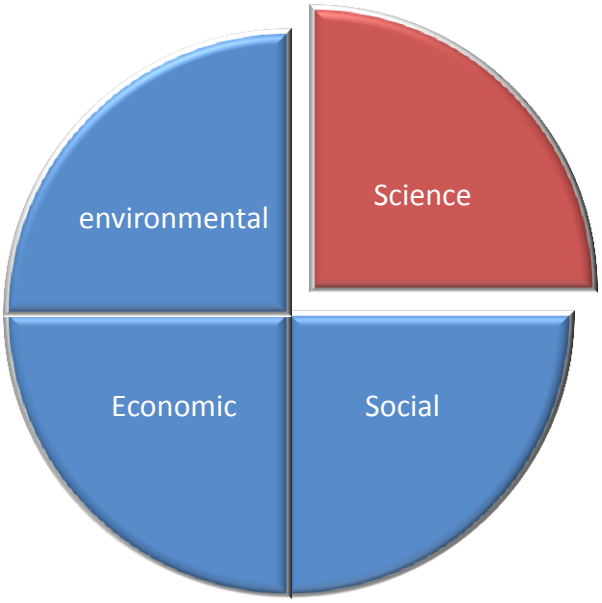
The Future Cities Project

A Problem-based Case Study in Sustainable Development



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Future Cities

A problem-based case study in sustainable development

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PROJECT BRIEF

Your University-affiliated spin out company, *Global Sustainable,* has won funding carry out a project in the field of renewable energy resources, assessing the construction and development of global project solutions for sustainability and green industry credentials.

Global Sustainable

A sustainable development construction team, Global Sustainable, views this as their flagship project showing potential future customers how they incorporate green technology into their designs. You will come up with the design and oversee the finances for the project as well as sourcing the technology you want to incorporate into the design. By the end of this task you should have established how much your project will cost and noted the key areas that enable this project to be the flag ship for the company.

You can choose one of the following projects:

Site 1 Physt River, Sekiu Washington, USA

- Develop a sustainable village for 480 people which can act as beacon for future development in green technology for Washington.
- The site must consider environmental impacts in both its construction and every day use.

Site 2 Postgraduate Campus, Hong Kong Island

- Develop a postgraduate site for at least 50 students and 22 research scientists
- The site must produce all its own energy and manage all its own waste.

Site 3 Midsummer University

- Increase the energy and water efficiency at the university through novel approaches.
- Incorporate green technology into the current systems.
- suggest good practice to be employed

Site 4:Greener public transport through biodiesel and bioethanol.

- Analyse the costs of producing biodiesel and bioethanol to be used in Midsummer's small fleet of 42 buses.
- Recommend which biofuel is most suitable to the company.

Once you have selected your project use the information provided and other research to design your site. Provide a written report and a budget for your project. Present an overview of your plans in a 10 minute oral presentation.

SITE 1 NEAR THE PHYST RIVER, SEKIU CHAMBER WASHINGTON, UNITED STATES OF AMERICA

Your Task:

For this site you will have to design a microgeneration sustainable village to house a population 480 people, but implementing technology that would reduce the environmental impact to the local ecosystem.

A bit more Information:

The site is located in Washington State, in the United States of America, on the Olympic Peninsula near Sekiu. It is a virgin site set in the heritage land of the Clallam people. There is a tidal delta, however, the level of silt deposits means that a harbour is out of the question except for small shallow bottom craft such as barges. Presently there is the 112 Road that runs to the south of the proposed site, and development of further road networks would be required in the area. An environmental and ecology study has been done of the area in addition to geological survey, all of which will be provided should the site be used. There are strict rules that you must obey when designing this settlement. They are:

- No mass industry can be moved into the area such as factories and wood processing plants
- Every care should be taken to reduce the environmental impact to both land and water either through technology or good environmental practice
- The site is declared as an area of outstanding natural beauty, so no building can be more than two stories high.
- Where possible local contracts must be used and 60% of all materials must be sourced locally
- Any repairs to the environment must be completed and not left for the local population.

You would have $64 million USD to complete the project. You must produce a report about your design for the site and the technology that will be used, as well as a financial report.

Positive Attributes	Negative Attributes
• The site is free. • Geological Survey has been completed. • The Ecology Survey has been completed. • Could benefit a wider population rather than just those directly involved. • There is local airport where some materials could be flown in.	• The rules are rigid and cannot be negotiated. • Limited access via road and sea. • Financial development of the site is uncertain.

What you might want to consider

How much energy will be required to run this site after construction?

How are materials going to be brought to the site?

What would be the most suitable type of energy source?

How are the costs going to be recuperated?

Some useful facts

- The average house in the USA uses about 8900 kWh per year, this includes using kitchen appliances and TV. However the value is taken from 2000, so consider how effective new technology will be.
- The weather in this location across the whole Olympic peninsula is a moderate marine climate with pleasant summers and mild, wet winters. Summers are fair and warm, with high temperatures usually between 18° and 25° C. Summer is the driest season, with heavier precipitation during the rest of the year. Winters are mild, with temperatures at low ground between 0° and 6° C. At high ground, snowfall is generally heavy layering at about 3 metres deep. More common at sea level, much of the precipitation comes as rain, with some infrequent cases of snow fall. The weather is generally unpredictable so all eventualities should be taken.

Tasks to be completed

- Calculate how many tonnes of carbon your site will produce in a year. On average 1.297 lbs of CO_2 are produced per kW, this is drastically changed if you use renewable sources.
- Draw a scale diagram of your site, showing the layout of your buildings and other structures.
- Complete a spreadsheet demonstrating the cost of constructing the site and where possible identify methods that would possibly recuperate the expenses involved. (see project description for an example)
- Consider the animal life discussed in the Ecology report and sustainable practises for the flora and fauna.
- Produce a report explaining the sustainable technology you will use, how each one works and how much it will cost.

Remember you are designing a sustainable village so include microgeneration projects and energy conservation initiatives.

Additional information for Site 1 Near the Physt River, Sekiu Chamber Washington, United States of America

Ecology and Environment Survey	Survey conducted on the 8th April 2011
Survey Conducted by: Dr Helgen	Site of Survey: Physt River, WA

Summary Report

The biodiversity of this area of natural beauty is very similar to that in Olympic National Park just south of the site. The flora at this site is considered to be fairly important comprising of very old trees. However there are no species of flora that have been identified as being on the endangered list or a list of concern. However there are some animals that are considered to be rare to the region such as the Long Eared Myotis and the Porcupine. Water quality is good to perfect, with siltation occurring at the mouth of the river to form a delta, this is signified by the presence of Pink Salmon which return alternate years, populations of these fish are in decline, steps would have to be taken to ensure that the species can continue to enter the river system and preserve their breeding grounds. Suggested procedures are that although the site would be suitable to be used, it would require protocols that would directly maintain or improve the current environmental situations, ensuring that the impact would be minimalistic.

