Professional Engineering Final Report

Group number: 7

TITLE

SUPERVISOR NAME

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Introduction

Engineers without border's global engineering challenge set numerous projects for student to tackle. Based on the structure of the village of Sandikhola, group 7 decided to work on the alternative energy supply challenge in the energy design area. We believe that this project would be very beneficial to their community since electricity plays an essential role in everyone's lives. Currently, their mains electricity is unreliable and inefficient. Therefore, villagers have unstable electricity supply and periodic power shortages. To tackle this, we have decided to build a system to supplement their current mains supply so as to provide sufficient electricity to support their essential household electricity usage when the mains supply falls below a certain level.

Last term, we broke down the different key areas of the project into a Product Design Specification (PDS). This then led us to each propose three different ideas to tackle the problem identified. Our interim reports allowed us to look at the issue from several different perspectives and come up with innovative ideas. This term, we have identified of our design criteria, selected the best design based on our design criteria and further developed our selected idea. This report will cover these in detail.

Design Criteria

From our PDS (see appendix 1) we selected the following points as the most important and relevant for the next stage of our project:

- Performance (PDS 1) – The performance of the electricity supply is important because it needs to provide a constant source of power that meets the demand of the village. One of the main issues is the lack of continuous power supply.

- Environment (PDS2) – Any solution that we decide on has to be conscientious of the environment it will be built in. The village is situated at high altitude subjecting it to high wind, therefore the chosen design has to be structurally sound in these conditions. The product would be implemented in or close to the village therefore consideration to the environment in designs is important.

- Target Product Cost (PDS 5) – As engineers without borders is a charity project design solutions are constrained by a budget, if product cost is unrealistic for the economic conditions the solution will not be feasible.

- Materials (PDS 14) – As the village is not easily accessible the use of local materials is essential and significantly reduce the cost of the project through minimising transport costs (this addresses PDS 7 and 8). Additionally it will reduce the carbon footprint of the project.

- Safety (PDS 24) – The safety of the villagers is of the utmost importance and as our design solutions involve high voltages we cannot compromise on safety. Risk minimisation has to be considered a priority.

- Installation (PDS 30) – Due to the remoteness of the village and thus the lack of specialized equipment usually in similar product's installation poses a challenge. This makes the simplicity of the product's installation key to the project's success.

- Maintenance (PDS 4) – The villages will have to independently maintain the product over its lifespan. It is important that the maintenance of the product has to be kept as simple as possible due to the lack specialised knowledge within the community. If the product cannot be maintained it would be detrimental to the long term success of the project.

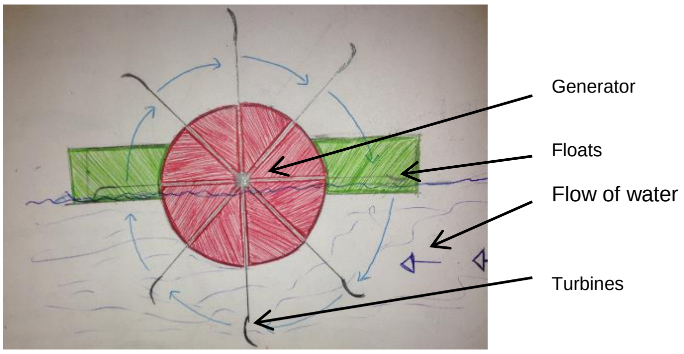
- Quality and reliability (PDS 19) – Quality of the product is crucial to its longevity and ensuring that it's reliable. With a high quality product breakdown maintenance will be minimised so play a key role in selection of design.

- Customer (PDS 11) – The aim of the project is to improve the standard of living for the villagers and therefore must conform to their needs and demands. It should also take into consideration aspects that may not have been requested but would greatly affect the village.

<u>Concept Designs Considered</u>

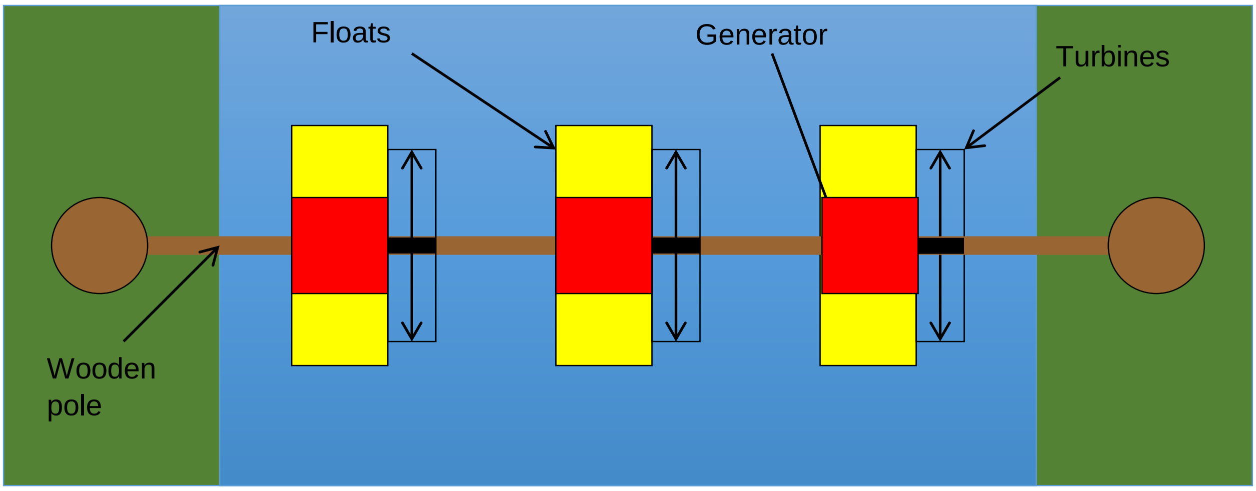
From each of our original three ideas we each selected the one that the felt would be best, the proposed solutions are as followed.

