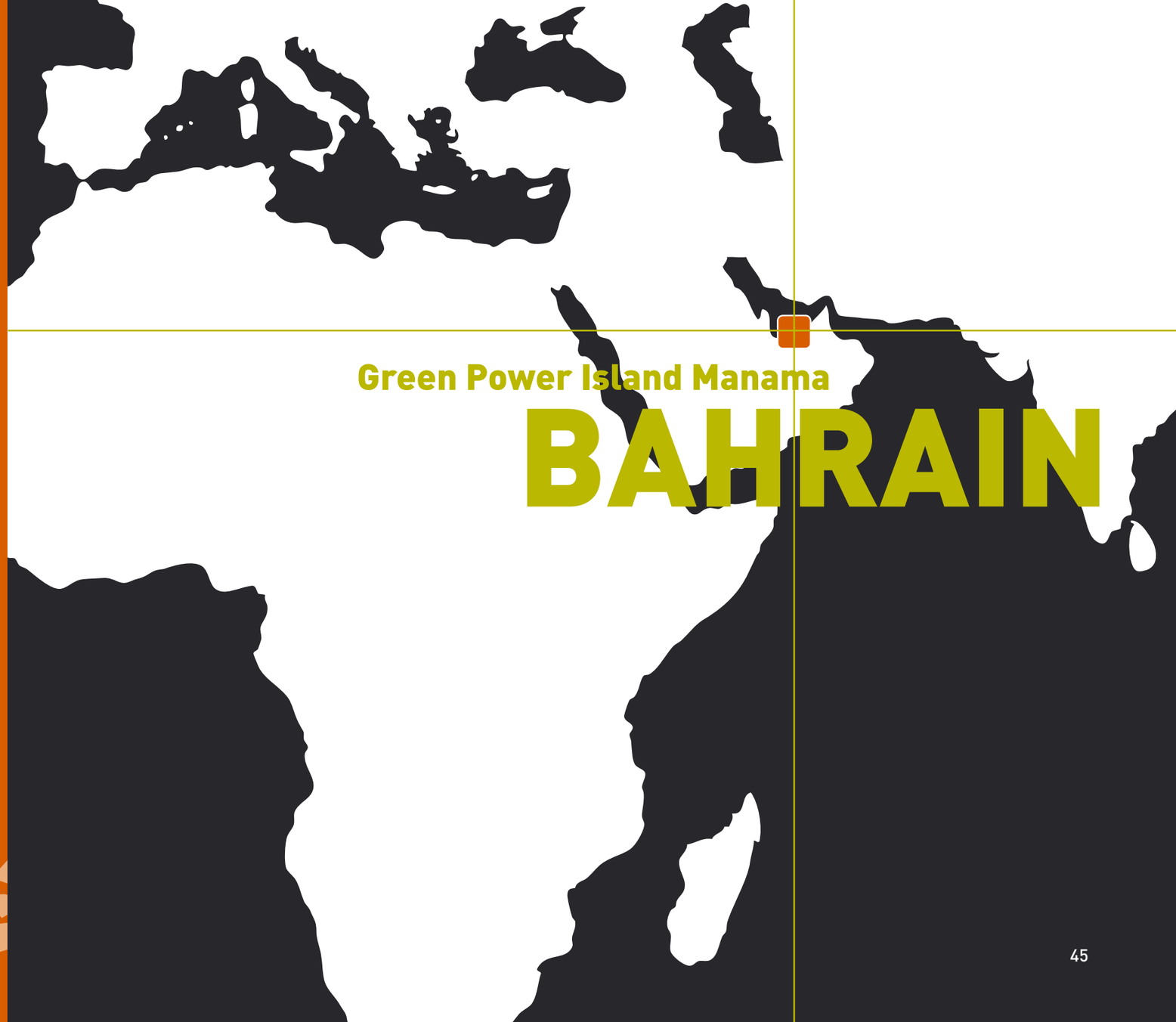
The island will also expand the volume of attractive waterfront real estate along the west coast of the Tampa Bay area.

The island's eastern shore is laid out for residential functions with a toothed coastline of 50 km to provide as many waterfront building sites as possible. The residential properties make room for 1,250 single-family waterfront homes, plus 580,000 sq m of residential and business development space in the two 'town centers' on the Green Power Island.

Leisure

In addition to its residential communities, the island features leisure facilities such as a golf course, a marina, and extensive areas set aside for outdoor recreation.