Plants: It should be noted that the biodiversity is very large, and there were no species identified from the endangered species list or the concerned species list. The plants showed good growth, and renewal of species was spontaneous with germination occurring without the need for human conservation projects. Limited mutations within species were observed, however nothing above that expected other than through random mutation events. The yield of fruits from the plants is biologically diverse to support a large variety of species. There are predicted to be over 700 different plant species in this area based on the data from this survey.

Common Tree Species: Sitka spruce - *Picea sitchensis*
Western hemlock - *Tsuga heterophylla*
Western redcedar - *Thuja plicata*
Red alder - *Alnus rubra*

Common Shrub Species: Salal - *Gaultheria shallon*
Evergreen huckleberry - *Vaccinium ovatum*
Salmonberry - *Rubus spectabilis*
Black Twinberry - *Lonicera involucrate*

Common Understory Species: Deer fern - *Blechnum spicant*
Beadruby - *Maianthemum dilatatum*
Sword fern - *Polystichum munitum*
Yellow skunk cabbage - *Lysichiton americanum*

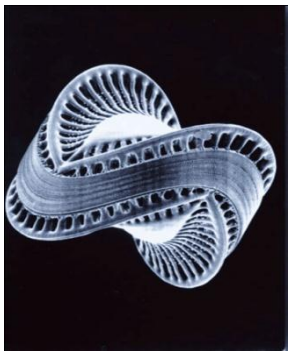
Mammals: There are a large number of mammalian species in and around the site. Mammals such as bats use the habitat for living, although their habitats cover a much greater are than just this site. There are a large number of rodent species, including the Pacific Marsh Shrew, Sorex bendirii and the Olympic Chipmunk, Tamias amoenus caurinus. In addition to the rodent and bat population there are also many larger mammal species including Beavers, Castor Canadensis; Deer Moose, Peromyscus maniculatus; and the Porcupine Erethizon dorsatum. In total there are predicted to be 38 mammalian species in this area based on observations and scat samples.

Reptiles: There is a low diversity in the species of reptiles found on this site, however when compared to the Olympic National Park, it is the expected level for the coastal forest area. The most noted species is the Rubber Boa, *Charina bottae.* This species is a good indicator to the abundance of the rodent population, because it lives in a small area, with the same snake being caught in subsequent years there must be enough prey for it. Further more the successful identification of the Common Garter Snake, *Thamnophis sirtalis* indicates a large population of amphibians although not necessarily varied species.

Amphibians: The amphibian population is quite expansive incorporating Newts, Salamanders, Frogs and Toads. This demonstrates the environmental situation in the water courses of the area. Olympic torrent salamander, *Rhyacotriton olympicus has been spotted within these waters, however this should not be considered normal as the species prefers pebble bottomed rivers rather than the silted bottom of the Physt River. This may require further study into the wider area as change in habitat preference may indentify a wider problem. Other notable species are Northern Red-legged Frog, Rana Aurora and* Northern pacific tree frog Pseudacris regilla regilla, both of whom demonstrate the low pollution levels in the environment.

Fish: There are a variety of fish found within these waters in addition to shellfish and Annelida. Such species that have been found are Brown Trout, *Salmo trutta* morpha *lacustris*; Dolly Varden, *Salvelinus malma malma* and the Fat-head Minnow, *Pimephales promela.* All these fish prefer residing in the silted areas of the river, however there are no recorded spawning sites for the Brown trout and Dolly Varden. The Fat-head Minnow has many spawning sites in an amongst the tributaries to the Physt River and as such they are very important to the survival of the species along this stretch. Importantly since there are no spawning sites for the trout dissolved oxygen levels are not an important aspect to maintain, although it would be advisable for the continued development of the ecology of the area. There was evidence of eel populations, however the species caught were sea eels (*Nettastoma melanurum)* which are not native to the area. Hopefully this species will not gain a foothold in the area and effect the other fish and invertebrate populations.

Water Quality: The samples of water quality were taken from 8 separate locations along the river and tributaries around the proposed sites. The samples were analysed for nitrate and phosphorus compounds using titration methods. In addition to this oxygen levels and depth of silt build up at each site were analysed. Finally each sample was subjected to microscopic analysis for parasites and diatoms. The following results were given:



Chemical Analysis of Water Samples

Sample	Nitrate Levels (mg/l)	Phosphate levels (mg/l)	DO Levels (mg/l)	Silt Levels (mm)
1	0.12	0.13	6.3	92
2	0.15	0.14	6.8	85
3	0.14	0.16	7.9	87
4	0.19	0.14	8.5	91
5	0.20	0.15	6.5	120
6	0.15	0.18	9.8	115
7	0.16	0.19	8.5	126
8	0.18	0.19	7.5	128

Microscopic Analysis

Sample	Parasites	Diatoms
1	Citrobacter; *Escherichia;* *Serratia*	5 Geometrically Different Samples
2	Citrobacter; *Escherichia; Serratia; Hafnia*	4 Geometrically Different Samples
3	Citrobacter; *Escherichia;* *Serratia*	5 Geometrically Different Samples
4	Citrobacter; *Escherichia; Serratia; Hafnia*	5 Geometrically Different Samples
5	Citrobacter; *Escherichia; Serratia; Hafnia*	3 Geometrically Different Samples
6	Citrobacter; *Escherichia*	4 Geometrically Different Samples
7	Citrobacter; *Escherichia*	1 Geometrically Different Sample
8	*Escherichia; Serratia*	1 Geometrically Different Sample

Air Quality:

Four samples of air were taken from the site at varying heights, they were analysed for the presence of carbon monoxide, ozone, sulfur oxides and radioactive particles. Sample 1 was taken at ground level, sample two was taken from below the canopy, sample three was taken above the canopy and the fourth sample was taken from an aircraft at 5000 ft above the site.

Sample	***Carbon Monoxide Levels***	***Ozone***	***Sulfur Oxides***	***Radioactive Particles***
1	*Very Low*	*Low*	*Low*	*Background*
2	*Low*	*Low/Medium*	*Low*	*Background*
3	*Low*	*Low/Medium*	*Low*	*Background*
4	*Low/Medium*	*Medium*	*Low/Medium*	*Low*

Geological Survey	Survey conducted on the 20th May 2008
Survey Conducted by: Dr Helgen	Site of Survey: Physt River, WA

Summary of Geological Analysis

The ground underneath the site is a composite layer of minerals resulting from a combination of silt deposits from the river Physt flood plain and the igneous deposits in the form of Eocene crescent formation basalts. The Eocene was created due to the submarineal formation through pillow lava. Some of these Eocene is embedded into an early Eocene limy red sediment, which has now transformed into limestone. Clastic sedimentation dating to the Oligocene and the early Miocene. The continental ice sheets during the Pleistocene period resulted in the mountain formations to the south of the site, leaving large quantities of sand and gravel at the mouths of valleys. There are wave cut platforms that have uplifted the sites to the West. There are known to be manganese deposits in similar crescent formations of basalt; however the rocks have not be prospected for their quantity. In addition copper deposits can be identified in the crescent formations. The basalt at the site also yielded high grades of zeolite specimens. Gas and oil has be identified in areas of the Hoh Melange 20 miles to the west of the site increasing the suitability of the site as a commuter location for these industries. The metamorphic deposits exhibited characteristic of clockwise tectonic activity. This is different from that observed at Sekiu, where the Hoko River Formations are exhibited counter clock wise tectonic movement.