<u>Concept 1</u>



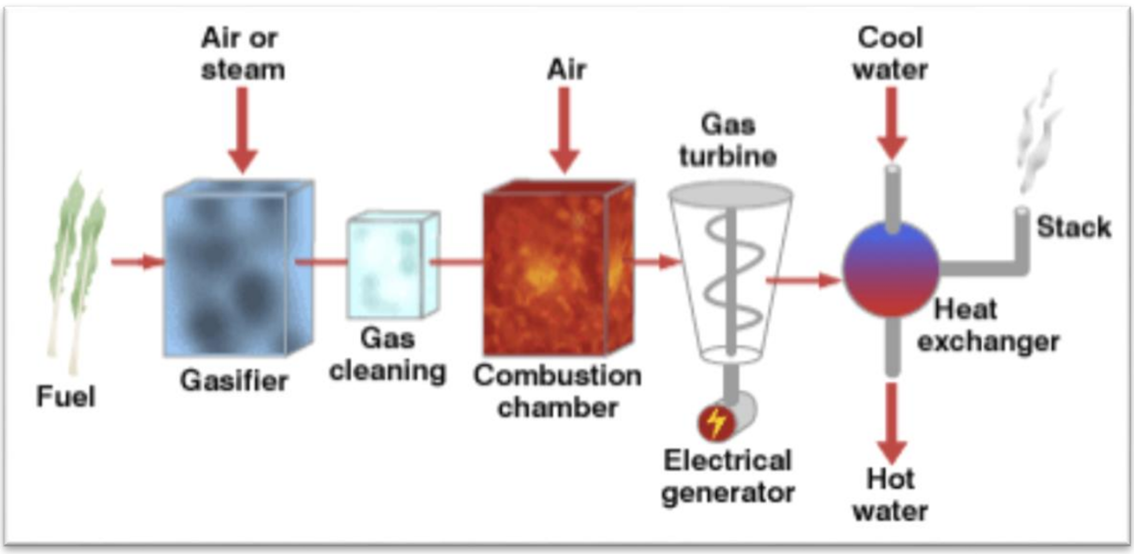
This concept is based on waterpower. The water wheel is placed half way into the water and the flow of the river makes the turbine spin. The turbine is connected to the generator that floats on the surface of the water. To make it float at the right height we would have to calculate the correct size and position for the floats connected to the sides of the generator. The floats would be made from locally sourced plastic – possible recycled water containers. The diameter of the turbines would be about 2 meter – but this could be changed for the depth of the river – so that the turbine dips 1 meter into the water and the span of the floats and generators would be 1.5 meters. The turbine would be made from locally sourced plastic that could be cut or moulded into the right shape.

The generator would be small but several of these systems would be placed across one point of the river, and then this could be repeated at several points along the river thus generating more electricity. The devices would be connected together and to the riverbank by a wooden pole that would be sourced locally, painted with a waterproof paint for wood to prevent decay. This would allow the systems to move up or down with the depth of the river (e.g. when there is heavy rain fall and the river swells) so that the turbines stay in the same position relative to the surface of the water. The electricity produced in each system will be transported from the system across the river through a cable (waterproof) attached to the wooden pole. From the river bank the electricity would either be stored in batteries if the demand in the village was low, or be transported up to the village via small telegraph poles and cables when the village needs it. (As seen in Zoe Williamson's interim report)



Concept 2

This design is based around biomass. The final proposed design was to generate electricity through the gasification and then burning of animal waste. The gasification process is presented below: (image http://news.bbc.co.uk/1/hi/sci/tech/4948052.stm)



Animal waste as a fuel is available all year round so unlike other sources of renewable energy such as solar or wind, the amount of energy will not change depending on the season. This means that the community could be dependent on only this one type of energy completely.

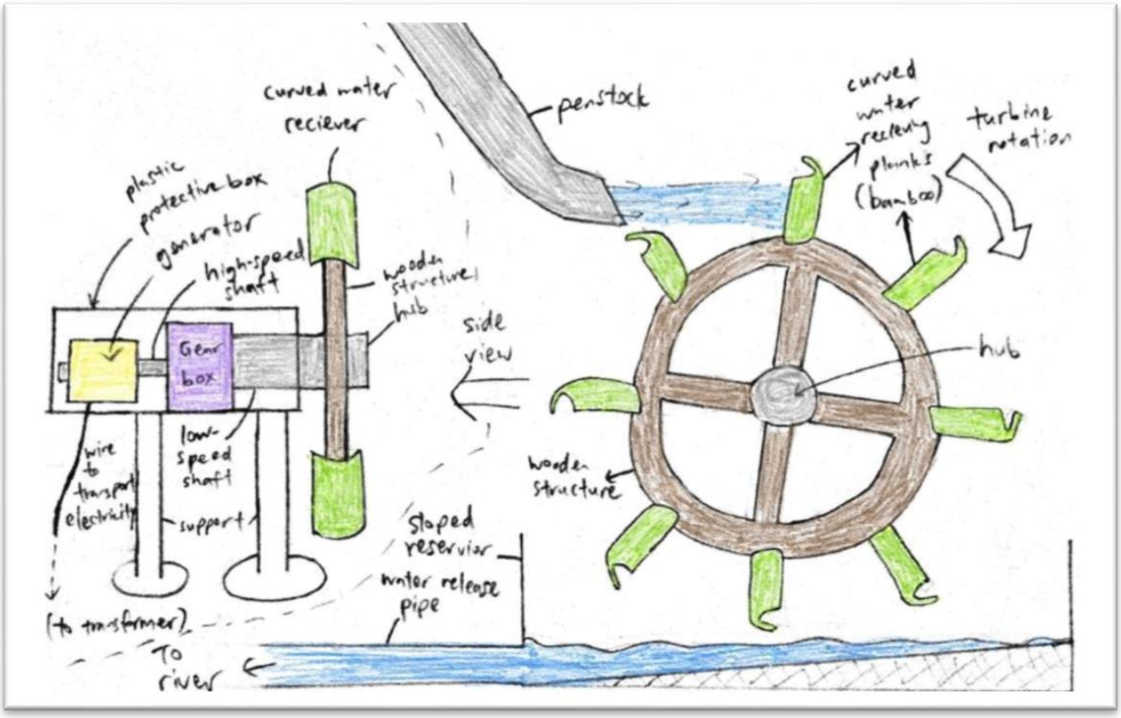
In fact, some members of Sandikhola's community already utilise animal waste to power stoves for cooking, and they praise the fuel for its cleanliness. This may mean that there is also already basic knowledge on this method of energy generation.

