OUR VISION OF A SOLENT ECO-CITY

Envisioned by Joe Griffiths, Hao-Cheng Lin and Charlie Rooks

E4E CHALLENGE 2018

HAVANT COLLEGE

Contents Page

Part I – Overview of our city and requirements

Our city is a vision of the future of the Solent Seafront in the South of England, UK. A prime location for such eco development due to the huge potential of energy generation from multiple natural sources such as the sea, rivers, and comparably large amounts of daylight hours (for solar energy), also there are many pre-established infrastructure links such as the ports of Portsmouth and Southampton along with an airport and major rail links.

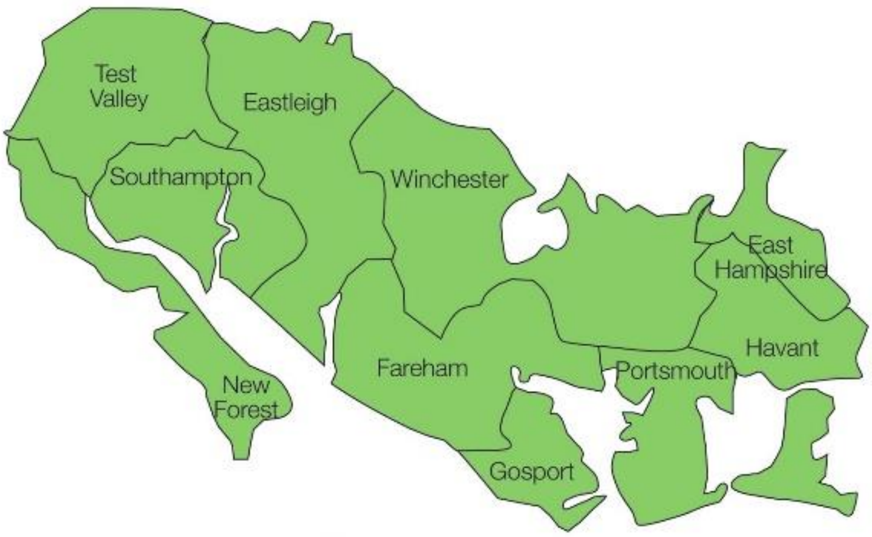

Figure 1 – Map of proposed Solent City development area

According to research carried out and published by the national department of Energy and Climate change, the average energy consumption in the UK in 2015 was approximately 4001 KWh for electricity and 12404 KWh for gas per consumer per annum, if the energy requirements are spread evenly across all 2 million people and disregarding temperature, industry and other factors, this gives 16405 KWh x 2 million people = 3.281×10^{10} KWh per annum.

The energy requirements also require us to deal with times of peak demand, where electricity consumption may be above average, and the usual energy supplies unable to cope with the demand, this means there must be freedom of movement between the energy produced and energy. According to this change we believe that the approximate demand of our city will be around 3.8×10^{10} KWh a year, due to the requirements from increased amounts of electrical based transport.

The final energy calculations are shown within the - Part VI – Calculation section

Part II – Generation of Energy within our city

The huge amounts of energy required are to be met through a variety of new, innovative and eco-friendly solutions, including; wind farms (offshore), tidal power solutions, hydroelectric solutions including gravitational vortex power plants, tidal power, solar power, and Nuclear Power.

After extensive research we decided that a centralised energy system would be the best method to deal with distribution and generation, backed up by a distributed solar panel grid as opposed to solely distributed supplies due to the proven effectiveness in the real world and the fact it promotes generation of electricity individually within homes since excess energy produced can be sold on the utility market. (The fact it is so effective lies within the higher distribution voltage of 230V which reduces the heating effect of the wire as the current is less). Insulated copper wires are to be used to transport the electricity across the grid, due to the abundance, the fact it is a relatively inexpensive material and availability of the material. This is to be used in tandem with a new underground power grid, due to the fact underground power cables have cheaper maintenance costs, smaller voltage drops, and no electric field is produced.

