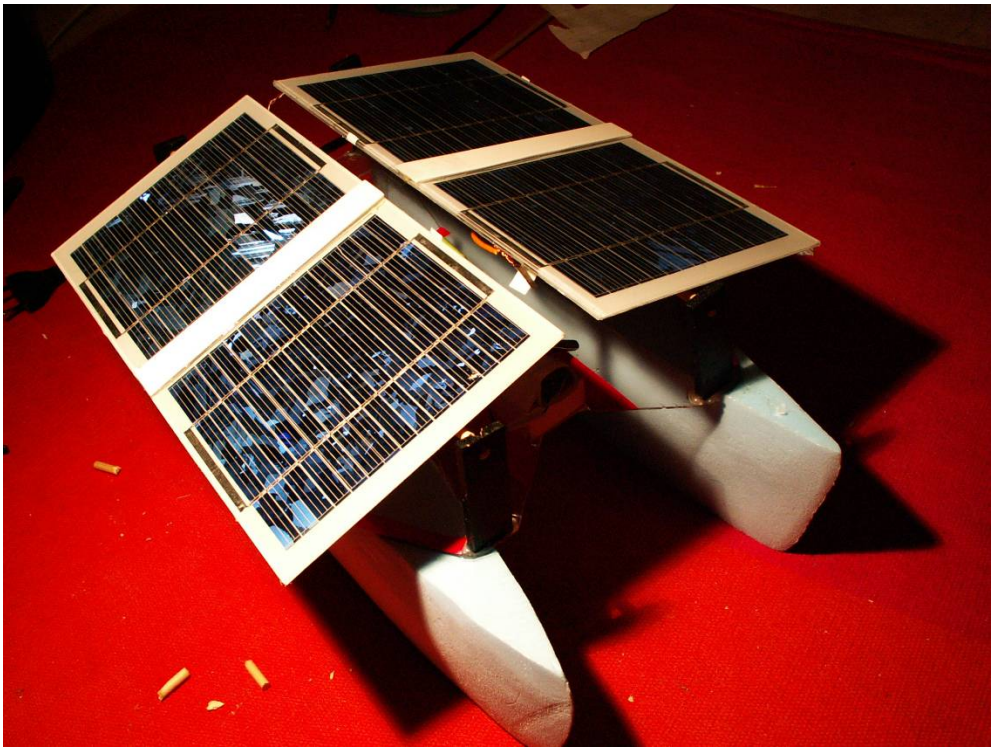
# Designing and Building a Solar Powered Model Boat



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## 1. Introduction

Using solar energy to your own advantage is a very old concept and goes back millions of years. All life on earth depends on the sun in some way. Using sun energy to create electricity is also not such a new concept. Research on it began as early as 1839 when Alexandre Edmond Becquerel observed a photoelectric effect when an electrode in a solution of conductive liquid became charged when in sunlight[1]. In this project I am going to explore the possibility of making a boat that is powered solely from the sun. I will then design and make a working model. It is generally thought that solar power is limited to sunny locations. However, contrary to what most people think, solar panels still can get energy if the sky is overcast but they do not absorb as much energy. Therefore, designing a solar powered boat for the use in The Netherlands is not that farfetched. Currently, there is huge amount of research going into solar power and many new technologies are being discovered. Over the past few years new flexible and light solar panels[2] have being invented and because of those it will be much easier to make a solar powered boat.

I have absolutely no previous knowledge of solar power however I do know a fair bit about model boats. Therefore, I am hoping to build on my knowledge of model boats and learn more about using solar energy. Furthermore, by presenting my work I am also hoping to raise awareness in the school about possible alternative energies and the great potential that solar energy has.

### *1.1 Research questions*

The overall goal or intended outcome of this project is to make a model solar boat which gets its power from solar panels. Nevertheless, it will still have a battery as a backup in case the boat goes into shadow or if it needed to sail during the night.

[1] Timeline of solar cells. http://en.wikipedia.org/wiki/Timeline_of_solar_cells, 3 October 2007.