The fuel is also carbon neutral and would produce no harmful by products. However, doubts are raised whether or not there is enough fuel to provide power to a whole village. Installation and maintenance may also be difficult as many wires would have to be installed and the machinery required for gasification may be very complicated. The pricing for such equipment may also be quite high. (As seen in Andrew Zhou's interim report)

<u>Concept 3</u>

Micro-hydro System

This system is made of many individual units aligned along the river. In each individual unit, there is a wide canal (with a filter to keep wildlife out), a narrow penstock (increase water pressure and speed), a water wheel made of Sissoo wood (a rot resistant wood) and bamboo that are treated to withstand moisture, a water turbine, a generator, a temporary reservoir and a water release pipe. Any water collected via the unit will eventually be released back to the river (Figure 7), allowing more units to be able to function downstream. The turbine and dynamowill be protected by a hut, to shield them from external weather. The main structure of the water wheel is made of local wood and bamboo for ease of transport, and reduction of cost. For maintenance, the bamboo planks will be worn out easily. Hence, frequent inspection of the turbine is necessary and the planks should be easily replaceable. The wooden wheel structure should also be replaceable. Additionally, the filter at the canal entrance should be cleaned periodically so as to prevent blockage. The small amount of water used in the proposed hydropower unit will ensure that this system can work even when the river water volume is low. Each hydropower collection unit will generate AC power. Thus, a transformer will be needed in each hut and rectifiers will be needed in the central facility. Since building pipelines might be costly, it will be safer to use this system as a complement to the village's existing mains electricity. This suggests that all electricity generated will be stored in batteries in a central facility and only be distributed to the households when mains electricity runs low. (As seen in Yumeng Sun's interim report).