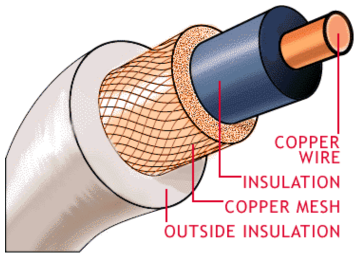

Figure 2 – Example of Copper wire to be used

In cases of breakdown in which up to 80% of our electricity supply is lost, our priority is ensuring that emergency services still have the power required to operate for up to 24 hours. this is done through green gas supplies, which have been prestored and have an almost instantaneous start up time. Power supplies can be diverted to essential services from the central grid through separated emergency power lines, ensuring a power supply is always available.

Nuclear Fission Reactors – This is set to provide the baseline of our cities power grid, using imported uranium and nuclear fission to produce a large amount of energy annually, however unlike conventional nuclear power plants, we propose that a large reactor be placed underground to minimise risk in the event of a disaster and reduces the visual pollution of the site, as well as saving space. The only bi-product of nuclear fission is water vapour which is released as the water used to turn the turbines is heated, meaning it is a clean way of producing energy. The major drawback with nuclear power generation is the radioactive waste after the uranium is depleted of its useful fissionable properties. A single mid-sized nuclear power plant can produce a staggering 15,174 GWh per year, which is more than enough to fill the remaining portion of power required for our city annually, as the potential power output is much higher than the energy required for our city, it would not have to operate at full capacity for a large proportion of the time and would mean less radioactive waste is produced and it would cost less to run.

Wind Power Generation – We will aim to have the equivalent of 2 offshore wind farms in the Solent area, with wind speeds averaging around 8 ms^{-1}, around the same (if not slightly higher) as the highly successful London array in the Thames estuary. This would provide us with an accurate estimate of the effective power output. This means that providing that the energy production values are similar to the London array, the turbines could average 2,500,000 MWh per wind farm annually, providing a total of $5x10^6$ MWh of electricity per year.

This would be a huge investment but is a completely clean renewable resource that is hugely effective at providing large amounts of power. The only drawbacks with this system would be marine concerns with animals and migration patterns around the Solent area, and the fact that wind speeds are variable, and are liable to be damaged during storm conditions.

Figure 3 – Picture of the London Array (Similar development to our proposed one)

Figure 4 – Map of Solent and proposed area for the massive wind farm project

Tidal power solutions – Currently being deployed rapidly across the world due to its efficiency tidal power would be an effective energy solution especially due to the cities location along the waterfront. we suggest the building of 1 major tidal generation plant, similar to the Sihwa lake tidal plant in Korea that is capable of generating a staggering 552.7 GWh of electricity annually. Providing a solution like the Sihwa tidal plant could be produced, it could support up to a quarter of our populations energy needs

Solar power – Providing that the sunlight hours for the Solent are roughly similar to those of Eastbourne to the East of the Solent, of 1888 hours per year, or approximately 5.17 hours daily and that we manage to install solar panels on most major buildings, especially the larger apartment blocks and office blocks in the major cities, as well as the installation of several solar farms we should be able to get upwards of 100,000 MWh annually – approx. 1000 watts per square metre x 24 hours x 365 days x 100,000 equivalent of $1m^2$ panels = $8.76x10^{12}$ watt hours = 8760000 MWh annually

Gravitational Vortex Power – A recent technological breakthrough that harnesses the power of rivers (hydroelectricity) and produces whirlpool like vortexes that produce energy. These are currently undergoing trial in places such as Germany and Austria and are proving very successful because they not only generate large amounts of energy (80% efficiency) for lower current rivers which could be applied to the river Hamble and Southampton water but also help oxygenate the river and increase water quality downstream while allowing wildlife to pass through unharmed. Providing we had at least 4 along the stretch of rivers that were 2 times bigger than the current ones in operation in Austria we could output as much as 440,000 KWh of electricity annually

Our Solution to emergency situations – There is a reason why natural gas is so popular as a fossil fuel resource to produce energy to power national supplies, due to it's fast start up time and the fact it is very reliable. Due to this popularity several green alternatives have already been put into development, such as **green gas** which we would have 2 backup plants for. This means that power can be generated in emergency situations for up to 24 hours.