[2] These panels are manufactured by Powerfilm Solar, an American based company that specializes in flexible solar panels. http://www.powerfilmsolar.com/

The following questions guided my thinking during the initial stages of the project:

1. What are the advantages of solar powered boats?
2. How fast and reliable are solar powered boats?
3. What issues need to be considered when designing, making and testing a solar powered boat?
4. Is it possible to run a solar powered boat in The Netherlands, given the relative lack of sunshine here?

These questions led to the following project objectives:

1. To research solar energy:
    a. How do solar panels work?
    b. How have solar panels been used in boats by others?
2. To design and build a working model solar powered boat.
3. To design and build an attractive boat.
4. To test the model solar powered boat at every stage of its construction:
    a. Does it float?
    b. Does it run?
    c. Can it run on sun alone?
5. To make recommendations for the design and construction of solar powered model boats.

### *1.2 Previous solar powered boat projects and initiatives*

After a bit of research I discovered that I was certainly not the first to have the idea of a solar powered boat. This was not surprising as there have been solar powered cars for quite some time.

In fact, in countries like Australia and the USA, many schools are incorporating into their curriculum making a model solar boat to help raise awareness about alternative energy sources. However the building of solar powered boat has only being done in a professional way with the introduction of the Frisian Solar Challenge[3] in the Netherlands which took place for the first time in 2006 and attracted participants from all over the world. The next of these races will be held in 2008. Another event, which took place in 2007, was the first crossing of the Atlantic on a solar powered boat. The boat was Sun21[4] and had a crew of six. It took them almost 6 months to do it having an average speed of 9km/h . As they were also charging the batteries, it could drive during the night . Again in 2007, a solar speed boat which was based on the boat which won the Frisian Solar Challenge was made by Czeer Solar and funded by the province Friesland, Senter Novem and Rabobank. It could achieve 55 km/h - an amazing speed. All of these initiatives were life-sized boats. I was focusing on model boats.

### *1.3 How this project relates to the Areas of Interaction*

This project addresses four of the five Areas of Interaction that are the base of the teaching and learning in the Middles Years Program. First is *'human ingenuity', man the maker*. I will be designing and making something relatively new and innovative. It also has many advantages. The one great advantage of a solar powered boat over other sources of energy is that its fuel is unlimited, its free and clean. Once you have invested in the panels, you have no more fuel costs. Solar panels typically last twenty years.

As the boat is solar powered, the energy comes straight from the sun and not from fossil fuels or from a battery which has being charged from electricity acquired from a coal power plant. This links the project to another area of interaction, '*environment'*. In the discussion of solar power versus other sources of energy typically used for boats, solar power does not damage the environment something which has been on the top of governments agendas over the past decade. Through using solar energy instead of fossil fuels you are minimizing the amount of harmful gases released into the atmosphere which relates this project to '*health and social education'*.

[3] Frisian Solar Challenge. http://www.frisiansolarchallenge.com/eng/page.php?nodeId=97, 2nd November.

[4] Turner, Michael. The "Sun21" http://www.transatlantic21.org/boat/ , 23 October 2007.

Such harmful gases are destroying the ozone layer which are a potential hazard to human health as well as contributing to global warming[5]. By making a solar powered boat you are also bringing people's attention to the amount of damage that is being cause by using fossil fuels and the advantages of solar power,

Through the process of researching and building the solar powered boat I will be considerably adding to my knowledge and my overall learning skills. Therefore this project also is linked to the Area of Interaction 'Approaches to learning'.

## 2. Background Research

### *2.1 How do solar panels work?*

The conventional solar panel consists of six layers: 1. the cover glass which protects the rest of the components from damage, 2. anti-reflect coat, this helps the panel absorb as much light as possible, 3. contact grid, this is what holds the modules together. 4. negative and 5. positive silicon is what transforms the light energy into electrical energy and then finally 6. the back contact which is simply the back support of the entire cell.