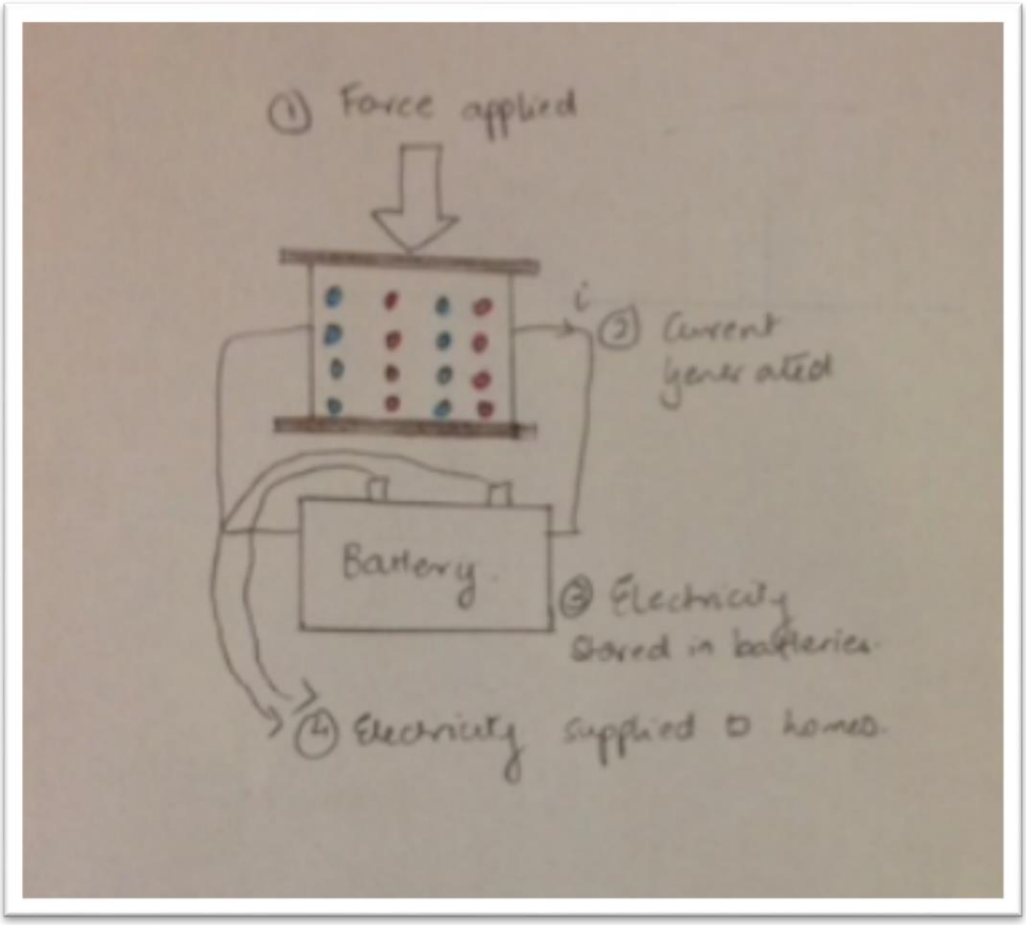


Inside the Turbine and Generator Hut

Concept 4

This solution included the use of piezo tiles along with a generator to produce electricity. Piezo tiles convert mechanical force applied on it to electricity. Physical distortion of these tiles cause a net dipole moment which produces an electric charge across the surface of the tile which can be converted into usable electricity using a generator. A number of these tiles are connected to each other and subsequently to a generator. The electricity generated from these tiles could be used to run small appliances such as light bulbs. The proposed idea included placing these tiles in places traversed by people on a daily basis, for example a source of water like a well or a hand pump, the entrances of homes or even public meeting areas. Every time someone steps on one of these tiles, a small amount of electricity builds up which will eventually add to produce a significant amount of electricity. Although this could be an expensive setup, piezo tiles require almost no maintenance and have a lifespan of about five years. In addition, technological advancements in this field happen every alternate day which means the prices keep going down reducing setup cost. ******Pavegen, a company that manufactures piezo tiles have been reported as saying, "…the tiles cost as much as £2500 in 2011, £120 in 2013, and as little as £45 in the future."

(As seen in Vigram Mohan's interim report).



Concept Selection

We decided that the weighted matrix method would be best to help us quantify our concepts and decide the overall best idea. We used the design criteria that we put together with the most important sections from the PDS as the criteria for our matrix, weighting were also giving for each section depending on how vital we thought it was to the projects viability.

	Weighting	Concept 1	Concept 2	Concept 3	Concept4
Performance	15	12	9	11	10
Environment	10	8	8	6	10
Target Product Cost	15	9	6	8	4
Materials	15	13	7	13	3
Safety	20	12	12	15	19
Installation	10	8	5	5	3
Maintenance	10	4	7	7	6
Quality and Reliability	15	11	13	10	12
Customer	15	12	15	12	8
Total Score	125	89	82	87	75

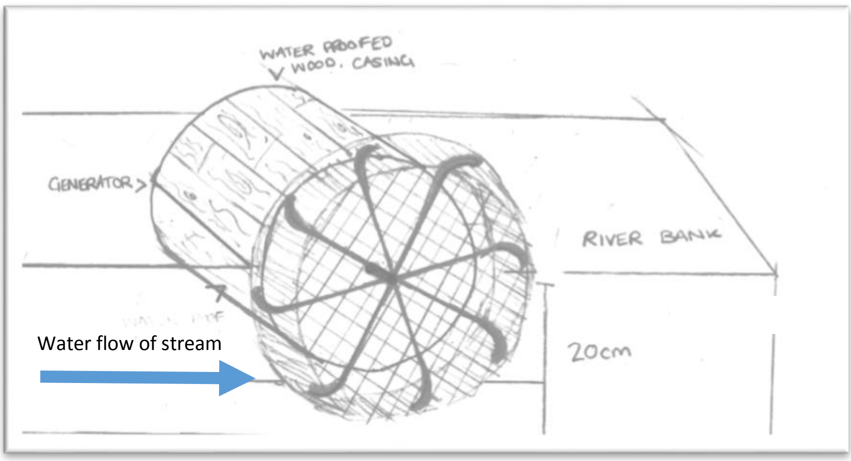
From this we have selected concept 1 which scored the highest in our matrix. It had high scores for the majority of the criteria, making it the most suitable choice.

For Performance, all concepts scored highly as they are all sustainable energy supplies. However, concept 1 edged out the others because of its impressive generation efficiency. Concept 1 also scored highly on environment due to the fact that it was very unobtrusive to the community. The concept's simplistic design also allowed it to utilise many local Materials, which also brought Target Product Cost down, resulting in high scores for both of these sections.

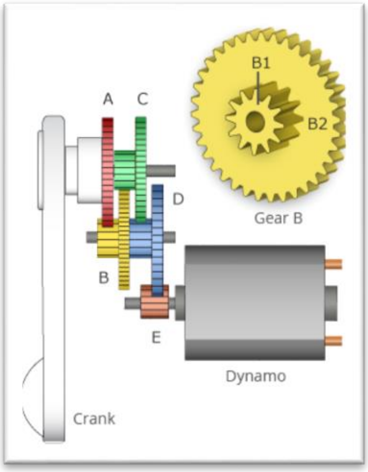
However, due to having moving parts, the concept scored poorly in Maintenance and Safety, but it simultaneously brought the Installation score up. It scored respectably on Quality and Reliability and Customer and overall the concept scored the highest overall.

We will now go on to develop the concept so that it better fits the criteria, such as Maintenance where it did not score as highly as some of the other ideas.