** Based on a daily consumption of 30 kWh / household*

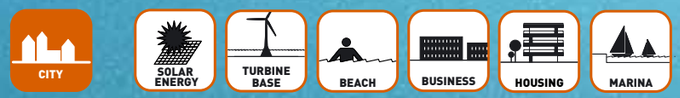


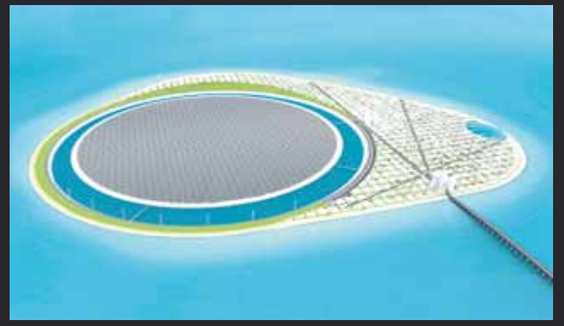
Green Power Island Manama

BAHRAIN

Bahrain
Green Power Island Manama

This island in the Bay of Manama will provide the small island nation of Bahrain with large-scale energy storage, as well as urban development opportunities for up to 48,000 inhabitants.





Bahrain
Green Power Island Manama

Energy storage and regeneration

The island's water reservoir of 12.5 sq km and 118,750,000 cu m in volume, holds a generation potential of almost 11 GWh of excess electricity from solar and wind power production. This equals the total electricity consumption in 24 hours* of closeto one million households in the Persian Gulf region.