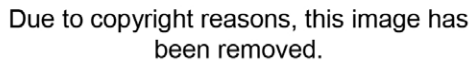
A solar cell with a setup like the one on the right will have an efficiency of ~15% which is not bad as even the really expensive ones NASA uses have an efficiency of ~25%. However, continuously companies and universities are trying to develop more efficient solar panels. The current world record for the most efficient solar panel was

| |
|---|
| 1. Cover glass |
| 2. Anti-Reflect coat |
| 3. Contact grid |
| 4. N-type Silicon |
| 5. P-type Silicon |
| 6. Back Contact |

[5] Global Warming. http://www.ucsusa.org/global_warming/science/global-warming-faq.html, 18th October 2007.

made on 30th July 2007 when an efficiency of 42.8% was achieved at the University of Delaware, United States of America[6].

*Photovoltaic cells*, also known as *modules* (these are other terms for solar panels), are simply a group of cells electrically connected and packaged in one frame.




They are made from semi-conductors such as silicon, which is the most commonly used element for solar modules. When the sun shines on silicon it absorbs some of the energy. The positive isotope of the Silicon (P-type Si) has lots of free 'holes' in it and will attract lots of negative electrons to fill it up. The negative isotope of silicon (N-type Si) has far too many electrons for its 'holes'. When the sun shines on it and emits enough energy, electrons will be knocked out of place. Consequently, many of the electrons from the N-type Si flow to the P-type Si. This is what makes the current. If metal contacts are placed at the top and the bottom of the module you can draw the electrical current off the module and use it for your own purposes, in my case powering a model boat.

### *2.2 Issues to consider when designing and building a solar powered boat*

#### *2.2.1 How and where will I find the information and materials?*

A large part of the research I will be conducting will be done on the internet, it will be my primary source. However I am also getting information and advice from other sources such as magazines, the staff in the Leiden model shop, books or another source was a television program

[6] Timeline of solar cells. http://en.wikipedia.org/wiki/Timeline_of_solar_cells, 3 October 2007.

about solar power. The technology teacher, Ms. H has agreed to let me use the equipment and some materials from the tech room during the construction phase. When testing the boat I will need to find somewhere outdoors with a long shallow body of water where I can test the boat unobstructed. Unfortunately during this time of year there is not much sun so I will just have to be ready and maximize the opportunity when the sun shines. I am going to film the entire testing as well as take picture.

### *2.2.2 Choosing the solar panels*

When designing a solar powered boat that will actually work there are a lot of things you need to keep in mind. Firstly and perhaps most importantly are the size and power output, and the weight of the solar panels to be used in combination with the power requirements of the motor and finally, the weight of the entire structure of the boat i.e. will it float and move?

Typically, solar panels have low current output. As the area available on the top of a model boat is very small, I will need to find a workable compromise between the size of the boat, the size of the solar panel and the ratio between current and voltage output. Costs, of course are another important consideration. Lighter weight panels and higher efficiency panels cost more.

I have found a solar panel company based in America but has sellers in Europe who sell super light weight, water proof and flexible solar panels, exactly what I need. Unfortunately they are very expensive and will be hard to get. As my funds were limited, I decided on using more efficient rigid solar panels from an English based company, *Sunshine Solar Limited*, based in Norfolk who I located via a Google search. The only problem is that they are quite heavy.

### *2.2.3 Choosing the motor*

Nowadays, common electric motors found in model shops usually require 3-50Amps and 3.6-12 Volts but a solar panel which could supply that power would be around 3metres squared, which is out of the question for a model boat. Fortunately there are low current motors available and solar panels to power them but then I will be greatly minimizing the speed of the boat. However,

I have decided that the speed of the solar boat will not be my main priority. I am more concerned with it being just able to run using solar energy. Nevertheless, it is important that the boat should be as light as possible.

### *2.2.4 Researching hull designs*

Using the internet I researched different kinds of hull designs. I discovered that the advantages of a multi hull (when there more than one hull, eg a catamaran {two hulls} or a trimaran {three hulls}) versus a mono hull boat are that they are more stable so they unlikely to capsize (flip over), faster (because with two hulls in the water there is less drag as the waterline {line where the water meets the side of the hull}is larger), lighter and the boat can sail in shallower water. The final material used for building will be very important as it has to be water proof, light, resistant and easy to work with and must have a high buoyancy (float).