Development

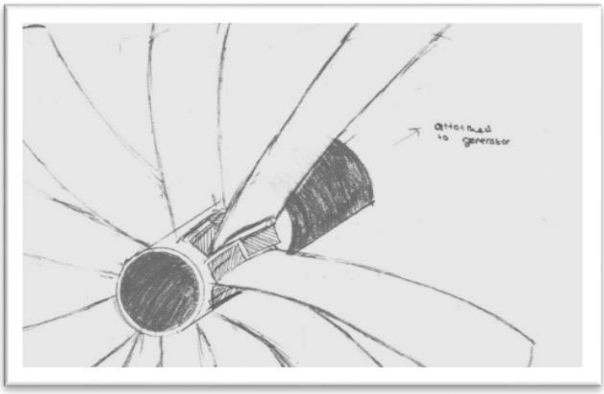


After reviewing the original design and doing further research, we have made numerous developments to the concept. From our research into the specifics of the environment (PDS 2), we realised that the size of the river was over estimated in the original design. The actual size of the stream close to the village is approximately 20cm deep and 50cm wide.(……….) . The system will now sit on the bank of the stream, the generator will no longer be floating on the water, now it will be placed in a small hole so that the turbines sit halfway into the stream. From our research we now know that the depth of the stream is about 20cm, so we have adjusted the size of the propellers to have a wingspan of 30cm. The holes will be dug so that the propellers will dip 13cm into the water, this ensures that the moment created on the axel is always in the direction we want it to spin. For this to happen on both sides of the stream, the turbines will be made in 2 orientations, one for clockwise spinning and the other for anti-clockwise spinning. In places where the depth of the river is less than 20cm, we can adjust how far the system is buried into the ground so that the propellers don't hit the river bed. This allows us to implement the systems in a more flexible manner at no extra cost. We have also added a mesh grid (similar to those on household fans) to prevent wildlife becoming caught it the turbine – this will both protect plants and animals as well as reduce the amount of maintenance needed. This also acts as a safety measure, because it would be dangerous for people using the river as they could get caught or hit by the propellers. By placing the system on the stream it reduces the materials (PDS 14) needed thereby reducing costs (PDS 5). Since the generators are no longer in the middle of the river, maintenance (PDS 4) and installation (PDS 30) of the system are vastly simplified. This also eliminates the need for floats which we initially had trouble with how we would install. Due to the reduced size of the structure, the safety (PDS 24) aspect of the system has been greatly improved.

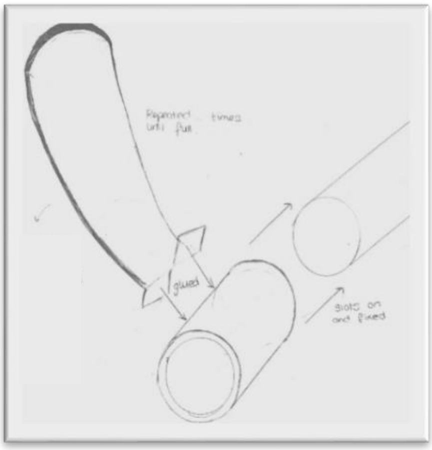


To improve the performance of the system, we have included a gear box which helps generate more power. This is based on the design of a conventional wind turbine as shown by the diagram. The crank in the following picture represents the turbine. We have decided to use a 1 to 3 ratio to generate more power but still considering the speed of water in the stream. (http://cdn.bigshotcamera.com/images/learn/Section01_Figure03_gearbox.png

Turbines

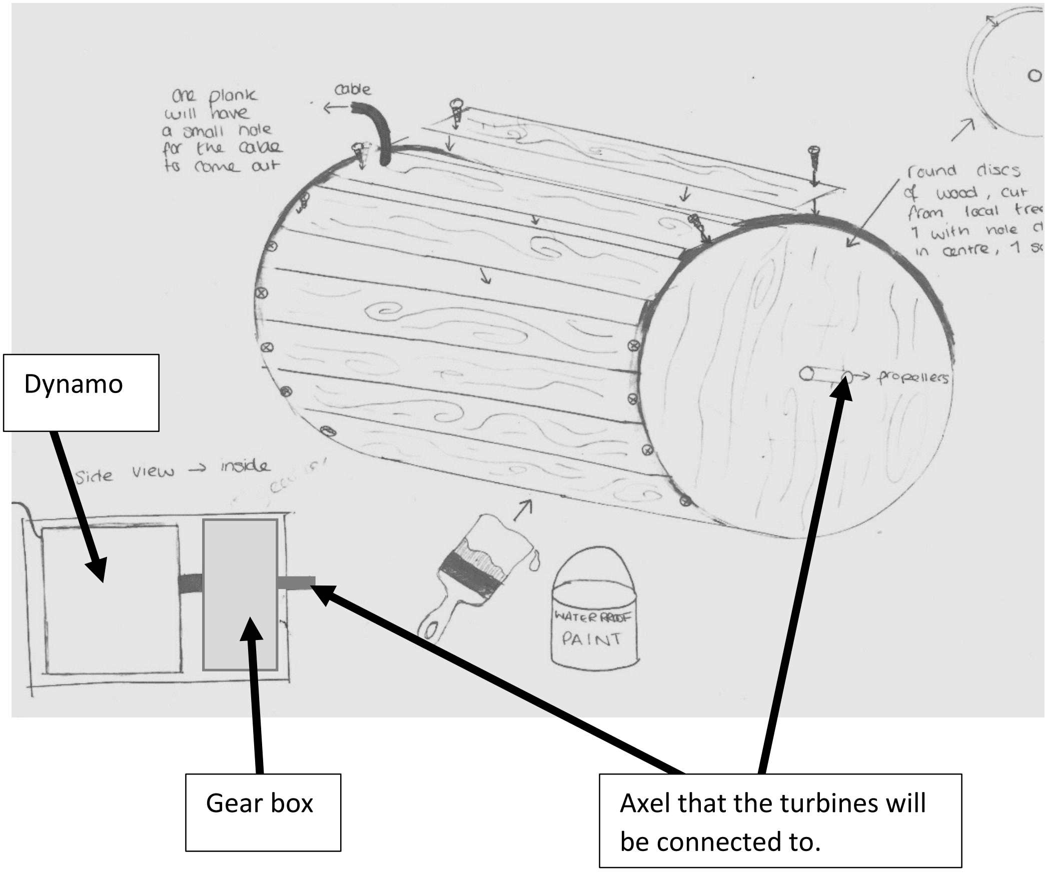


We also developed the shape of the turbines, they will have a cupped concave design to make them more effective at spinning in the water. Turbines will be made by attaching stiff plastic blades with a strong adhesive on to a plastic cylinder which is attached to the axel of the gear box using adhesives. The plastic for the cylinder and the turbines will be sourced locally from Nepal reducing delivery costs. The blades will be made with lips, perpendicular to the blade and one in each direction (as seen in the drawings) so that they can be glued stably to the cylinder, doing it this way also allows the blades to be easily slotted together on the cylinder. The dimensions or each blade will be: 15cm long, 4cm wide at the base, 8cm wide at the tip, with a curved concave shape (this is not including the glue tabs).