This site would be suitable for future construction provided that the foundations for construction were dug to tolerate minor seismic activity. The bedrock is stable and there is relatively little transformation of rock occurring throughout the site suggesting that there are no to minor fault lines for developing igneous intrusions. The is cleared for construction in the future.

Building Costs List

Here is a list of common materials and buildings that might be required by your site. Costing of materials in British pounds, some of the items are very general in price so that there is less confusion. Remember the prices are there to simulate the expenses rather than be their genuine cost.

Item	Description and Energy Usage	Size of Site (l x w)	Cost
Land Treatment and Preparation			
Light Land Clearance	(Tall Grass, small shrubs)	1 m x 1 m	£1/m^2
Medium Land Clearance	(trees and small shrubs)	1 m x 1 m	£3/m^2
Heavy Land Clearance	(Densely packed trees and shrubs)	1 m x 1 m	£8/m^2
Land Drained	If there is a large amount of ground water at the location then you might require the land to be drained prior to construction. This is essential so that you ensure that foundations of buildings and road surfaces to not move and crack.	1 m x 1 m	£30/m^2
Communications and Infrastructure			
Road	The road construction regulations differ between countries, however this is the price for a generic road surface including the base and sub base materials.	1 m x 1 m	£45/m^2
Footpaths	The footpaths are designed for pedestrian traffic only, this is reflected in the price as the materials used are not strong enough to support cars and lorries.	1 m x 1 m	£40/m^2
Cycle paths	The cycle paths is the same price as the footpath because it is composed of the same material. The only difference is its colour to denote the different proposed use.	1 m x 1 m	£40/m^2
Main Sewage Drain Pipes (Concrete)	This is required if you intend to have your sewage processed at a central location rather than individual properties processing their own waste materials.	5 m x 1 m	£50/ m
Traintrack	The cost of a train track is quite high and is the same for both electric and diesel powered locomotives.		£6,000,000 / km
Telephone Cable	This is a Category 3 cable which is suitable for telephone communication and dial up internet connections. This is the price for the cables to be laid during road construction.		£0.6/m
Data Cables	This is a Category 6 cable which is suitable for telephone communication and high speed broadband connections. This is the price for the cable to be laid during road construction.		£0.8/m

Fibre Optic Cable	This cable enables the rapid exchange of data and information throughout your network of communications		£1.2/m
Mobile Phone Masts	The mobile phone has become an integral part of our modern communication network. Everything from telecommunication and surfing the internet are now used using our mobile phones. The installation of a mobile mast can cause controversy over their appearance, but modern mobile masts can be camouflage to blend more into the environment. Very Low energy consumption at about 2000 kWh per year. Mast covers a radius of 20 miles.		£2000 per mast.
Sewage treatment Centre	This site can process enough waste for 500 people, producing clean water that is free of pollutants straight into the local water course. The site can be run based on the taxation of those 500 people that use the site, costing them £103 per person per year. Consumes 22000 kWh of energy per year. Provides 6 jobs to the local area.	Covers an area 140 m x 150 m	The cost to install the site is £1,300,000
Environmental Treatment Centre	This site is used for a more environmentally friendly treatment site for sewage waste. This site requires a large area to be set aside as wetlands. It uses natural biological processes such as reed beds to process the polluted water and providing a habitat for wetland creatures. This site also requires very little maintenance, Provides 1 job at the local government office.	Requires an area of around 1 m^2 of Cattails (*Typha*) per person.	£30/m^2
Biomass Processing Site	The Biomass Processing plant uses organic materials and turns them into a fuel source. Household waste such as cooked food, paper and garden waste such as grass and tree cuttings. They are then burnt and transformed into energy. An alternative source is to transform fresh and used oil into a biodiesel and use this to generate electricity. Both plants will provide jobs for 6 people. Each type of plant can process 7000 tonnes of organic material/oil a year which produces 1MW of energy.	The Biomass Plant covers an area of 62 m x 38 m	The sites cost £5.3million
Hydroelectric Plant	This type of energy source requires a non-tidal river to convert potential energy into electrical energy. The benefit is that you will rarely run out of water because of the natural water cycle, it can also help with flood management and irrigation distribution during dry seasons. The site will produce 22 jobs and generates around 200 MW of energy per year. The cost of	Depends on the width of the river. Each turbine requires 10 m x 10 m	£6 million

	producing the hydroelectric dam is £150million.		
Nuclear Development Program	This program seeks to develop a small scale nuclear development program, using nuclear fuel cells as seen on NASA probes. The Radioisotope Thermoelectric Generators (RTG's) can be used to generate a small amount of energy using controlled reactions. The development of this technology could be key to providing solutions to remote habitats. This could produce 100 MW of energy.	Requires a research Facility to be considered.	The price of developing the program is £46million
Recycling Processing Site.	This recycling plant processes large quantities of household rubbish and packages them ready to be sent to industrial centres for reuse. Items collected are aluminium cans, glass, paper, cardboard, garden and kitchen waste, PET plastic. The site can process 60 tonnes of recyclable material a year. It requires 6 workers and generates income from the sale of the recyclable material.	The Site covers an area of 25 m x 2 2m	The Recycling plant would cost £3 million to produce.
Central Government/ Administrative Building.	This is the administrative building for the site, whereby governmental and project developments can be coordinated. It is comprised of the following central offices. Office of Energy Efficiency (Provides statistics on energy consumption adn runs community energy schemes) Centralised Computer Management System (Monitors energy levels and manages the systems for water quality and air quality) Office of Ecology and Environmental affairs Management (Manages the environment and required to use the reed bed water system) Office of Tourism and Communities	Covers an area of 42 m x 26 m for the whole building	Each office costs £230,000
Police Station	Local Police station facility, aimed at community policing in locations of no greater than 500 people. Incorporates a local magistrates court too. Consumes 9000 kWh of power per year. This site also provides 6 jobs to the local community.	Covers an area of 10 m x 10 m	This building costs £490,000
Fire Station	The Fire Station is a local community fire station that accommodates 2 engines and a crew of 15 people. The building consumes 9000 kWh of energy per year.	Covers an area of 15 m x 25 m	This building costs £590,000
Residential			
Brick 4 Person Home	Complete with connections to the utilities. The house is fitted to use about 8500 kWh per year.:	A typical family house built on a plot	Standard