## 3. The actual designing, building, testing and adaptations made to the model solar-power boat

### *3.1 Designing the boat*

I have decided to use a double hulled boat (catamaran) to reduce drag (more speed), so that the boat will be sitting higher in the water and because catamarans are far more stable than single hulled boats. This will protect the motor and other electrical components. I made a series of drawings which were based on a particular computer generated design, Pringle18[8] (see picture 12 and drawings in the Appendix), made by William D. Anderson using a program called 'Delftship'[9]. The hulls will be made of foam which I will have to carve into shape using a knife and then sand paper to get a smooth finish. To get as much area for the panels as possible on the

[8]D. Anderson, William. Design Details of Pringle 18 http://delftship.net/downloads/showdetails.php?DetailsID=217, 21st January 2007.

[9]A program that computer generates hulls of ships. http://www.delftship.net/

roof, the motor and battery will be attached under the panels. As the solar panels collect more energy when they are at a right angle to the sun, the two rows of panels on each side will be able to swivel to get a better angle. Following telephone discussions with customer service, re: technical details such as weight, output and size and how easy the solar panels were to connect, I ordered four panels[10] from Sunshine Solar Ltd.

The panels will need to be mounted on a strip of plastic and then put on hinges. The solar panels (total output = ~7.2V ~1Amp) will be elevated a few centimeters above the hull of the boat to allow the swiveling. The motor (see picture 4), a Graupner 280 speed motor[11] (3-8.4V ~700mA) will be placed near the bow of the ship so the shaft is at the right angle therefore the battery, a Rechargeable Nickel Metal Hydride Battery (6Volt 600milliAmphour)[12] will need to be placed with care to make sure the boat is balanced.

The panels (see picture 9) will, when in full sunlight be able to produce in excess of 8 Volts but this is not a problem as to charge the batteries you need to supply more than the voltage of the battery (6V). However there is a problem if the solar panels are producing less than 6V (the voltage of the battery) as the batteries will not be able to charge fully.

I decided to have swiveling panels because they would generate more electricity when pointing at the sun. This requires building a frame to hold them up and let them swing and another mechanism to make sure they don't point in the opposite directions.

Following testing, it was clear that I needed to strengthen this frame. This was done by joining the supports at each end with a wooden rod. I also attached another support creating a triangle shape (see picture 11)

### *3.2 Sequence of work*

Once I had all the materials I needed I could safely start creating the product. The following summarises the tasks (in chronological order), tools, materials used:

[10] Monocrystalline Solar Modules. http://www.sunshinesolar.co.uk/khxc/gbu0-prodshow/74V250MA.html, 12 October 2007.

[11] https://shop.graupner.de/webuerp/servlet/AI?ARTN=6328 which I bought at the RC Model shop in Leiden (http://www.rc-modelshop.nl/ )

[12] These are the batteries I used ( http://www.powerpax.co.uk/nickel-metal-hydride-batteries.htm) which I purchased at the Leiden RC Model shop

| Description of Job | Tools | Materials | Time |
|---|---|---|---|
| Cut out the (very) rough shape of the two floats and then sand and cut them until the required shape is made | Saw, Stanley knife, sand paper and ruler. | Foam chunk (20x40cm) | 180minutes |
| Cut out the acrylic deck of the boat and sand it. | Piercing saw, drill, sand paper, file, ruler | 30x40cm sheet of acrylic | 30mins |
| Cut out all the pieces you will need for the prop support and sand the parts that will be in the water a lot so that it cuts through the water like a knife. | Piecing saw, ruler, sand paper and file. | Acrylic | 30min |
| Stick the prop support onto the bottom of the deck of the boat using a hot glue gun | Glue gun | Pieces for support (acrylic) | 15min |
| Cut and then drill a hole into each of the supports for the solar panels and then glue those on the top of the deck using a glue gun. | Vibra saw, ruler, glue gun. | Sheet of ply wood 0.5x10x10 | 30min |
| Cut out the pieces of acrylic needed to attach the panels in pairs and then glue those onto the panels, sticking the panels together. At the same time stick a wooden rod onto the back of the panels so they can swivel when in place. | Stanley knife, 5min epoxy, wooden rod | Sheet of acrylic, the four solar panels | 40min |
| Cut the shaft for the propeller to length and then cut out a piece of wood for the motor support, glue both of these in place. Slide out the inner part of the shaft and glue the propeller onto the end of it. | Piercing saw and vibra saw, ruler, 5min epoxy | Prop shaft, prop, wood | 60min |
| Using a rubber tube attach the motor to the shaft. Then link up all the wires and it will be ready to run. | | Shaft, rubber tube, linking wires. | 15min |