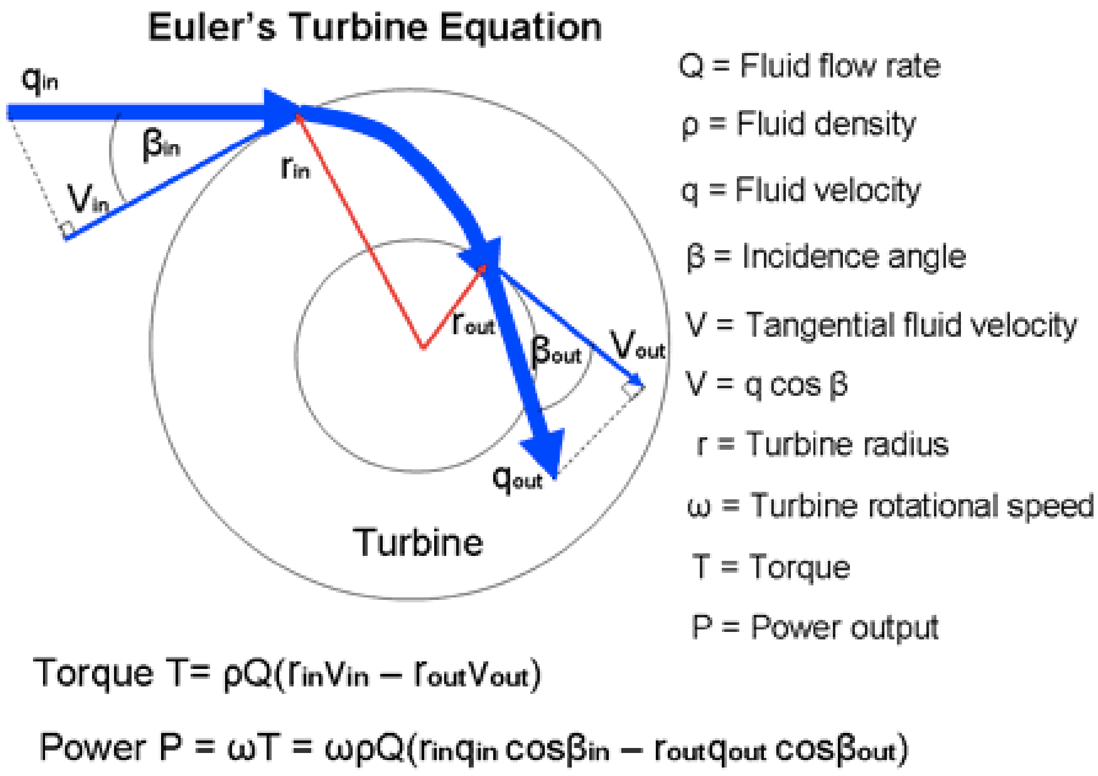
The Generator

As mentioned previously we will be using a gear box and connecting it to a dynamo which will create electricity that will be passed by a short cable to a rechargeable battery which will be placed close by. The dynamo and gear box will be enclosed in a water proof case because it is so close to the river and could be potentially dangerous to have electricity close to water. We will construct the casing from locally source wood that will be cut and screwed together. Two round discs for each end will have to be cut, and on will have to have a hole drilled in the centre with an appropriate size hole for the axel to the gear box. The two discs will then be connected by wooden planks, they will be attached with screws to the discs (as shown in the diagram below). Using screws means that if there is an issue inside the casing, it won't be too difficult to take off some of the panels to get inside and fix. One plank will have a small hole the same size as the cabling to allow the cable out to connect to the battery. It will be placed at the back – farthest from the turbines – so that it is as far as possible from the water. The entire casing will then be coated in several layers of waterproof paint, similar to that used on boats, to protect it from the water. The axel will sit above the surface of the water so this will minimise water getting in through the front hole but we will also use a small plastic stopper on the axel on either side of the casing to stop water getting in. The casing will be 50cm long and 20 cm in diameter, the ends on the casing will need to be cut at least 5cm thick to ensure that the screws we use will not split the wood and will screw in securely. The planks connecting the two ends will be 6.2cm wide, 50cm long and 3 cm thick. The axel of the gear box will be 2cm in diameter so we will drill the hole to be 2.1cm in the centre on the disc.



Energy Calculations

Theoretical power generated from the water turbines can be calculated using Euler's Turbine Equation.



http://www.mpoweruk.com/hydro_power.htm 1

The estimated flow rate of the local stream, Q, is 0.42 cubic metres per second, and the incidence angle, β, is roughly 26.6 degrees. We also see that the cross sectional area of the stream is $0.13m^2$, giving a fluid velocity, q, of 3.23m/s. (http://www.ewbchallenge.org/nepal-water-health-newah/forum/water-flow-rate). The water quality in these streams is very unpolluted, and so the fluid density can be assumed as being 1000g/l. From the fluid velocity, we find that the turbine rotational speed is roughly 3.427 revolutions per second. Using a 1:3 gearbox, our speed will almost 11 revolutions per second. Substituting these into the given equations, we find that the theoretical power produced by one generator would be 1.38W.

Hydropower is also one of the most efficient methods of generating energy, capable of converting almost 90% of energy (www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/eng4431). Assuming an efficiency of 70% for our system, the power generated would be roughly 1W. This is equal to 720Wh per month.