		30 x 40 metres.	Spec: £55,000 Good Spec: £72,000 High Spec: £89,000
Prefabricated Family home	These house are prebuilt offsite so that they only require a pre-laid foundation prior to their arrival. The houses can be erected in 4 days and then decorated. The houses are fitted to use about 8600 kWh of energy every year. Suitable for dry conditions, and high disaster areas due to their cheap rebuild costs.	the property is based on 30 x 40 metre plot of land	Standard Spec: £35,000 Good Spec: £42,000 High Spec: £50,000
Low Energy Housing	The low energy housing contains state of the art insulation to reduce heating costs and has windows and doors that retain the heat during winter and reflect it during the summer that help with the internal environment. The property would require 6800 kWh of energy per year.	the property is based on a 30x40metre plot of land:	Standard Spec: £68,000 Good Spec: £81,000 High Spec: £95,000
Commercial Facilities			
Cinema	The cinema complex is a 3 screen cinema, designed for the local community to air movies and host local conferences. The cinema provides 8 jobs to the local community and costs 15000 kWh	56 mx120 m	£2.3million
Shopping Centre/ Supermarket.	The shopping centre can be a large mega mall to small group of community shops. Clearly depends on what you require in your area. The power consumption is 5000 kWh per shop, and provides 2 jobs to the community	Each shop unit is 15 m x 10 m	£52,000 per unit
Medical Centre	This could be the life line of your community, it is a small practice designed to accommodate 2 doctors and 2 nurses. It has facilities to process minor surgery such as appendectomy and general practitioners. Requires 15,000 kWh of energy due to 24 hr service. Provides 9 jobs to the local community including the doctors and nurses	20 m x 25 m	£2.2million
Football Pitch	This is an all weather pitch with timed flood lights, similar design to many community playing fields in America. It is suitable for other sports	The size of the football pitch is 105 m x 68 m	£143,000

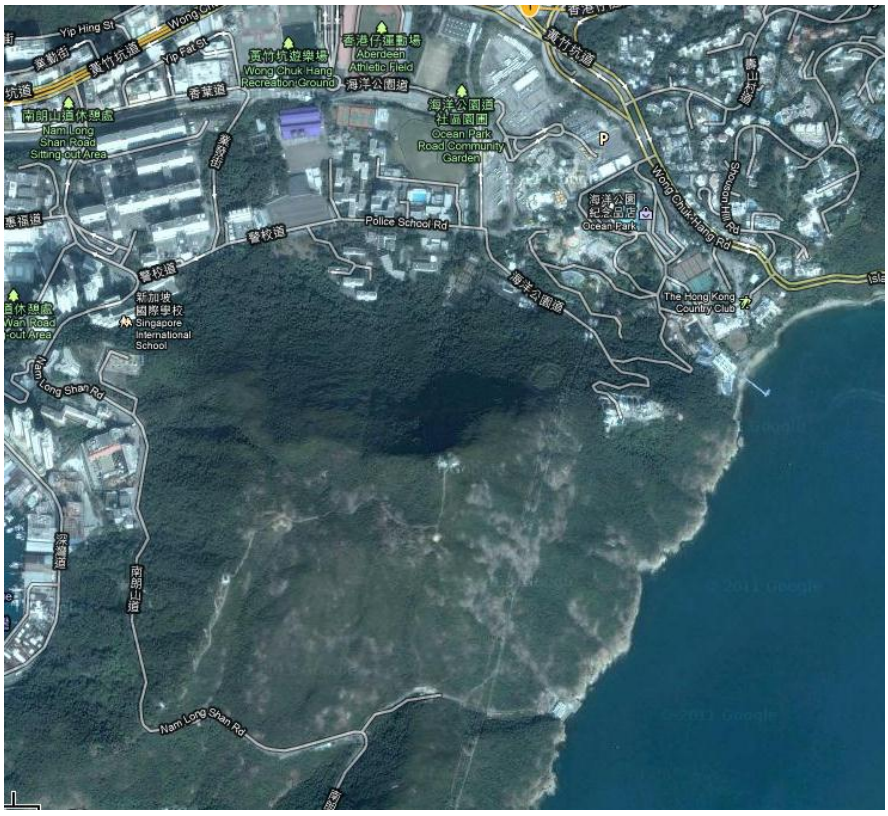
	such as hockey and even rugby. The site uses 1000kWh of energy a year		
Basketball/Tennis Courts	This is a flood lit court that has timed lights which switch off at certain times. They are all weather pitches. The site uses 1000 kWh of energy per year.	The court size is 28 m x 15 m	£36,000
Marina	This is a small construction providing sheltered berths for yachts. Each berth provides power, and could be used as a place of residence or a site for small fishing boats. The power consumption for each berth depends on the user but generally averages to be 1000 kWh for none residential and 4000 kWh for residential	Each berth can accommodate a boat 12 m x 6 m	£12,000 + £3000 for each berth
Hotels	The hotel that can be constructed for any number of guests. The typical energy consumption per room is 2000 kWh. Each room can hold 2 people	The hotel is 10m x 15 m + 5 m x 6 m for each room	£26,000 + £5000 for each room
Holiday Cabins	The holiday cabins are constructed using wood and accommodates 4 people. Each accommodation would be expected to use around 4000 kWh of energy per year.	Each holiday home is 25 m x 25 m	£22,000 each
Industrial Sector			
Port	Ports are useful for the transport of large quantities of material from one location to another. Less energy is required to move large objects, in comparison to road transport and air freight. A port requires alot of energy to run, requiring 150 kWh/m^2.	Depends on building, minimum size of 100 m x 30 m	This building costs £12000/m^2
Light Manufacturing	This area produces farm land and cottage industries. These use relatively little energy and as a result their output is quite low. However this type of industry produces the least amount of pollution. The amount of energy required ranges from 5000 kWh to 16,000 kWh and providing jobs for 1 person per 12 m^2	Depends on the Building, minimum size of 200 m x 200 m for the farm, or 30 m x 40 m for cottage industry.	costs £500/m^2
Medium Manufacturing	Medium intensive industry is associated with factory develops, such as those that produce clothes, fish processing factories. These types of industry use more energy than light industry, but this is also reflected in the amount of money they produce. The energy requirements for this type of industry range from 14,000 kWh to 55,000 kWh and providing jobs for 1 person per 25 m^2	Depends on building, minimum of 30 m x 30 m	This building costs £2000/m^2.
Heavy Manufacturing	The implementation of mining, chemical works and metallurgical furnaces. These types of	Depends on size, minimum of 20 m x	To set up a heavy

	industry produce large amounts of pollutants to both the atmosphere and the water courses unless suitable green technology is implemented into the design. They also use large amounts of energy, typically using anywhere between 12,000 kWh to over 112,000 kWh. The furnace in Redcar Cleveland produces 8000 tonnes of steel a day, producing close to a £500,000 a day. and produces 1 job/ 40 m^2	20 m	industry area in your project it will cost £10,000/m^2
Green Technology Research Facility.	The green technology research facility provides jobs for 8 scientists and 4 local people. The site is responsible for the development of green technologies that could be incorporated into industry, without impacting on the environment. This would include water filtration, chimney stack scrubbers, pollution scrubbers etc. It requires a lot of energy to continue the research here, costing 36,000 kWh of energy per year, however this could be the flag ship of your site for sustainability.	50 m x 45 m	£1.96 million

SITE 2 POSTGRADUATE DEVELOPMENT SITE IN HONG KONG.

