# Energy Duck

## So much more than just a duck

Energy Duck is an entertaining, iconic sculpture; a celebration of local wildlife; a renewable energy generator, store and exporter; a habitable destination and a city scale information beacon.

The common eider duck is resident in great numbers in Copenhagen, however its breeding habitat is at risk from the effects of climate change[[1]](#footnote-1) . Energy Duck takes the form of the eider to act both as a solar collector and a buoyant energy store.

Solar radiation is converted to electricity using low cost, off the shelf PV panels. Some of the solar electricity is stored in the form of gravitational potential energy via water pressure. At night, when there is no solar radiation the water pressure can be released through hydro turbines within the duck’s belly providing renewable electricity at all times. The floating height of the duck is an indicator of the amount of city wide energy use relative to the renewable generation.

Often the prospective negative environmental effects of climate change, brought about by excessive C02 emissions can seem a removed and distant issue. Energy Duck frames the issue of climate change, ecology and the importance of renewable energy in a local context.

Energy duck is certainly a spectacle to behold. Equal in height to a 12 storey building the duck offers the city of Copenhagen unique experiences from afar, from near and from within.

## Addressing the needs of a renewable energy future through fun

Copenhagen has the admirable aim of becoming carbon neutral by 2025. To achieve such a low carbon future requires a city scale transition to renewable electricity. At this scale, due to the inherent intermittency of renewable energy sources it is essential to be able to store energy and release it as electricity at a later time when the wind is not blowing or the sun is not shining.

Energy duck stores solar energy by making use of its floating nature. Energy is stored by virtue of the difference in water heights inside and outside the duck. Solar energy used to pump water out of the duck and buoyancy brings it to the surface. When stored energy is required to be delivered, the duck is flooded through one or more hydro turbines to generate electricity which is transmitted to the national grid by the same route as the PV panel generated electricity. Energy Duck can be used to cover short term fluctuations (e.g. cloud cover) for hundreds of houses or long term (a few days) demands of around fifty houses.

We have undertaken computer modelling of the proposed Energy Duck to simulate the effects of variable solar radiation and variable demand. The results of the modelling show that annually we expect the duck to generate 400 000 kWh of electricity. Copenhagen’s 2025 plan states a target of 1000kWh/person/yr and on average Copenhageners live 2.5 people to a house. So that’s enough annual energy for around 160 houses. Of equal importance is the pairing with the energy store which allows the electricity to be delivered when it is needed. The embodied energy is predicted to be equivalent to about 15 years worth of generation, that is, 6000MWhr. This may seem high but it is comparable with other generation and storage techniques.

At night the duck is lit with very low power colour changing LED lamps. The colour pattern undulates with a rhythm proportional to the output of the hydro turbines.

## How to make a giant duck

A lightweight steel space frame makes up the duck volume and define its shape. Very light weight steels support the PV panels and the dummy panels. The skin is not water tight, it doesn’t need to be. Internal sheltered spaces can be formed inside the frame by ETFE transparent membranes. The energy store is formed using the established technique used in vast water storage sectional tanks with internal steel bracing. These tanks are ubiquities thought out the world can withstand high pressures and are typically constructed from GRP, which has recently become much more readily recyclable.

PV panels are only applied to the areas that receive a good amount of solar radiation (which is most of the duck’s upper half). The remainder of the duck is clad with cheap, lightweight dummy panels, which could be made from recycled plastic. Modelling shows that even with the panels orientated duckwise, the energy yield is 75% of that of a fully optimised solar farm on the same site.

Visitors inside the duck move through an enormous honeycomb mesh of light weight steel. Views upward reveal the striking pattern of a mesh of PV panels in silhouette, backlit by daylight streaming in through the air gaps. Looking downward allows one to see sea water rising and falling within the pressure storage tanks. When the duck is pumped out, in addition to providing automatic cleaning to the PV panels all manner of fun and interesting things could be done with the ensuing water spouts.

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| Materials List, Costs and Embodied Energy |
| **item** | **quantity** | **unit** | **cost rate (£/unit)** | **cost (£)** | **embodied energy quantity** | **ee unit** | **embodied energy rate (kWhr/unit)** | **embodied energy (MWhr)** |
| pv system | 2700 | m2 | 200 |  540,000  | 2700 | m2 | 190 | 513 |
| non pv dummy panels | 1100 | m2 | 50 |  55,000  | 29700 | kg | 10 | 297 |
| steel structure and framework | 336 | tons | 3000 |  1,008,000  | 336000 | kg | 10 | 3360 |
| water storage tank panels (GRP) | 4600 | m2 | 50 |  230,000  | 124200 | kg | 10 | 1242 |
| hydro turbines and pumping system | 1 | item | 100000 |  100,000  | 1 | item | 400000 | 400 |
| lighting and electrics | 1 | item | 100000 |  100,000  | 1 | item | 150000 | 150 |
| project management and design fees | 1 | item | na |  304,950  | 1 | item | 100000 | 100 |
|  |  |  |  |  |  |  |  |  |
|  |  |  | **total (£)** |  **2,337,950**  |  |  | **total (MWhr)** | **6062** |

## The energy kit

The space frame of the duck is not restricted to a particular type of PV panel. The design can accommodate any manufacturers’ panels. For this submission we propose the Panasonic HIT panels which are most efficient panels commercially available. They do not have the lowest £/W cost but we feel in this context the energy benefit is the right choice.

The hydro turbine(s) will be of the high flow rate, low head type. In the proposals shown the water pressure head is 8m. Either Kaplan or Francis turbine types of 100 to 500kW are available in range.

The PV and hydro electrical equipment will all be installed within the body of the duck. A flexible transmission cable will run underwater and onto shore into the egg gatehouse where it meets the connection switchgear of the national grid.

## Bold but considerate and scalable

An important part of our proposal is to maximise the energy yield whilst being sensitive to the site. Large scale wind would provide the best energy return on investment but we don’t consider it appropriate for the site. The next best option are PV modules. Simple, effective and incredibly low maintenance. By siting the installation in the water, valuable land remains available for other uses.

Our team comprises of artists, an architectural practice, a renewable energy systems engineer and a mechanical engineer. An important part of our submission is that we feel whilst the proposal is certainly bold it is indeed buildable. Should the proposed duck be deemed somewhat large, no problem. Energy duck is completely scalable. A 40m high duck serves a town, a 20m high duck serves a village and a 4m high duck serves and individual house.

## Environmental impact assessment

The effect to land is negligible since we propose to make hardly any change.

There will be no operational pollution to air. There are no liquids other than water stored within the duck. The duck will be made from inert materials so the risk to water is minimal.

There will need to be a marine biodiversity and habitat survey. The future design will need to respond to this. Possible mitigations could include designing the duck base and sides to provide enhanced marine habitat, for example creating mussel beds, a favourite of the common eider.

Blocking light from existing and future neighbours could be an issue. A light access study will be required to influence the design development. An advantage of the proposed design is that as well as being scalable the duck itself could have a limited range of movement to manage and partially mitigate overshadowing.

1. Baltic Sea Environment Proceedings No. 140, HELCOM Red List of Baltic Sea species in danger of becoming extinct. 2013. Table 7.4. cites common eider as “vulnerable” for breeding and “endangered” for wintering. [↑](#footnote-ref-1)