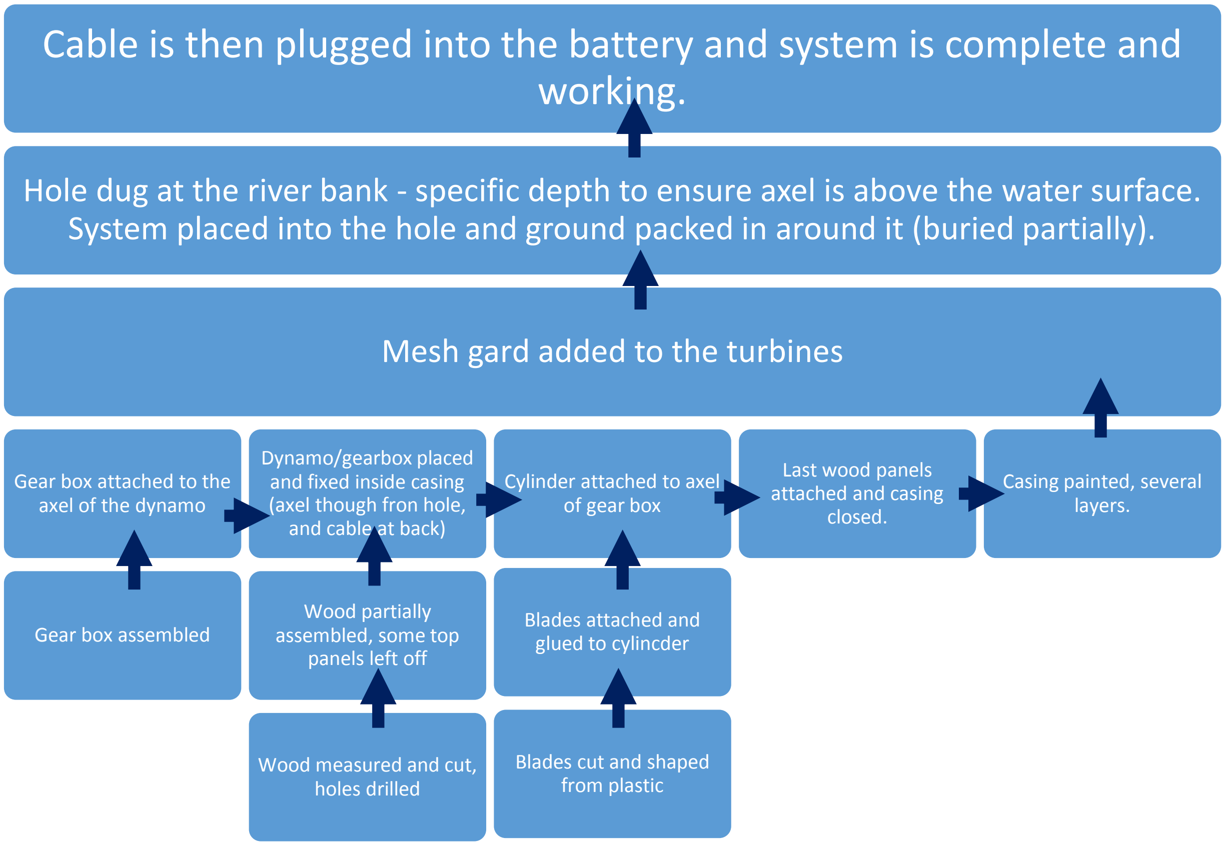
Assuming there are 60 households, each of which on average powers a 60W light bulb for 4 hours a day, 14.4kWh would be required to power the 60 light bulbs for a day thus 432kWh for a month. If the whole village were to be powered completely by these stream generators, 14,440 of them would be required. The stream is not large enough to hold this many generators, however, there are two larger rivers that are slightly further away, the Dhuseni and the Judhi, where the power in potential generators could reach up to 7 and 10W respectively which can be used to further supplement the energy generation. These figures are equal to 5.04 and 7.2kWh per month, meaning we would only need 60 of the systems to be implemented in these rivers. (data from http://www.ewbchallenge.org/nepal-water-health-newah/forum/water-flow-rate

When considering all other electrical components required by the village, we expect the total energy consumption to be around 700kWh per month. If we assume that three quarters of this demand is met by the existing energy generation infrastructure – the mains supply - we only need to meet 175kWh with our hydropower generators. This would be enough to supply the villagers with electricity when the mains power has cut out to run lights or charge phones, creating a continuous source which was our original goal.

This demand would be met by putting 243 generators in the stream near the village or 15 generators in Judhi and 14 in Dhuseni. However, having generators in these distant rivers may necessitate the need for infrastructure such as overhead lines. Considering the price of overhead lines is about $10 per foot (https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0CCAQFjAB&url=http%3A%2F%2Fen.wikipedia.org%2Fwiki%2FUndergrounding&ei=zVYIVfXNA8rgaoq7gPAI&usg=AFQjCNGWj3FopBL2eSMenh-6M99kq2ESfw&sig2=Ys7awi5_HQ0YWv7KdvrsEA&bvm=bv.88198703,d.d2s). This is where we have to take into consideration the cost of each system and compare it to the cost of overhead cables because it may actually be less expensive to have cabling from the larger rivers than having such a large quantity systems. As well it is not feasible to have 243 generators in the stream because it would not be able to fit this many in the stream. However we could possibly reduce the cost of the cabling by using locally sourced wood for the telegraph poles.

In future, work could be done to measure the total length of distance from each river to the village, and considerations could be taken to calculate the most efficient permutation of generators, as both quantity of generators and total cable price must be considered.

The following is a flow chart of the previously explained manufacturing and assembly process.



Cutting locally sourced hard plastic will make the turbine blades. Stencils will be provided to locals so the cutting process will be easy.

The cylinders will be locally sourced plastic cylinders. These can either be made by reforming local plastic or bought from industrial stores from urban areas of Nepal and then transported to Sandikhola via truck.