Part III – The technical details and practicality of energy generation

Wind Power Generation – Wind power works rather simply by harnessing the power of the wind, massive turbines with up to 150 feet blades spin as the wind turns them, this then internally drives a main shaft which is connected to a gear box which spins another shaft fast around a generator, producing electricity (Shown in figure 5). This would be a huge investment to construct the proposed two wind farms, but is a completely clean renewable resource that is hugely effective at providing large amounts of power. The only drawbacks with this system would be marine concerns with animals and migration patterns around the Solent area, and the fact that wind speeds are variable, and are liable to be damaged during storm conditions.

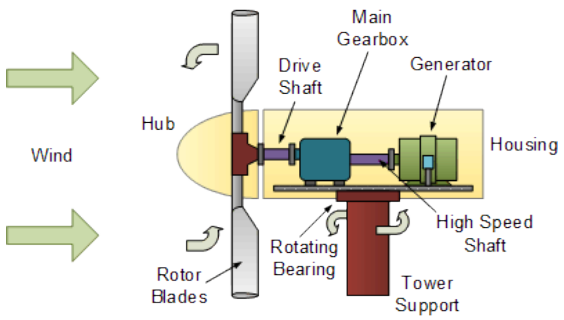

Figure 5 – Diagram detailing the technical process behind generating electricity via wind

Tidal Power Generation - The tidal energy are large barrages that also be used as flood defences and they would be built across the Solent in multiple rows. When the tide comes into the Solent, it causes the water level to rise and water is allowed in. The water turns the turbine, in much the same way as it turns the wind turbine. The turbine turns the generator which produces the electricity. The tides are extremely reliable because the tides happen at least twice a day. There is no fuel cost and no running or maintenance costs.

Solar Power Generation – Each solar panel is constructed from sandwiched pieces of a semiconducting material, normally silicon, then it is doped with different materials to give either side a positive or negative charge. Then as photons from the sun knock an electron free, an electric field pushes the electron out of the silicon junction, a few other components of the cell turn the electrons into usable energy.

Gravitational Vortex Generation – This uses the principle of the conservation of energy as there is a slight difference in elevation, and the GPE of the river gets converted into KE, this then collides with an obstacle in a circular bowl to create a stable line vortex which drives a water turbine, which in turn drives a generator

Nuclear fission Generation – This uses the idea of thermal energy being released during the process of nuclear fission as the uranium 235 atom is hit by a neutron causing it to split into two smaller fragment nuclei. The process is done in a sealed environment with Lead walls to prevent contamination and with graphite control rods to control the rate of reaction and prevent nuclear meltdown. As thermal energy is released it is used to heat water and produce water vapour (steam) which then turns a turbine as it escapes through the cooling tower as harmless steam. Although nuclear power is a non-renewable resource it requires little fuel to produce a large amount of energy and thus has a feasibly long life-span compared to other non-renewable fuels. During usage we would assume new renewable energy methods would become more efficient and allow the city to become entirely self-sufficient, producing all its energy from renewable natural resources.

Green Gas Generation – Instead of using naturally occurring gases, an artificial gas known as green gas is burnt, produced from biomethane (Through anaerobic digestion), meaning it is completely 100% renewable and carbon neutral as the carbon taken in by the organisms such as grass during photosynthesis, producing the methane is equal to the output of carbon when it is burnt. This biomethane can also be collected from sewage treatment plants in big domes as the human waste decays. The way that energy is produced is very similar to the nuclear fission powerplant, however instead the gas is burnt which produces the thermal energy to boil the water and turn the turbines which drives the electrical generator. The majority of the biproducts from burning the gas can now be captured or reduced through new filtering technologies to massively to lessen their impact on the environment. Also, as it is a redundancy technique, it will only be in operation for limited amounts of time per year.