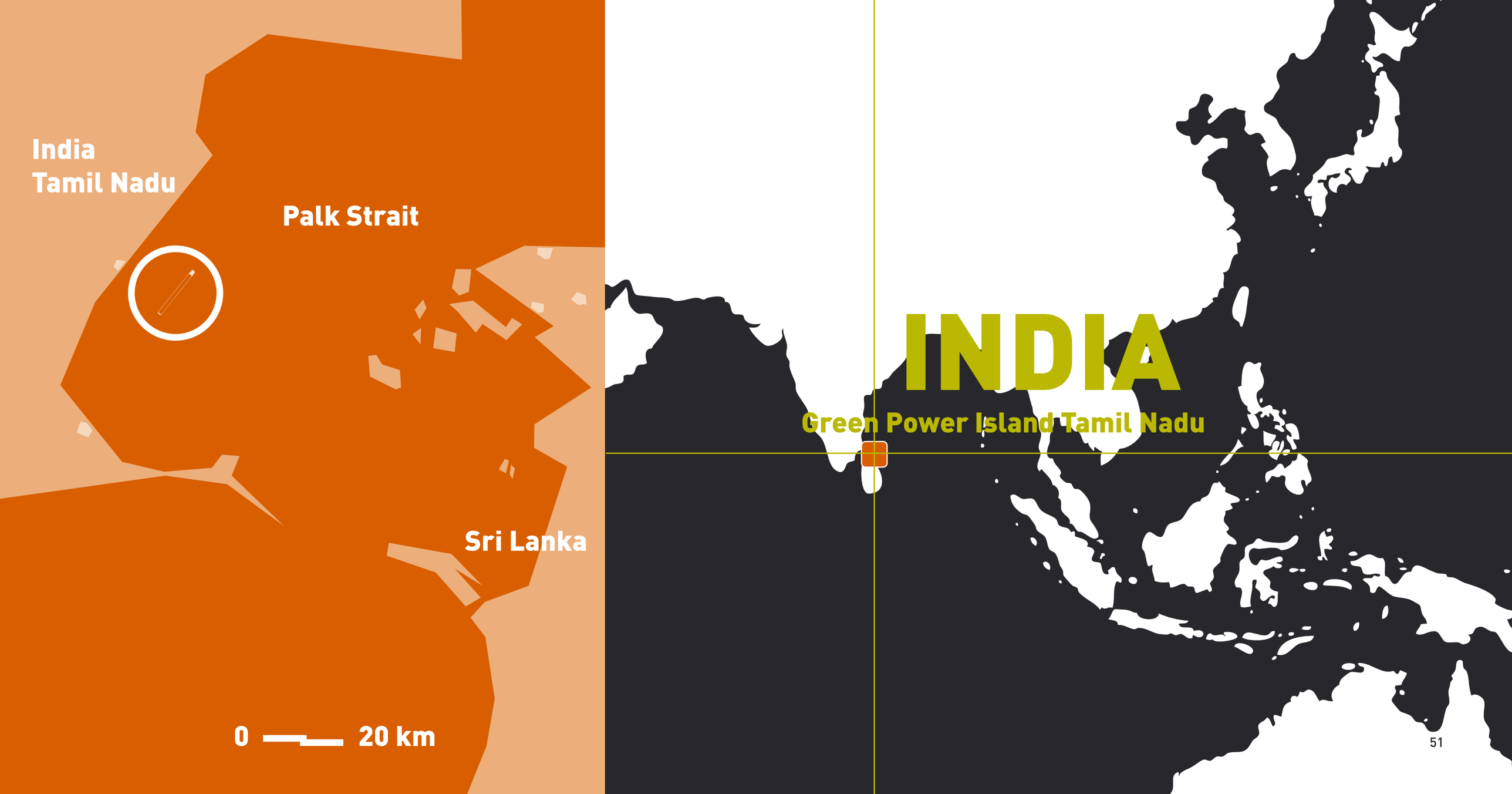
Energy production

The surface of the reservoir is laid out for a 10 sq km floating solar power plant, and the rim of the reservoir supports 36 wind turbines of 5 MW each. This adds up to a total installed production capacity of 640 MW.

Urban development

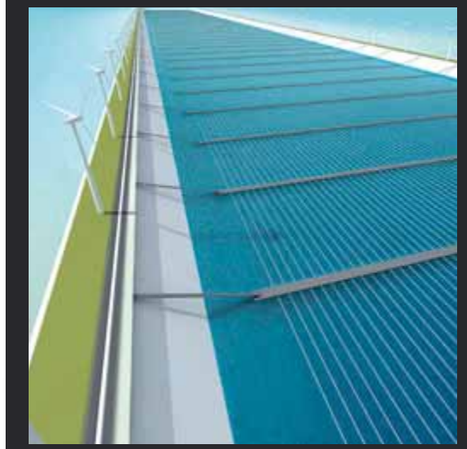
The island's position off the northern coast of Bahrain in close proximity to the capital of Manama offers vast urban development opportunities. The island includes 9 sq km of waterfront properties suitable either for businesses or for residential communities that can house up to 48,000 people.

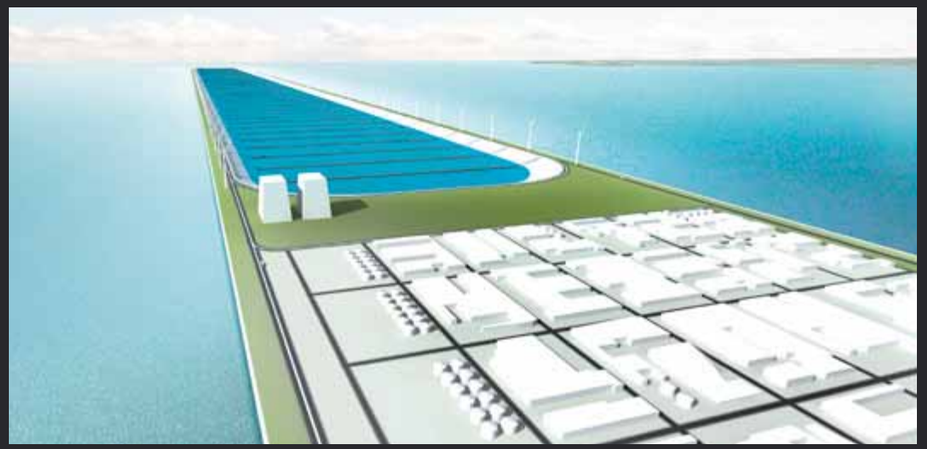
** Based on a daily consumption of 10 kWh / household*


India
Tamil Nadu
Palk Strait
Sri Lanka
0
20 km
INDIA
Green Power Island Tamil Nadu

India
Green Power Island Tamil Nadu

In the coastal district of Rameswaram on the southern tip of India, the Centre for Wind Energy Technology in Chennai has conducted surveys showing the area to be a promising spot for setting up offshore wind farms. The offshore farms will supplement the many onshore wind farms already established in the state of Tamil Nadu, which holds more than 40% of India's installed wind power capacity.





India
Green Power Island Tamil Nadu

Energy storage

The island stores excess energy from wind power production. The water reservoir of 11.6 sq km and 110,200,000 cu m has a generation potential of 9.7 GWh of electricity equalling the total electricity consumption of 420,000 Indian households for a week.*

Wind power

The rim of the island is used for installing offshore wind turbines ‘onshore’ – thereby avoiding the high costs of building solitary turbine bases on the seabed. The island houses 86 wind turbines of 5MW each with a total installed capacity of 430 MW.

Marine biomass

To support the official biodiesel policy of Tamil Nadu, the free waters of the storage reservoir are used to grow macroalgae for biofuel, as an alternative to the traditional land-based cultivation of oil-rich jatropha.

The algae grow in the upper 10 meters of the reservoir’s seawater, organized in a floating grid of buoys and gangways that move up and down as water levels change.