| | | | |
|---|---|---|---|
| Saw two lengths (15cm) of a wooden rod and then four small lengths (6cm). Attach the longer rods between two panel supports and glue them in place. Then with the four smaller rods lay them against each support making an isosceles triangle, glue these in place | Piercing saw, 5min epoxy glue | 50cm wooden rod (diameter = 0.5cm) | 30min |

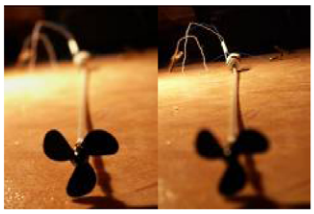
### *3.3 Series of pictures which illustrate the building stages*

The following pictures illustrate the construction process:

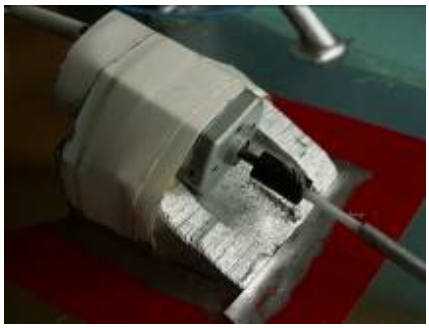
1. These are the first hulls I made and were far too small for the solar panels and the deck.

2. Finishing off the deck, almost ready to attach the propeller

3. Testing the motor with the propeller which was temporarily attached.



4. Attaching the motor to the deck and connecting it to the shaft which links to the propeller (still to attach)



5. Attaching the propeller to the other end of the shaft.

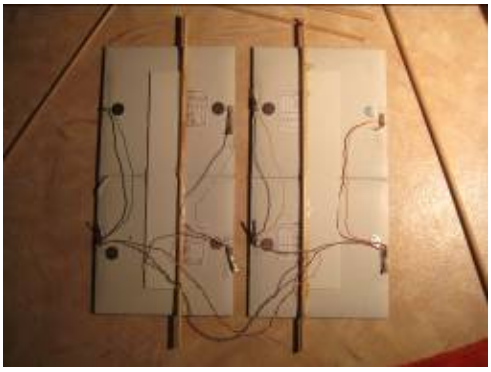
6. Attaching the structure of the boat to the hulls

7. The solar panels arrive by post from England

8. Testing the solar panels functionality with a desk lamp and a multimeter

9. Attaching the panels in pairs strips of plastic and very strong glue.

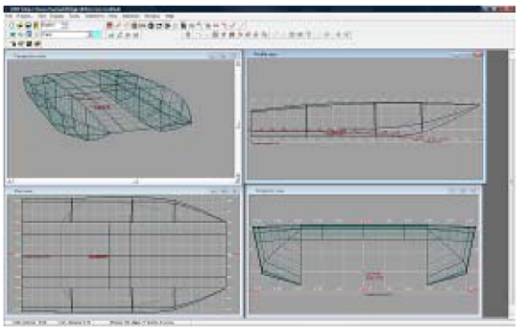
10. Hooking the solar panels up and attaching the axel onto the back.



11. The new reinforced panel support

12. Attached the panels onto the boat, ready to test run!

13. First hull design based on DELFTship program



14. The second hull design was adapted from a hull similar to those of a large yacht.

Due to copyright reasons, this image has been removed.