Part IV – Optimisation of energy usage within the city

We will include several key features to help promote efficient energy usage within the city itself, both domestically and as a city itself, these include replacing older streetlamps with newer, more efficient LED lampposts that are programmed to only come on at certain light levels to prevent energy wastage, new housing regulations that state

Domestically we will include a brand-new housing scheme, like those deployed at BEDZED in South Wallington on the outskirts of London. BEDZED was a proof of concept that showed that eco-living could be achieved within the UK. After several years researchers had calculated that they have emitted 37% less carbon dioxide than the average UK resident, along with saving £3258 on utility bills, some of the key concepts and designs used in BEDZED could be applied to the housing around the city over time, to help reduce energy usage. These include wind cowls instead of air conditioning units, thicker insulating walls and triple glazed windows to reduce heat loss during the summer months and reduce the need for gas for heating. On top of this 52% of the materials used in the construction of BEDZED were sourced locally to reduce import costs and pollutants emitted during transit. This shows that domestically we could cut down energy usage within Solent city by up to 25% or more. This means that according to our calculations of energy requirements we could save up to $9.5x10^9$ KWh of electricity per annum on domestic uses.

Part V – Transport Solutions

Private Land Transport (Cars) - The main problem we faced when designing the transport infrastructure in our ecocity was the fact that many people privately own cars and would be unwilling or consider it impractical to give them up. Our solution to this would be a huge push on electric cars, with the excess electricity generated from our energy supply plan being utilised. This means that people are still free to use their cars but without the huge amounts of pollutants being outputted through the exhaust. We took some inspiration from tesla with our city design and think that development and integration of some of their fast charging points at key locations around the city would be a huge step forward in convincing people to go all electric. This should still mean the cars are practical as the newer electric models can travel 400-600km on a single charge that can be done overnight, while at work or just while having a coffee thanks to fast charging technology

Figure 6 – Fast charging points for electric cars to be used in our city

Potential for car pool – Several other eco-developments around the world have also employed the idea of a car pool, we believe city wide this could be an effective idea as it allows people to use cars on a need only basis, so they can still have the convenience of a car, without being tied to the repair fees etc. It also further encourages more environmental forms of transport to be used and if it works as effectively as BEDZED it could reduce people's mileage in cars by as much as 65%.

Public Land Transport - The solution to public transport, we believe also lies with the utilisation of electrical motors, especially for buses and trains. We believe within the next 10 years buses will also be fully electric, using the same universal charging points as cars along their routes. Trains we believe may not be as suited to electrical solutions as buses as the amounts of power required are much too high to be able to be supplied by non-polluting renewable resources (Solar power could only power one tenth of the energy required for the Southern rail network, instead we believe hydrogen fuel cell-based trains would be a much better alternative. Hydrogen-based trains are already in use in Germany (along the Wesser-Elbe Services) and is slated to become available in the

UK by 2020. The trains require little time to refuel and can reach a range of up to 300km in as little as a few minutes, allowing the trains to remain in operation for long periods of time and keep to timetables.

Air Transport – To cover air transport we believe that taking a step back in time to take a step forward in terms of helping the environment may be key, this is why we intend to run a zeppelin service as opposed to traditional aircraft from Southampton airport, as although they may be much slower in getting to places however they require much less power to travel the same distance. The zeppelins would be powered by onboard batteries charged while at the airports, generated through our environmentally minded methods. Electronic motors like those found on newer electric hovercraft would be used to drive the aircraft forward. We believe this would not only help reduce carbon emissions but also provide a unique, fun selling point for the city which may boost tourist numbers and allow guests to travel in more comfort.

Sea Transport – Sea transport can be divided into 3 major sub-categories

Pleasure boats and Smaller Vessels – We would slowly phase out fossil fuel powered pleasure vessels and yachts and replace them with hybrid, electric-sailing yachts or solar powered vessels these would reduce the amount of carbon emissions by such vessels massively and still promote one of the core values of the Solent which is accessibility and enjoyment of the waterfront, this excludes emergency response vehicles which would have backup biofuel motors. An example of this technology in action is through a company known as solar-wave who have built solar powered private yachts that have been largely successful in industry leading yachts that still provide access to the water while not emitting any harmful pollutants and harnessing the suns energy.