Your Task:

To develop a self sustaining postgraduate school in Hong Kong where all energy has to be produced on site and all waste processed. The school will provide education for at least 50 students and research facilities for 22 research scientists.



The University of Midsummer is seeking to extend their global influence by constructing a postgraduate school in Hong Kong near Ocean Park and Deep Water Bay. The site has been approved under the firm understanding that the site will remain green and self sustaining for both waste management and energy production. Further to these requirements the school must have very low impact to the Nam Lang Shan environment. A suggestion has been made to terrace the development in order to maintain the hill environment and lower the impact on the environment and influence on the aesthetics.

The aim of the site is to:

- Provide facilities to a variety of disciplines for at least 50 postgraduate students.
- Accommodation must be provided for the postgraduate students.
- Create a centre of excellence in the development of green industrial processes providing research space for 22 research scientists.

Accommodation does not have to be provided for research academics.

You will have a budget of HK$300 million and must ensure that it is the flagship design for future green development sites. You will produce a report outlining the design of the site including the waste management, and energy production, technologies used.

What you might want to consider

How much energy is going to be required for the whole site?

How will the energy be generated for the site?

How are you going to manage waste to ensure that the site is sustainable?

The gradient of the slope is very steep as seen in the image. How are you going to construct this site?

Useful information

- Hong Kong Island is the most densely populated city in the world with 17,259 inhabitants km2. London has 11,536 inhabitants km2.
- Hong Kong has the largest number of skyscrapers in the world with 8000 of them across the city. This is double the figure of its nearest rival in New York.
- 80% of the cities smog originates from other areas of the Pearl River Delta.
- Large amounts of rainfall fall between May and September averaging 364 mm/month of rain, The annual rainfall is 2382.7 mm.

Tasks to be completed

- Calculate how many tonnes of carbon your site will produce in a year. On average 1.297 lbs of CO_2 produced per kW, this is drastically changed if you use renewable sources.
- Draw a scale diagram of your site, showing the layout of your buildings and other structures.
- Complete a spreadsheet demonstrating the cost of constructing the site and where possible identify methods that would possibly recuperate the expenses involved.
- Produce a report explaining the sustainable technology you will use, reasons for your design, financial details.

Remember to design your postgraduate site with the idea of self sufficiency and low environmental impact. Hong Kong is a prime piece of real estate and symbolises what can be achieved to many areas surrounding the Special Administrative Region. Make it bold and consider innovative technology in your design.

Building Costing List

Item	Description and Energy usage	Area covered (l x w x h)	Price
Land Treatment and Preparation			
Light Land Clearance	(Tall Grass, small shrubs)	1 m x 1 m	£50/m^2
Medium Land Clearance	(trees and small shrubs)	1 m x 1 m	£150/m^2
Heavy Land Clearance	(Densely packed trees and shrubs)	1 m x 1 m	£400/m^2
Land Drained	If there is a large amount of ground water at the location then you might require the land to be drained prior to construction. This is essential so that you ensure that foundations of buildings and road surfaces to not move and crack.	1 m x 1 m	£400/m^2
Communications and Infrastructure			
Road	The road construction regulations differ between countries, however this is the price for a generic road surface including the base and sub base materials.	1 m x 1 m	£120/m^2
Footpaths	The footpaths are designed for pedestrian traffic only, this is reflected in the price as the materials used are not strong enough to support cars and lorries.	1 m x 1 m	£120/m^2
Cycle paths	The cycle paths is the same price as the footpath because it is composed of the same material. The only difference is its colour to denote the different proposed use.	1 m x 1 m	£120/m^2
Main Sewage Drain Pipes (Concrete)	This is required if you intend to have your sewage processed at a central location rather than individual properties processing their own waste materials.	5 m x 1 m	£50/ m
Telephone Cable	This is a Category 3 cable which is suitable for telephone communication and dial up internet connections. This is the price for the cables to be laid during road construction.		£0.6/m
Data Cables	This is a Category 6 cable which is suitable for telephone communication and high speed broadband connections. This is the price for the cable to be laid during road construction.		£0.8/m
Fibre Optic Cable	This cable enables the rapid exchange of data and information throughout your network of communications		£1.2/m
Mobile Phone	The mobile phone has become an integral part		£10,000 per

Masts	of our modern communication network. Everything from telecommunication and surfing the internet are now used using our mobile phones. The installation of a mobile mast can cause controversy over their appearance, but modern mobile masts can be camouflage to blend more into the environment. Very Low energy consumption at about 2000 kWh per year. Mast covers a radius of 20 miles.		mast.
Air conditioning Control	The air conditioning units can be mounted on an external wall and require pipes to distribute around the building. Highly suitable to a location with high temperatures. 2000 kWh	Air Conditioning Plant Room 10 m x 6 m x 3 m Air Conditioning Pipes 0.5 m x 0.5 m x 5 m	Air Conditioning Plant Room £12,000 Air Conditioning Pipes £70
Campus Buildings/Rooms			
Corridors	These corridors are used to travel between rooms and can be constructed out of reinforced concrete or brick depending on location, consume 36kWh per year	2 m x 5 m x 3 m	£1525
Storage	These are rooms that can be fitted with shelves or remain as large storage rooms 1 kWh per m^2 per year.	Minimum of 3 m x 3 m	£152.50/m^2
Office Room	This room comprises of small space that can be used by one person. The room includes cabling for LAN connections and power connections, Desk, Computer, filing cabinet, window and door. 450 kWh per year.	3 m x 3 m x 3 m	£9000
Chemistry Laboratory	The chemistry laboratory is configured to be used as work benches including gas taps, water supply, 2 fumecupboards, benches and workstations. The area is large enough for one postgraduate student or researcher and can be setup to accommodate any of the four major disciplines. (specialist equipment NMR equipment are not included but would require this type of room due to power demands) 2000 kWh per year.	25 m x 15 m x 3 m	£39,000
Biology Laboratory	The Biology Laboratory is configured for the research such as Entomology, Anatomy, Agriculture, Ecology, Genetics and Pathology. They are equipped with both Normal and	30m x 20m x 3m	£52,000