### *3.4 Testing and further adaptations made to the boat*

There were about five stages of testing during this project. At first there was the testing of simple solar panels and seeing how well they worked, as this was crucial to how well the motor would run. Secondly, was the testing of the hulls as without the right buoyancy (floating power) the boat would either sink or simply float too high in the water which would make it unstable. The third stage of the testing was ensuring the motor was in line with the shaft and that they ran with the least amount of friction as possible. The fourth stage was to test the final made boat in the

water and see how well it ran. I could then see how using the solar panels directly change the performance to using the battery that is being charged by the solar panels.

During the testing of the solar panels I discovered that they in fact supplied more power than I had previously thought. However another aspect that I noticed was that the panels were quite heavy and this would be a problem as then the hulls will need to be bigger and there will be more drag – motor under more strain and the boat will go slower.

When testing the first hulls in the water I quickly realized they gave far too little upwards thrust to support the weight of the boat. The second hulls made were quite different design which I adapted from a yacht design I found on the internet (see picture 14[13]). They were more like a sailing boats hulls than a speed boat. The reason I did this was because I knew the boat wouldn't be going fast enough to plane (when the front of the boat is partially out of the water and just the back of it with the propeller remain in the water) and a sail boats hulls cut through the water a lot better at lower speeds – producing less drag.

After testing the boat in the water with the solar panels I realized I would need to strengthen the solar panel supports. After a bit of planning, I decided on a way to do that using wooden rods to attach the supports to each other and to give the supports another 'support' to the boat's deck. This made the entire boat more sturdier and the boat now no longer bends in the middle, something it used to do under the weight of the solar panels.

## 4. Analysis and evaluation

### *4.1 Choice of panels*

While I was overall happy with the company I purchased the panels from, however I was not happy with my choice of panel. The panels I used weighed almost 200grams each and there are panels which only weight 10grams (Powerfilm[14]). Though their output is less and they are triple

[13] Hartman, Gail. Catamarans. http://www.visailing.com/catamarans.html, 27th July 2007.

[14] Author Unknown. OEM components. http://www.powerfilmsolar.com/products/oem_components/index.htm, 2007.

the price. Although their output is less they weigh 20 times less so as long as the rest of the boat is light weight the boat will be capable of higher speeds. The reason I didn't use the lightweight panels was because of the price, if however I have an unlimited fund I would have used the lightweight panels.

### *4.2 Choice of motor*

I am very happy with the motor (see picture 4) I chose as it seems to be the perfect motor for the job as it runs very well with the output the solar panels give which was a surprise as it was the only option in the model shop. (all the other motors had a too high power requirement). Another good thing about the motor is that it was light weight (30g) as a heavy motor would have slowed the boat down a lot.

### *4.3 The design of the hull*

I realized at the initial testing of the hulls in water that the solar panels were far too heavy for the hull I had built so I then made new hulls using a design closer to that of a sailing boat catamaran. So now instead of gliding over the water the boat slices through it. These hulls were also much larger and gave far more lift. Overall I am happy with the change in design, although it took a few study periods to fix the problem. However this was important learning and if I were ever to make another solar boat I would use that design of hull.

### *4.4 Evaluating the boat's performance*

After testing the boat is in the canal for the first time and seeing it run was a great relief until it crashed into the side of the canal and one of the panels almost slide out of place. That is when I decided to make the entire deck and supports sturdier. Once that was done the boat looks better

and I am pleased with how that turned out. During the building of the boat I was extremely worried that the panels would produce far too little power and that the motor wouldn't have enough current to turn at all. However once the panels arrived and I tested them those doubts disappeared. The solar panels produced much more power needed to keep the motor going. I spent quite a bit of time planning on how to attach two solar panels together as it would inevitably change the design of the boat.

### *4.5 Evaluating the boat's appearance*

An untidy aspect of the boat was that basically all the wires were visible as was the fact that some of the glue was also clearly visible. Overall although I invested a lot of time in sanding and painting the boat it still had a somewhat unfinished appearance. One possible solution to that problem could have been to construct a structure that would cover the motor as well as the wires. This could have been a cabin. Initially it was my plan to construct a cabin however, due to the lack of space on the finished boat it would have been very difficult. However in the last days I added red tape to the edges of the deck, and secured the wires. This has improved the appearance.