Mid-Size Boats & Potential Water Taxis – We are aiming to integrate a system of “water taxis” into the Solent area, this includes transport between the Isle of Wight, Portsmouth, and Southampton. The design is based around multi hull catamaran to reduce drag experienced in the water, so the efficiency is higher and less kilowatt hours are needed to travel the same distance, even if this I minimal. On the boat, there will be wind turbines, solar panels, and electrolysis equipment to break down water into hydrogen-based fuel, giving it a potentially unlimited range. Even if there is no sun or wind, stored hydrogen generated by the electrolysis conversion will take over, as a result the vessels trip will not use any carbon emitting fossil fuels. If we aim to carry 50 people per trip, this would allow it to become a viable alternative to typical land transport. These types of large boats are still in early developmental stage now, however the technology should become widely available within the next 15 years.

Larger Transport Ships – We suggest using the same concepts as stated above but with a new intricate system that would help reduce almost all carbon emissions from the huge container ships using Southampton water and Portsmouth harbour. This includes larger scale cargo variants of hybrid solar, wind and hydrogen catamarans. To deal with the increased energy requirements of the larger cargo boats, we would instate several charging points around the world, which charge via solar and wave power but then allow fast charging of the larger cargo boats to reach the next charging station or their destination. We realise this is a rather extreme step from the huge, polluting cargo ships that are in use today, and would require worldwide co-operation however the benefits would be huge, and it would allow us to achieve the truly carbon neutral city dream. If this is not feasible within the next 15-20 years we instead suggest reducing the amount of imported goods and instead locally sourcing materials and goods to reduce the amount of carbon emitted from shipping.