	Microscope benches, gas taps, water supply, workstations and glove boxes/fumecupboards. 2000 kWh per year		
Physics Laboratory	The Physics Laboratories are configured with basic equipment that might be needed. They have work benches, gas and water supplies and workstations. Other equipment that might be required must be sourced from an alternative location. 1500 kWh per year.	25 m x 15 m x 3 m	£25,000
IT suite	The IT suite is fitted with 10 workstations, printing facilities and a server node to provide computer solutions to the university. The facility will use 4500 kWh per year	10 m x 5 m x 3 m	£15,000
Staircases	The staircase provided is made of concrete and elevates 3 m. The staircase requires 36 kWh per year to power the lighting	2 m x 5 m x 3 m or 2 m x 5 m x 1.5 m	£9000
Elevators	The elevators are a suitable method to ensure disabled access throughout your site. It can be used to transport materials around the campus, however will require reinforcing should heavy materials need moving (such as NMR apparatus, GCMS, etc). The energy required for this construction is 1250kWh per year	3 m x 3 m x 3 m	Normal £20,000/floor Reinforced £50,000/floor
Lecture Hall	This room provides seating for 50 people with a workstation at the front. In addition to a workstation the hall includes a projector, sound system and a media station 2560 kWh per year	20 m x 20 m x 9 m	£83,000
Seminar Room	The Seminar room is designed similar to the lecture hall, however it is designed to accommodate 10 people in stead of 50. The room comprises of desks, chairs, a workstation at the front with a projector, sound and media system. 2000 kWh per year	10 m x 15 m x 3 m	£43,000
Library	The library facilitates an area of study for all members of the school. Requires 2000 kWh per year	23 m x 15 m	£49,250
None Academic			
Single Room	This is a single occupancy room designed to accommodate a single postgraduate student. The room comprises of a bed, desk, sink and wardrobe. These rooms require 1750 kWh per year of energy	4 m x 7 m x 3 m	£8255
Shared Room	This is a shared room set out very similar to the single room however it caters for two postgraduate students. It consists of beds, desk, sink, and wardrobes. The energy required	9 m x 5 m x 3 m	£15,583

	for this room is 4100kWh per year.		
Kitchen	This is designed to be a shared kitchen for self catered accommodation. It is fitted with electric cooker, fridge, freezer, microwave, dining table and chairs. This kitchen is suitable for 6 people. This kitchen will require 3600kWh per year	9 m x 9 m x 3 m	£28,520
Canteen	The canteen provides jobs for 3 local chefs and can accommodate 3 meals a day. The kitchen is fitted with all the mod cons and caters for a variety of cuisines. The seating area provides seating for 50 individuals, however there would be space for additional individuals on rare occasions. The kitchen requires 5000 kWh per year of energy.	25 m x 40 m x 3 m	£95,855
Common Room	The common room is a seating area that has televisions, telephone facilities, vending-machines all with sofa and armchair seating. The Common room is designed to provide seating for 13 individuals. The common room will require 1950 kWh per year of power.	10 m x 10 m x 3 m	£38,000
Bedsit	A bedsit is similar to a studio flat. It comprises of a bedroom area, with bed, side table and Wardrobe; living area with a kitchen unit, comfortable chair and desk. The bedsit also has an en suite with a shower. The bedsit would require 5000 kWh per year of energy.	10 m x 10 m x 3 m	£52,000
Shops	These are shop units that could provide the basic requirements for the students. It could be an onsite bank, convenience shop or even a travel agents. The price is for a basic unit shell and would require about 4250 kWh per year to run	15 m x 10 m x 3 m	£8000
Energy Production and Waste Management			
Solar Power	Solar Power comes in two different forms, Photovoltaic cells which convert solar energy into electricity and Solar heating cells which can be used to heat water. Which one you require will depend on your needs. One Photovoltaic Cell will produce 100 kW of energy a year assuming 10 hrs of sunlight a day. Solar heating cells will produce 1165 kW of energy to heat water.	Each solar cell is 1 m x 1 m	The Photovoltaic Cell costs: £1000 The Solar Heating Cells: £1000

<table>
<tr>
<td>Wind Power</td>
<td>
<table>
<tr><th></th><th>Drive train</th><th>Power rating [kW]</th><th>Diameter [m]</th><th>Tip speed [m/s]</th></tr>
<tr><td>Vestas</td><td>Geared</td><td>36,000</td><td>90</td><td>87</td></tr>
<tr><td>GE Energy</td><td>Geared</td><td>30,000</td><td>100</td><td>86</td></tr>
<tr><td>Gamesa</td><td>Geared</td><td>24,000</td><td>90</td><td>90</td></tr>
<tr><td>Enercon</td><td>Direct</td><td>24,000</td><td>82</td><td>84</td></tr>
<tr><td>Suzlon</td><td>Geared</td><td>25,200</td><td>88</td><td>71</td></tr>
<tr><td>Siemens</td><td>Geared</td><td>43,200</td><td>107</td><td>73</td></tr>
<tr><td>Acciona</td><td>Geared</td><td>36,000</td><td>116</td><td>74.7</td></tr>
<tr><td>Goldwind</td><td>Geared</td><td>9000</td><td>48</td><td>58</td></tr>
<tr><td>Nordex</td><td>Geared</td><td>30,000</td><td>99.8</td><td>78</td></tr>
<tr><td>Sinovel</td><td>Geared</td><td>18,000</td><td>70</td><td></td></tr>
</table>

There are many types of Wind turbine that can be purchased depending on the energy requirements. The table above show the potential energy production by each of the turbines. However this is not the amount of power that they will be produced all the time
</td>
<td>Each turbine varies in size. Look at the size of the blades. Each tower will stand 200 m off the ground</td>
<td>The price of creating a wind turbine is £50/kW of energy</td>
</tr>
<tr>
<td>Biomass</td>
<td>The Biomass Processing plant uses organic materials and turns them into a fuel source. Household waste such as cooked food, paper and garden waste such as grass and tree cuttings. They are then burnt and transformed into energy. An alternative source is to transform fresh and used oil into a biodiesel and use this to generate electricity. Both plants will provide jobs for 6 people and will provide. Each type of plant can process 7000 tonnes of organic material/oil a year which produces 1 MW of energy. This building cannot be built underground.</td>
<td>The Biomass Plant covers an area of 62 m x 38 m</td>
<td>The sites cost £5.3million</td>
</tr>
<tr>
<td>Radioisotope Thermoelectric Generators</td>
<td>These are small generators powered by nuclear material, most commonly PuO_2. Or AmO_2. Instead of initiating a fission reaction, the material degrades releasing heat. Each cell creates 1000 kW of energy, and must be in a room lined with lead.</td>
<td>5 m x 5 m x 3 m</td>
<td>£18,000,000</td>
</tr>
<tr>
<td>Geothermal</td>
<td>Geothermal heat pumps are renewable</td>
<td>Geothermal</td>
<td>Geothermal</td>
</tr>
</table>