## 5. Conclusions, recommendations and learning

### *5.1 Conclusions*

My overall goal in this project was to research, design, build and test a model solar powered boat. I achieved all of these objectives. I discovered that solar panels work by using a semi conductive material like silicon to absorb the energy from the sun and then two metal contacts built into the panel make an electrical circuit to use the power from the solar panel.

After considerable research I discovered that I was certainly not the first to make a model solar boat. However, although there were guides to making a model solar power boats I did not use any of those guides, as I wanted to make an original boat entirely from my own creation.

Through the course of the project the design was continuously changing and being modified to improve it and to accommodate the solar panels and motor I had decided to use.

If I had used the first set of hulls I made, the boat would probably have sunk. The second hulls I made kept the boat high in the water and were definitely a big improvement. The boat remained afloat during all testing. The motor worked, turned the shaft which in turn turned the propeller which propelled the boat forwards at roughly 1 metre per second (~3.6km/h).

I have tested the boat running directly from the solar panels and it went even faster although when the boat sailed into shade it slowed down. The reason the boat went faster when in sunlight was because the solar panels can produce more voltage (over 8Volts), meaning more power when in sunlight than the battery which has a maximum voltage of 6.

Finally, although the solar panels look 'cool' and give the boat a nice look, the rest of the boat is not really 'appealing' to look at. So in that sense I did not fully achieve my goal which was to design an attractive model boat. However after plenty of testing I can definitely conclude that the solar boat works.

The content and the process of this project have integrated four Areas of Interaction. It primarily involved design, construction and alternative energy sources (Human Ingenuity). It also offers the possibility of running a model boat which is 'clean', which does not pollute and therefore you could say Health and Social education are also addressed although to a lesser extent

A very important part of this project was learning about how I approach learning (Approaches to Learning). During this project I learned a lot of things, not only about solar energy and information related to boat design but also I learned more about myself. The technical things I learnt through this project are: how solar panels work and how to connect them to each other; about charging batteries and Amp hours; about different types of hulls, their characteristics and effects; about electric motors and different kinds of propeller shafts. This technical learning came quite easily to me.

Another positive thing I learnt about myself was that when I came up with problems or obstacles I was able to find solutions. However, other personal learning was the fact that I always seem to underestimate the amount of time required for tasks. I definitely enjoyed the actual designing and

building more than writing about the process although I found it easy to write the recommendations. Overall though the writing was a real challenge. Nevertheless I am convinced that designing, building, and engineering would be an interesting area for me to study further.

### *5.2 Recommendations*

As a result of the experience and learning gained in this project I can make a number of recommendations regarding building a model solar powered boat. Some of these may apply to a full size solar boat.

1. The hull plays a large role in the speed and efficiency of the boat. Be very careful when choosing or making a design. You want the hull which will create the least drag at low speeds (two long and thin hulls are probably the best).

2. Choose your solar panels carefully. The boat will be designed to fit their output and size. Weight is extremely important. DON'T get heavy panels as it will hugely decrease your boat's efficiency and speed.

3. You can attach your solar panels in series (to increase voltage) or in parallel (to increase current). Having the solar panels perpendicular to the sun is when the panels absorb most energy, having panels that can swivel to point at the sun is also very useful.

4. Your motor will depend on your solar panel's output (voltages and current). Try to get a motor that operates well below the given output of the panels but also operates at the solar panels maximum output without being damaged (over voltage damages electrical motors). After the panels your motor will be the next heaviest object on the boat. Try to get a light motor. Be careful when attaching the motor to the shaft and propeller. They should be all perfectly in line. Otherwise a lot of energy will be lost in friction. The

propeller size should be in proportion to the motor. Don't get a big propeller as they increase the current drain (require more power).

5. The batteries' voltage should be a 1 to 3 volts below that of the max voltage of the solar panels. The capacity of the battery is up to you. However, you have to keep in mind the larger the capacity the heavier and slower your boat is going to be which means it will not necessarily run longer on battery power.

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# Appendix