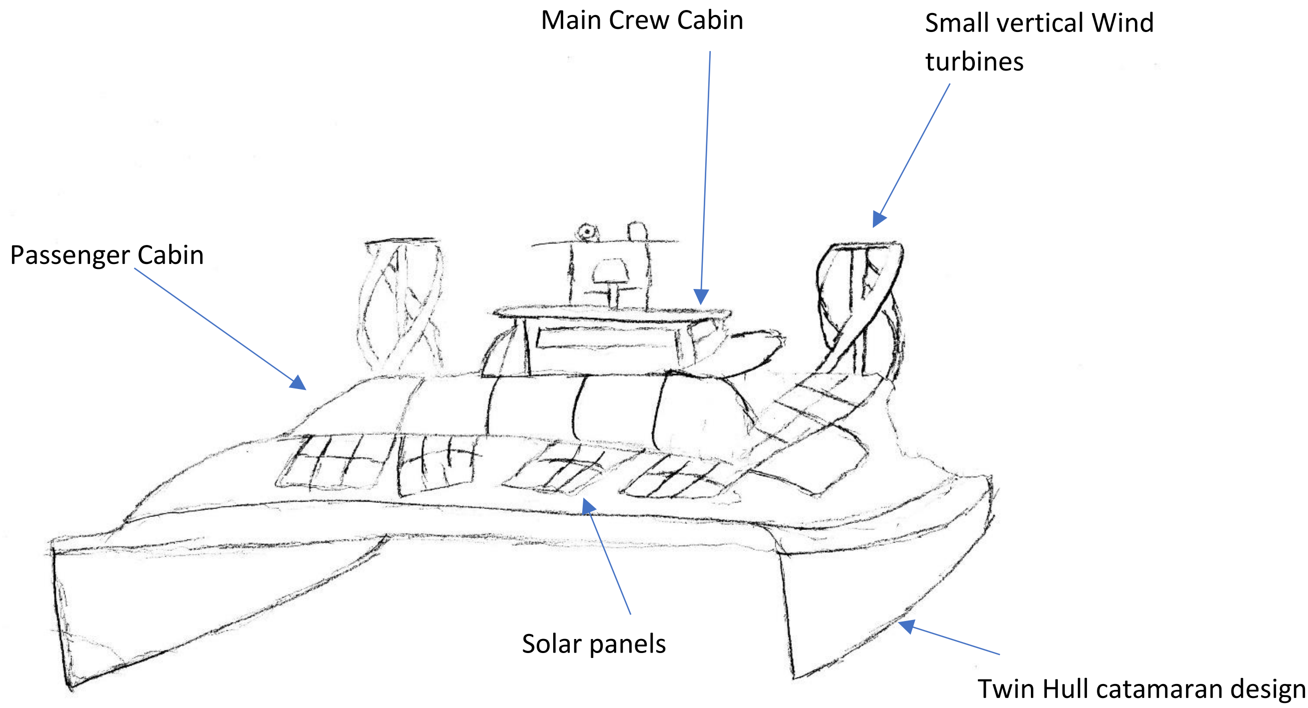

Figure 7 – Concept Design for The Eco Solent Taxis – We took inspiration from the boat L'energy Observer

Road Layout Changes – In order to promote greener travel and reduce the amount of electricity needed for public transport, we would make several changes to the road layout, this includes a new format along all major routes, that accommodates cyclists, pedestrians, cars, and buses alike, this is done by a low dividing barrier between the pedestrian section of the footpath and the cyclist section of the footpath as well as another dividing barrier between the road and the footpath. We believe that this added safety feature will encourage more people to take up cycling or walking to commute to work and will cut emissions tenfold.

Other Ideas - Another idea we have had to make transport easier around the Solent city is the integration of one payment method for all forms of transport, resonant of the oyster card system in London, whether you wanted to charge your car, take the bus or tram or even catch the train from Southampton to Portsmouth it would all be done with one tap. And introduce credit system based on the number of steps you do, or distance cycled, the more steps an individual does or the further they cycled (tracked by an app on their phone) the greater the amount they save on public transport or car charging fees. This we feel will help promote people to walk places as they are motivated to save money.

Part VI – Technical description of transport solutions

Many of our transport solutions focus on the same key process – The conversion of electrical energy provided by our carbon neutral sources into kinetic energy which allows the vehicles to transport goods and people around. This process is usually carried out by electronic motors found in each of the vehicles, which powers a drivetrain in the case of the land vehicles and then turns wheels, or a propulsion device in terms of sea and air transport. The electric motors are operated based on electromagnetism and the fact as the current flows through the coil found within the motor, an electromagnetic force is induced upon it according to the Lorentz law, so the coil will start to rotate and provide kinetic energy to cause the required movement. This movement is usually transferred through a gearbox to provide the right amount of rpm required.

The trains however focus on a hydrogen fuel cell-based design. This concept uses the same stored fuel approach as a conventional engine however instead of producing energy through combustion of fossil fuels, which emits lots of harmful waste products, it chemically fuses oxygen and hydrogen across an electrical circuit to produce only pure water, heat and an electrical current which drives the electrical motors. The oxygen required for the reaction can be collected from the air and the hydrogen required can be produced from the electrolysis of water, powered by our renewable and eco-friendly methods.

Efficiency will be a core aspect of our vehicle design, with us taking inspiration from the latest designs to reduce drag that the transport experiences and maximise the number of miles per kilowatt-hour a vehicle is able to use. For our cars, this will be especially important because we imagine they would still be the forefront of transport within our city. The boats will be designed around a catamaran basis, as they have proven to be the most effective and efficient overall design and appear to have been chosen with many carbon neutral boat projects in recent times.