Heat Pumps	systems that uses the heat of the earth to maintain the temperature of the building and heat water. The process works by pumping cold water through pipes into the ground and pumping out hot water from underground. It can be used to produce heat only and not electricity. It would produce about 13000 kW of heat to be used in heating or hot water systems. You would require 6 pipes per building	plant 10 m x 6 m x 3 m Geothermal underground Pipes 0.5 m x 0.5 m x 35 m	Plant £16,000 Geothermal Pipes £1250 each
Sewage treatment Centre	This site can process enough waste for 500 people, producing clean water that is free of pollutants straight into the local water course. The site can be run based on the taxation of those 500 people that use the site, costing them £103 per person per year. Consumes 22000 kW of energy per year. Provides 6 jobs to the local area. This building cannot be built underground due to the levels of gas produced.	Covers an area 140 m x 150 m	The cost to install the site is £1,300,000
Environmental Treatment Centre	This site is used for a more environmentally friendly treatment site for sewage waste. This site requires a large area to be set aside as wetlands. It uses natural biological processes such as reed beds to process the polluted water and providing a habitat for wetland creatures. This site also requires very little maintenance, Provides 1 job at the local government office. This site is required to be built above ground because it contains plants that require sunlight.	Requires an area of around 1 m^2 of Cattails (*Typha*) per person.	£15/m^2

Site 3 Sustainability at Midsummer University

The Midsummer University is located in the UK and requires the investigation into the improvement on its sites environmental impact. It is a large community based university currently hosting around 12000 students on various courses, with 3000 of them in university residency. It is attended by students from a variety of backgrounds from over 30 different countries. The rest of the students are either in private accommodation in the vicinity of the university or live at home. There is also a small percentage of distance learners. The faculties that the university caters for are the same as those found at a majority of universities in the United Kingdom, including Law, Sciences and Humanities. Water and electrical usage are relatively high and wastage is increasing due the increase demand by the population for higher education. Two departments have been identified for their large wastage. The chemistry department has been identified as having the highest water wastage, consuming around 1/3 of the universities annual water bill. The accommodation department was identified as having the largest bill for electricity consumption due their student residences.

The information you will receive is a recent audit by the university about its sustainability practice, and the price of its current consumption. The cost of the new sustainable practises suggested should cost no more than £1.5million. The information that you will be provided with is an energy audit for the university. The current methods employed by the university are:

- Recycling bins set at various location around the campus.
- Whole site composting of organic materials such as food waste from canteens and gardening.
- Lights with sensors so they only come on when someone walks past.
- Low Energy light bulbs in the external lighting around campus.

Remember that for this site it may not be cost effective to implement renewable energy sources even with current feed in tariffs outlined by the government, however they might not want to be fully discounted, as renewable energy provides a visual demonstration of a green initiative.

Positive Aspects	**Negative Aspects**
• Do not have to purchase the site. • Energy Audit identifies strategies already in place at the University.	• Small Amount of money in comparison to other projects. • Scope for drastic change is small.

Questions that you might want to consider

When you are creating your assignment there are a few things that you might want to consider before making your decision.

- How easy will it be to alter the system already in place?
- Is there anything that could employed to encourage those not in university accommodation to be more self sustainable?
- Are there any new technologies that could be implemented to reduce the costs of energy consumption?
- How could the university tackle the problem of wastage across the whole campus, and not just in those that are identified as a problem?

Useful information to know

- Using an energy saving light bulbs uses about only 1/3 of the power of a conventional bulb.
- The average household in the UK will spend about £30-£40 a month on electricity, however considering each student will probably have a computer they would rise drastically.
- In February 2011 University budgets were cut by £1billion meaning there was a drive to become self sufficient as a means of cutting costs.

Tasks to be Completed

For this project you will have to:

- Identify possible solutions to specific areas of interest
- Produce a report explaining your technology solutions to be presented to the University Senior management Team.
- Demonstrate calculations with regards to energy efficiency and complete Carbon Energy Improvement Project Documents for each area of interest.

The Baseline figures for energy consumption and carbon footprint for Midsummer University.

1990/91

Electricity (kW	CO_2 from electricity (tonnes)	Gas (kW)	CO_2 from Gas (tonnes)	Oil (kW)	CO_2 from Oil (tonnes)	Transport Emissions (0.71% of total emissions	Total CO_2 (tonnes)
17,323,333	13,364	28,234,001	5,230	1,421,890	361	135	19,090

2005/06

Electricity (kW	CO_2 from electricity (tonnes)	Gas (kW)	CO_2 from Gas (tonnes)	Oil (kW)	CO_2 from Oil (tonnes)	Transport Emissions (0.71% of total emissions	Total CO_2 (tonnes)
24,516,390	13,216	28,179,027	5,220	2,781,010	686	136	19,258

2009/10

Electricity (kW	CO_2 from electricity (tonnes)	Gas (kW)	CO_2 from Gas (tonnes)	Oil (kW)	CO_2 from Oil (tonnes)	Transport Emissions (0.71% of total emissions	Total CO_2 (tonnes)
22,089,491	11,991	38,517,146	7,135	0	0	136	19,261

By 2019/20 the university should have reduced its carbon foot-print to 12599 tonnes of carbon per year.

Water Consumption at the University

The amount of water that is consumed at the university, however the table below demonstrates the required year on year targets til 2020

Year	Water (cubic metres)	%
2009/10	249,305	100
2010/11	244,407	98
2011/12	239,419	96
2012/13	234,431	94
2013/14	229,443	92
2014/15	224,456	90
2015/16	219,388	88

2016/17	214,468	86
2017/18	209,492	84
2018/19	204,504	82
2019/20	199,516	80

Current Tariff Rates

Energy Source	Tariff (p/kW)
Electricity	9.94
Gas	1.676

When considering your carbon footprint it is not always the most extravagant solution that is the best. Renewable energy looks like a very proactive means of reducing the amount of carbon a site produces, however a business such as the university has to consider the simple payback (the number of years it will take to recover the project's cost), as well as the amount of carbon it has reduced. Possible areas that you might want to be considered are:

Area of Interest	**Type of Intervention**	**Area to consider intervention**	**Total Current Energy Consumption (kW/yr)**
Buildings	Technical	Air conditioning in buildings	365,000
Buildings	Technical	Temperature controls in accommodation (112)	Heating energy (400,000)
Buildings	Technical	Insulation in the plant building	38,000 (lost energy)
Buildings	Technical	Loft insulation in Accommodation (112)	Heating energy (400,000)
Buildings	Technical	Cavity wall insulation in accommodation. (112)	Heating energy (400,000)
Buildings	Technical	Insulation on pipework (127km)	158,000 (lost energy)
Buildings	Technical	150W light bulbs in campus buildings (23000)	13,065,320
Buildings	Technical	External lighting (8000)	4,380,000
Buildings	Technical	T12 lighting (8000)	4,380,000
Buildings	Technical	Old boilers (95 C rated boilers)	369,000 (lost energy)
Buildings	Technical	Gaps in Doors	198,000
Buildings	Technical	Single glazing	1,777,023
Staff/Students	Behavioural	Free laundry service (42 category C washing machines)	420,000
Staff/Students	Behavioural	Energy consumption metered	n/a
Building	Technical/Behavioural	Non-recyclable material in vending machines (12)	42,048
Building	Technical	Zoned heating	n/a
Building	Technical	Zoned electricity	n/a
Building	Technical	Oversized radiators	1,739,520

For each of the above mentioned intervention areas you are to create a Carbon Reduction Project Assessment Form and suggest a possible solution sourcing suitable technology that will allow the university to meet its emissions targets and water wastage targets. You will have to explain how your technology works and how it will function to reduce the carbon foot-print or water wastage on site. This should be explained in non-scientific language as you may be presenting your solutions to individuals who might not understand the scientific language, but clearly showing the figures.