** Based on a daily consumption of 3.3 kWh / household*


East China Sea
Shanghai
0 20 km
Green Power Island Jiangsu
CHINA

China
Green Power Island Jiangsu

Located off the coast of China's future green-energy centre in Rudong County, close to the bustling metropolis of Shanghai, this energy island addresses some of the key challenges that China's energy systems face: Distribution, security of supply, and the integration of renewable energy.

China
Green Power Island Jiangsu

Infrastructure

Making the most of synergies in the local infrastructure, the island is designed as an extension of the artificial Sun and Taurus Islands of the Yangkou Port project off the coast of Rudong County.

Energy storage and regeneration

The island is designed to store excess energy from wind power production. The water reservoir of 63 sq km and a volume of 598,500,000 cu m holds a generation potential of 52.5 GWh of electricity. This corresponds to the total electricity consumption of 2.3 million average Chinese households for about one week.*

Energy production

The 29.5 km perimeter of the island facilitates the installation of 64 wind turbines with a total installed capacity of 320 MW.

Aqua culture

The upper 10 meters of the reservoir water is used for long-line shellfish farming in a system of buoys and gangways that rise and fall with the water level in the reservoir. The processing and packaging of harvested shellfish takes place in facilities located in the island's harbour area. This allows for one continuous work flow throughout the operation – from cultivation to distribution.

** Based on a daily consumption of 3.3 kWh / household*

PROS AND CONS

Advantages

The Green Power Island concept offers a variety of valuable benefits:

Green Power Island can rapidly regenerate stored green energy at peak hours – even in the absence of wind and sun – ensuring a better match between supply and demand.

Green Power Island addresses the problem of effectively handling green energy overflow, which will intensify as we move towards energy systems based on renewable energy sources.

Green Power Island enables local use of locally produced energy, thereby limiting the requirements to the transmission grid and enhancing the security of supply.

Green Power Island uses 'pumped hydro', the most cost-effective means of storing large amounts of electrical energy, limiting energy losses to around 25%.

Green Power Island makes use of the most abundant and easily accessible resource in the world – sea water – to solve a pressing environmental problem.

Green Power Island demonstrates how large energy installations can be incorporated into landscapes and citycapes – and even bring new value to local communities.

Green Power Island is based on well-known technologies – not on 'rocket science' – and the concept is practically possible today.

Green Power Island enables the installation of offshore wind turbines in onshore conditions, also presenting large surface areas for solar plants.

Challenges

Green Power Island is a development project that is still in its initial stages, and so further research is called for in the following areas:

Supply security
Green Power Island is a regulatory installation, aimed at neutralizing energy waste. Therefore strategic decisions are needed as to what level of supply security and efficiency is desirable in the energy system. These decisions will aid in defining the need for a Green Power Island.

Seabed conditions
Locating a perfectly suited site for the island is crucial to establishing an impermeable and stable reservoir bed, which is necessary to prevent seawater from seeping in. Natural conditions are decisive, since constructing such a bed in the relevant dimensions would be far too expensive.

Financial feasibility
Establishing a Green Power Island is a major infrastructural undertaking, comparable to building a major bridge or tunnel. A cost-benefit analysis for such a project must assess a number of factors, including building costs, the energy market, and potential synergetic functions to support the financial equation.

Marine environment
When choosing a location, there must first be a thorough investigation into the impacts on local marine environments, to prevent adverse effects.

Building technology
Depending on local conditions such as water depths and currents, waves and wind, planners will assess the suitability of various tried and tested landfilling and dike-building techniques.

Definition of ‘pumped hydro’

”Pumped storage hydroelectricity is a type of hydro-electric power generation used by some power plants for load balancing. The method stores energy in the form of water, pumped from a lower elevation reservoir to a higher elevation. Low-cost off-peak electric power is used to run the pumps.
During periods of high electrical demand, the stored water is released through turbines. Although the losses of the pumping process makes the plant a net consumer of energy overall, the system increases revenue by selling more electricity during periods of peak demand, when electricity prices are highest. Pumped storage is the largest-capacity form of grid energy storage now available.”

Wikipedia

A blue battery for green energy

How can we make the necessary transition towards a renewables-based energy system, yet still maintain an efficient, stable and secure power supply?

Wind and solar power, which we plan to use to obtain clean, renewable energy in the future, are forces of nature that cannot be regulated to match our demand.

Devising methods for storing power to make our future energy systems work effectively is an urgent task. If we are to rise to this test, we will have to pool multiple technologies – and many such projects are well on their way. Even so, we still lack a method for storing truly massive quantities of electricity.

Green Power Island is a visionary concept that offers a large-scale, low-tech response to the growing problem of green energy imbalance and overflow.

Imagine being able to store surplus energy by combining conventional hydrotechnology with our most abundant and easily accessible natural resource, seawater.