Part VII – Calculations and Costs

Energy Breakdown for each sector

If energy consumption for Britain was roughly 145 Megatons of oil equivalent in 2015, then the ratio of the breakdown of services can be filtered into the projected energy demand of our city. The formula for this estimation is given as our **projected energy requirements x Sectors Mtoe / Total Mtoe**

Transport - 145 Mtoe – 90 Mtoe = 55 Mtoe

Domestic – 90 Mtoe – 50 Mtoe = 40 Mtoe

Industry – 50Mtoe – 30 Mtoe = 20 Mtoe

Other final uses = 30Mtoe

* data taken from ECUK report from 2015 (Energy consumption per sector)

Therefore, assuming the ratios stay roughly the same for our city and the total energy requirement is approximately 3.8×10^{10} KWh Per year, then the breakdown would be as follows;

Transport – 1.4×10^{10} KWh

Domestic – 1.05×10^{10} KWh

Industry – 5.2×10^{9} KWh

Other – 7.9×10^{9} KWh

Final energy requirements vs demand

Our projected total energy requirements were estimated at 3.281×10^{10} KWh

Energy Type	**Projected optimum Output per annum (KWh)**
Wind Power	2.5×10^{9}
Tidal Power	5.527×10^{8}
Gravitational Vortex Power	4.4×10^{5}
Nuclear Fission Power	1.5174×10^{10}
Solar Power	8.76×10^{9}
Total	3.822×10^{10}
Minimum Required	3.281×10^{10}
Maximum Estimated	3.8×10^{11}

* Here we can see that our chosen Power supply methods are able to meet the typical energy demands laid out in the criteria, with some freedom, allowing for the increased estimated demand brought about by the huge amounts of electrical transport solutions.

As our energy supplies do not have any net carbon emissions, the total amount of carbon emitted would be equal to the amount taken in while producing the fuel hence making our city, a truly carbon neutral city.

Our green gas emergency power plant will have an estimated approximate capacity of 750W, traditionally operating at 500W. This would require an estimated store of 4 cubic feet of gas (using the conversion 1 cubic feet of natural gas generates approximately 0.3 KWh of power) for 24 hours it could produce 12,000-Watt hours or 1.2 KWh. This is enough to supply the approximated critical services listed below (Either Estimated or approximated from actual data if available):

100-Watt Hours for Medical Services

200-Watt Hours for Other Emergency Services

400-Watt Hours for Water Treatment services

300-Watt Hours for other non-government medical service centres e.g. care homes and

1000 Watt-Hour total or 1 KWh

Timescale

We believe on the technological side, our cities energy grid is deployable within the next 20 years, providing that research carries on at the current rate.

The solar panel systems would be installed over time, slowly integrated into housing and larger office blocks as they are renewed. We will also introduce new building regulations within the city that state solar panels must be installed on all homes large enough to accommodate them as well as new, efficient heat loss techniques etc.

The Nuclear power plant which would help relieve most of the strain on polluting resources currently being used could be completed as early as 2022, if construction were to begin in 2018, the rest of the renewable resources would slowly be phased in as time goes by e.g. solar panels installed as the buildings are modernised.

The wind farm could be completed as soon as 2 years into the future, assuming both wind farms can be built simultaneously, and the construction takes a similar amount of time as the London array

The tidal power plant construction time would be considerably longer at approximately 13 years, following the same schedule as the one in Sihwa, South Korea.

The two vortex farms could be completed roughly in 3 years. Providing they follow the same schedule as the current two in operation in Austria

This means that all the energy power plants could be completed as soon as 2031, meaning up to 2 million homes could be powered by non-polluting carbon neutral resources.

Costs (Approximated)

Construction

Item	Cost (Adapted to size)
Nuclear Power Plant	**£2,250,000,000**
Gravitational vortex power plants	**£500,000**
Solar panels	**£23,800,000**
Tidal power plant	**£400,000,000**
Offshore Wind farms	**£3,600,000,000**
New transport Infrastructure	**£10,000,000 +**
Backup Green gas power plant	**£200,000,000**
City infrastructure (e.g. New Roads & lampposts)	**£10,000,000**
Total	

Nuclear Power plant based off the 2008 Finnish Power plant - http://news.bbc.co.uk/1/hi/business/7180539.stm

Gravitation vortex plant Based off Zoloeterer Power plant - http://www.zotloeterer.com/welcome/gravitation-water-vortex-power-plants/

Solar panels - £5000 for 21 square metres (https://www.greenmatch.co.uk/blog/2014/08/what-is-the-installation-cost-for-solar-panels) therefore £238 per square metre and for the estimated 100,000 equivalent of square m solar panels – £23,800,000