Carbon Reduction Project Assessment			
Area of Interest		Project Intervention	
Type of Project		Capital Expenses	
Current Energy Consumption		Current cost of using	
Current Emission Factors ($kgCO_2/kW$)		Saved Emission Factors ($kgCO_2/kW$)	
Energy Reduction		Costs Saved in Energy	
Number of years recuperate capital expenses			
Description about the technology used to improve energy efficiency:			

SITE 4: GREENER PUBLIC TRANSPORT THROUGH BIODIESEL AND BIOETHANOL.

Your Task:

To analyse the costs of producing biodiesel and bioethanol to be used in Midsummer's small fleet of 42 buses. Decide which biofuel is most suitable to the company.

Biodiesel is produced when vegetable and plant oils undergo esterifaction to produce a type of diesel. Many biological feedstocks have been tried from soybeans, sugarbeat and even old chip shop oil. It is an area of particular interest to many cities, especially with the possible implementation of green taxes and increased costs of waste management. Midsummer's Bus Company is looking to use a biodiesel mix in their fuel for the town's buses. The company want you to assess the feasibility of constructing their own biodiesel processing plant and the best reactants to use in its production. In Tucson Arizona, a company called Sun Tran operates the local bus network. They have a fleet of 240 buses which travel 28,000 miles a day. There entire fleet is powered by B20 (fuel mix of 20%biodiesel:80%petroleum diesel), B5 fuel or CNG, significantly reducing their annual carbon tonnage. This is the similar scale we hope to achieve with this project. You will have to determine the percentage mix to ensure that the company can remain solvent.

Bioethanol is the fermentation of plant matter to produce ethanol as a fuel source. It uses similar crop sources to biodiesel. However, instead of using the oils from the plants, it uses the fructose and glucose stores in the plant. Furthermore, the octane levels in the final product can be manipulated to produce an improved combustible fuel. Midsummer Bus Company had not considered this as a possible fuel alternative and would like you to compare this to the production of biodiesel. A company in Ukraine called KoronAgro who started construction of an industrial sized fermentation plant. It cost €110million to construct and is expected to produce 380,000 l/day.

Data will be provided for the fleet in order to assess the ideal percentage mix of biodiesel in the current fuel, as the sustainability of sourcing materials for B100 could prove difficult. The managers want to know how much it will cost to start production and the council are concerned about safety implications. Consider the reactions for the biodiesel production including possible biproducts that might be created. Current fuel consumptions of each bus, the costs of materials, waste disposal and reactants and the resale value of possible by-products will be provided. At present there is no final budget. However should the project demonstrate that it is feasible to implement then funds will be made available.

What you might want to consider:

What are the positive aspects of using biofuels?

What are the negative aspects of using biofuels?

What are the possible sources of plant oils?

What other reactants might be required?

Are the manufacturing costs of the biodiesel less than current costs of diesel?

What are the possible side reactions and by-products of this reaction?

Useful Information

- You get 34% more energy out of ethanol than is required to produce it (from corn). On the other hand, you get 320% more energy from producing biodiesel than you put into it. (source: http://www.usda.gov/oce/reports/energy/aer-814.pdf)
- Ethanol 30% less CO_2, biodiesel 74% less CO_2 produced than diesel (source: US DoE)
- Corn yields 230 gallons per acre for ethanol (source: EERC). Brazil's program that produces ethanol from sugar cane currently achieves about 600 gallons per acre. site has a table with the yields for other crops. Most U.S. biodiesel is made with soybean oil which yields a low 70.13 gallons per acre. Euro biodiesel is primarily rapeseed which yields a better 127gallons per acre, while palm oil yields an impressive 635 gallons per acre. Biodiesel can also be produced from algae, but it remains to be seen how many gallons per acre that will yield. (source: Journeytoforever.org)

Tasks to be Completed

- Produce a reaction mechanism for the production of bioethanol. Include MSDS data
- Produce a reaction mechanism for the production of biodiesel. Include MSDS data
- Analyse the feasibility of using the biofuels against the use of petroleum fuels (compare the sale of diesel to the price of producing and using biofuels).
- Suggest a waste management program for the project including the handling of all by-products.
- Compile report identifying the major costs involved in setting up and using biofuels and suggest which of the biofuels would be most suitable to use. Also identify which reaction mechanism you will use and the materials required to improve efficiency. (2000 words)

Bus	Annual Mileage	Annual Fuel Consumption (l)	Amount of Carbon Produced (kg)	Running Costs (13th June 2011, £)
1	38522	1834	4860.1	2539.72
2	30605	1330	3524.5	1841.78
3	42894	1949	5164.85	2698.98
4	32292	1196	3169.4	1656.22
5	33327	1190	3153.5	1647.91
6	43095	1390	3683.5	1924.87
7	32200	1463	3876.95	2025.96
8	33089	1504	3985.6	2082.74
9	31266	1202	3185.3	1664.53
10	39380	1875	4968.75	2596.50
11	39308	1965	5207.25	2721.13
12	38470	1831	4852.15	2535.57
13	28813	1309	3468.85	1812.70
14	34013	1619	4290.35	2241.99
15	27149	1131	2997.15	1566.21
16	43960	1911	5064.15	2646.35
17	41054	1368	3625.2	1894.41
18	36162	1166	3089.9	1614.68
19	33046	1321	3500.65	1829.32
20	41855	1443	3823.95	1998.27
21	36994	1608	4261.2	2226.76
22	39093	1348	3572.2	1866.71
23	43881	1755	4650.75	2430.32
24	28533	1240	3286	1717.15
25	28109	878	2326.7	1215.85
26	37463	1560	4134	2160.29
27	39041	1501	3977.65	2078.59
28	38962	1771	4693.15	2452.48
29	41371	1798	4764.7	2489.87
30	39696	1368	3625.2	1894.40
31	36352	1580	4187	2187.98
32	42971	1652	4377.8	2287.69

Author	Tina Overton, Christopher Randles
Title	Problem-Based Learning Case Study
Classification	Case Study
Keywords	cpbl, HESTEM, sustainable development, case study, biofuel
Description	Student handout
Creative Commons Licence (url)	
Language	English
File size	3209 kB
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