Skilled locals can easily make the 2-speed gearbox by intersecting 2 gears, which can be bought in the urban areas of Nepal and then welding them onto axels. Alternatively, if there are no skilled welders in the area, a whole gearbox could simply be purchased, but these would be very difficult to source locally. Fortunately, these gearboxes are small and cheap so they could just be transported by truck from an urban area to Sandikhola. Typically prices of these gearboxes in the UK do not exceed £17. (http://www.ebay.co.uk/itm/02076-Plastic-2-Speed-Gearbox-Sonic-HSP-Hi-Speed-Parts-/331423412090?pt=LH_DefaultDomain_3&hash=item4d2a5fef7a)

The dynamo cannot be sourced locally easily. A suitable generator such as the "SP hub dynamo PD-8 32h" (http://www.ebay.com/itm/SP-hub-dynamo-dynohub-PD-8-32h-The-most-efficient-and-lightest-/281576819544?pt=LH_DefaultDomain_0&hash=item418f494b58) and would cost around £90. These are very small and compact generators and so they can be easily transported to Nepal by plane and then transported from the airport to Sandikhola by mini-truck, which costs £50 for one trip. One trip should be sufficient.

The generator and gearbox will then be covered by a wooden casing, which can simply be constructed from local wood. This wood would then have to be coated in a layer waterproofing paint, which would have to be bought from a more urban area. The price of this paint is not expensive, costing about £5 per unit. The generator will then be charging a 9800mAh, 12V battery, which costs £20. This gives a price of £132 per unit excluding transport. Assuming 35 units are required, the total price including transport will be £4670.

Item	Quantity	Cost (Rupee)	Total Cost	Transportation	Transport Cost	Construction	Labour: price x people x days	Final cost
Dynamo	35	13,134	459,690	Plane /Small truck	109,453	--		569,143
Gear box	35	2,480	86,832	Small truck *	//	Unskilled	400x10x5	106,832
Wood	11.3155 m^3	--	--	Sourced locally	--	Unskilled and skilled	400 x6x4 600x4x4	19,200
Paint	20l	729	2,918	Small truck*	//	Unskilled	400x10x2	10,918
Screws	700	145 for 40	2,626	Small truck *	//	Unskilled	400x10x2	10,626
Glue	35 bottles	504	17,512	Small truck *	//	Unskilled	400x10x5	37,512
Plastic	10m^2	7,296 for 3.7 m^2	21,890	Small truck *	*(should all fit in 2 small trucks)	Skilled	600x5x3	30,890
Chicken wire mesh	10m^2	197.75	1977.50	Small truck*	7000x2	Unskilled	400x10x5	21,977.50
Battery	35	2918	102,130	Small truck*		--	--	102130

Tools								
Paint brush	10	201.14	2011.40	Small truck*	//			2011.40
Shovel	10	394.37	3943.70	Small truck*	//			3943.70
Tape measure	1	110.74	110.74	Small truck*	//			110.74
Hack saw	10	22.6	226	Small truck*	//			226

Total cost of our project would come to approximately 920,000 Rupee (£6100).

Prices sourced from, http://www.rapidonline.com/mechanical-fastenings-fixings/forgefix-csk124ebb-gen-purpose-pz-screw-csk-tt-elec-brass-1-2x4-blister-40-84-7538, http://www.rapidonline.com/mechanical-fastenings-fixings/magmabond-superglue-medium-viscosity-yellow-cap-20g-87-8002 , http://www.ebay.com/itm/SP-hub-dynamo-dynohub-PD-8-32h-The-most-efficient-and-lightest-/281576819544?pt=LH_DefaultDomain_0&hash=item418f494b58 , http://www.plasticstockist.com/PVC-Sheet/White-Gloss-Pvc-Cladding-Sheet.aspx, http://www.ewbchallenge.org/challenge/37/node/234 .

Feasibility

We believe that the concept can realistically be achieved due to several factors.

The concept is based on a very simplistic design with no extremely high tech machinery that could cause problems in either installation or maintenance. This means that the materials can also be easily sourced.

This inherently brings the cost down too, so capital to fund the project can be easily secured.

The transport methods are also very realistic as the mini trucks that were detailed earlier are provided by EWB themselves.

Future challenges and solutions

Currently there are a few factors that we have not yet considered that could be tackled in future.

Firstly, the streams tend to dry up during summer time. To solve this, canals may be built or rivers may be propagated to boost the flow of water during summer time. However, we have also not yet worked out the distance from the larger rivers to the village or stream so if changing the batteries near the river generators is difficult, telegraph poles may need to be implemented.

The Sandikhola area is also prone earthquakes, landslides and floods. Currently, the waterproofing casing will only protect the generators and gearboxes from floods, which may actually improve the generator's performance. In future, more robust metal casing can be used to further protect the system to earthquakes and landslides.

Another challenge may also be village expansions in terms of size or energy consumption due to more electrical devices. Either of these circumstances would increase the total energy consumption and so the amount of energy provided would also have to increase. We may solve this by increasing the number of generators. We could achieve this by making sure that the generators are spaced in a fashion that allows space for further expansion.

Another solution to this problem would be to increase the rate of water flow by propagating the rivers. However, this would require a lot of manual labour and may damage the environment so careful research would have to be done in order to prevent major ecological damage.

Lastly, all of the different parts of the system are bound to fail at some point, so scheduled maintenance tests should take place and regular orders for new parts should be made in order to ensure that any interruption to power generation can be minimised.

If more time was provided, the average lifespan of all the components could be calculated and so proper maintenance schedules could be planned. A “subscription” to reorder parts could also be set up with the manufacturer.

Any environmental and ecological impact to the surroundings would also have been considered as if any species of fish or animal was impacted by the system, a domino effect might occur, wreaking havoc on the local eco system.

Legal legislations have also not yet been reviewed. This is quite important as if any part of the system is not legal to implement, the whole project could grind to a halt. Thus lawyers must be hired to review our plans.