Tidal power plant based off Sihwa tidal power plant – https://www.hydropower.org/blog/technology-case-study-sihwa-lake-tidal-power-station

Gas power plant based off Pembrooke except ours has a quarter of the capacity so we assumed about ¼ of the cost - https://en.wikipedia.org/wiki/Pembroke_Power_Station

City infrastructure and Transport Infrastructure estimated as little data about pricing is available

Annual running costs

Nuclear power plant – 1.5 pence per KWh – approx. £237,000,000 for 1.58×10^{10} KWh per year

Solar Panel Upkeep Cost per year – Avg. £107 per year for 20 metres squared, so 5,000 x 107 = £535,000

Tidal Power Upkeep Cost – 0.02p Per KWh, so £1,105,400 per year

Wind Power – 6p per KWh – £150,000,000 per year

Green gas – Negligible cost other than upkeep due to the fact much of the green gas supply will be sourced from waste treatment sites.

Transport / Infrastructure – £10,000,000 per annum – Estimated

Gravitational vortex Power – £4,000 Per annum for upkeep

Total Per annum – £398,644,400

Part VIII – Final Summary & Final Words

Summarising we have designed and planned out an eco-city ready to be deployed in the near future across the Solent area, providing transport, energy and other essentials required for a population of 2 million, covering all the points included within the specifications. There would be no net carbon emissions from our city as all the energy generated is from either renewable sources or carbon neutral sources, the transport is accounted for under the energy budget and we have suggested ways that such a city council could further help boost energy production while helping to lower their effect on the environment.

We hope you have enjoyed reading about our visions for a future eco-city as much as we have enjoyed designing it. We believe a city like this will become a reality one day and hopefully that one day is not too far into the future. As cities like this become more commonplace hopefully we as a species can help lower our carbon footprint and reduce our ecological effects on the environment.

Part IX – Bibliography

Clipart Images used under copyright laws – https://openclipart.org

2015 UK Energy Data taken From UK National Department of Energy and Climate Change – DUKES 2015 & ECUK 2015

Solent Wind Speed Data + Thames Estuary data - https://www.windfinder.com/windstatistics/solent_mrsc

London Array Energy Data + Information - http://www.londonarray.com/project/renewable-energy-record-achieved-at-london-array/

Sihwa Tidal Power Plant Data + Information - https://www.hydropower.org/blog/technology-case-study-sihwa-lake-tidal-power-station

Gravitational Vortex Plant Data + Information - http://www.zotloeterer.com/welcome/gravitation-water-vortex-power-plants/

Solar Panel Explanation Information - https://www.livescience.com/41995-how-do-solar-panels-work.html

Gravitational Vortex Power Information - https://en.wikipedia.org/wiki/Gravitation_water_vortex_power_plant

Hydrogen based train info + figures - http://www.railwaygazette.com/news/traction-rolling-stock/single-view/view/hydrogen-fuel-cell-multiple-units-ordered.html

Self Sufficient boat info - http://fortune.com/2017/07/15/a-5-25-million-self-powered-hydrogen-boat-has-set-off-on-a-6-year-trip-around-the-world/ - http://www.energy-observer.org/en/#bateau

Adapted Map - https://www.lepnetwork.net/organisation/solent/

BEDZED Info - https://en.wikipedia.org/wiki/BedZED - https://www.bioregional.com/bedzed/

Pembroke Power Station Info - https://en.wikipedia.org/wiki/Pembroke_Power_Station

London Array Picture - http://www.londonarray.com/

Wind Turbine Diagram - http://www.alternative-energy-tutorials.com/wind-energy/wind-turbine-design.html

Copper Cable Diagram - http://ecomputernotes.com/computernetworkingnotes/communication-networks/write-short-note-on-coaxial-cable

Electric Car Charging Points - https://www.airportparkingmarket.co.uk/pdx-airport/

Tesla Information - https://en.wikipedia.org/wiki/Tesla_Model_S - https://www.tesla.com/en_GB/