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USING ACCUMULATORS IN NORTHERN SOLAR POWER PLANTS

Degree Programme in Environmental Engineering

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Satakunnan ammattikorkeakoulu
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AKKUJEN KÄYTTÖ POHJOISISSA AURINKOVOIMALOISSA

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Tämä lopputyö on tutkimus akkujen käytöstä pohjoisissa aurinkovoimaloissa. Tutkimuksen tilasi ENE Solar Systems Oy. Tämä lopputyö sisältää myös soveltuvuustutkimuksen akkujen käytöstä Suomen alueella. Erilaisia akkuteknologioita pohdittiin, jotta optimaalinen ratkaisu löytyisi ENE Solar Systems Oy:n suunnittelemaan aurinkovoimalaan. Litiumioniakkuja käytettiin soveltuvuuden laskennassa.

Maailma tarvitsee uusiutuvia energialähteitä ilmaston lämpenemisen hillitsemiseksi. Uusiutuvien energialähteiden ominaisuuksia on kumminkin epäsäännöllinen tuotto, jolloin energian varastointiratkaisuja täytyy tutkia lisää.

Tutkimus osoitti, että lopulta ei ole järkevää käyttää litiumioniakkuja. Järjestelmän hinta on liian korkea ja sähkön hinta on liian matala, huomioon ottaen sähkön tuntihinnan vaihtelun. Näyttää siltä, että ei edes sähkön hinnan tuplaaminen tekisi akuista kannattavia. Tutkimus tehtiin pääosin Microsoft Excelillä.

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Keywords: Lithium-ion, Battery, Accumulator, Solar power

This is a research of using accumulators in northern solar power plants. This final thesis was done for ENE Solar Systems Oy. This thesis also includes a feasibility study to use accumulators in Finland area. Different accumulator technologies were considered in order to find out optimal solution for solar power plant designed by ENE Solar systems Oy. A lithium-ion battery was used in the calculation for feasibility.

The world needs renewable energy sources to control global warming. One feature of renewable energy is intermittent production so it creates a need to study energy storage systems.

It became clear that in the end it is not feasible to use lithium-ion batteries. The price of the system is too high and the price of the electricity is too low even with hourly price fluctuations taken into consideration. It seemed that not even doubling the price of electricity would make it feasible. The study was conducted mostly with Microsoft Excel.

CONTENTS

1 INTRODUCTION

ENE solar systems Oy has a solar power plant design which is being sold around Finland. Customers for the company are municipalities and energy company groups. ENE solar systems has ordered this thesis. Research is about using accumulators or later called just batteries in their power plant.

In Finland it is studied that it is feasible to produce energy in large scale with PV technology. Sun is shining efficiently through summer months. With batteries we could even out the output power fluctuations caused by the night. Most of the electricity is consumed during the noon when most of the people get home from work. Also every hour is priced individually and it is studied if it can make a difference in profitability. Just by extending power output to these demanding hours with carbon neutral energy solution would be a huge improvement to a better future by releasing less greenhouse gases to the atmosphere.

Battery technology has made a lot of progress with new systems like Tesla Power wall, it’s a scalable energy storage system that can be stretched from kWh systems up to GWh systems. (Website of Teslamotors, 2015)

1.1 Goal of the study, purpose and research problem

The goal of the study was to find out if it is feasible to use lithium-ion batteries to get extra profit from solar power plant in Finland. World is in a transferring phase to move towards more green energy sources and away from fossil fuels. Cutting CO2 and other greenhouse gas emissions is more important than ever since the effects of global warming are exponential. This is putting strain over Finland to also jump in to the renewable energy business and to start plan ways to utilize solar energy and other sources as well. One problem is that sun doesn't shine in Finland particularly lot besides summer and energy storage has been always one of the biggest problems renewable energy has encountered. Production rate of solar energy is unstable so energy storage is highly wanted. Problem is that storage systems are not very efficient so far. Lithium-ion batteries are considered here to be the solution for short term energy storage and their feasibility is studied. Real data is used where possible.

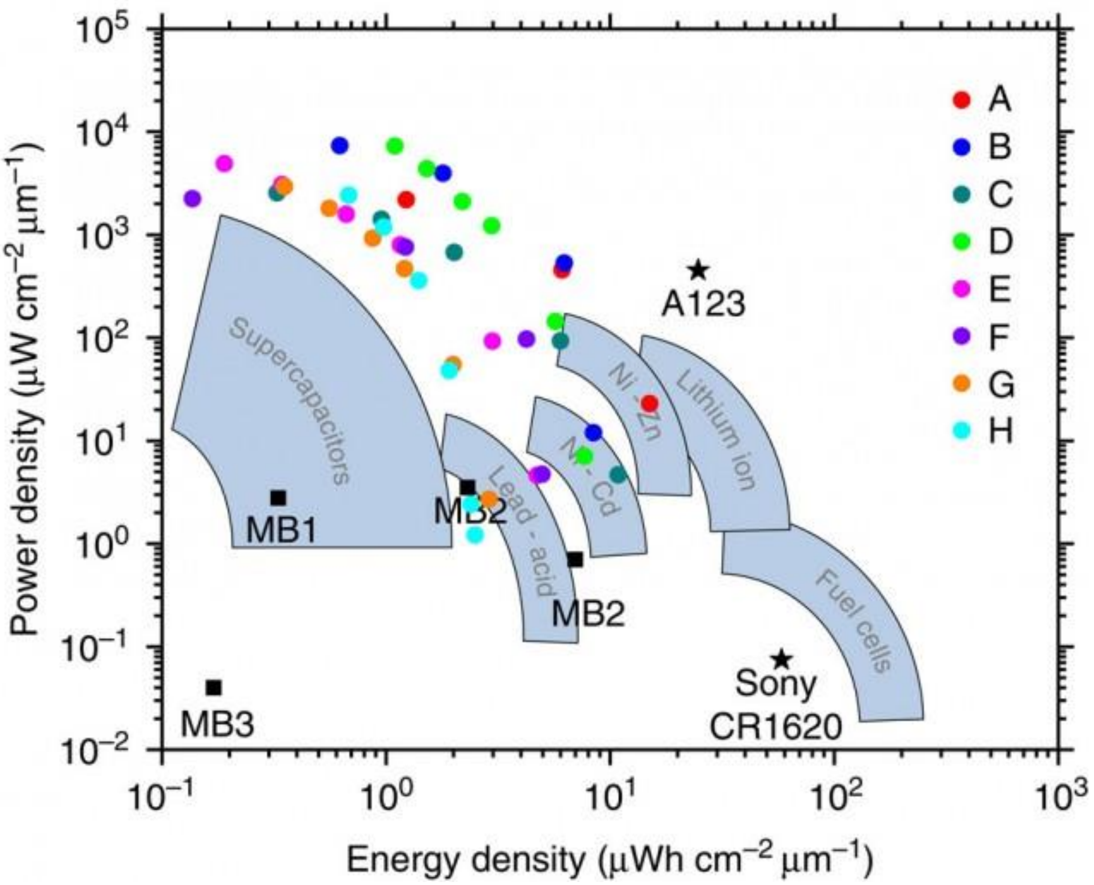
1.2 Company introduction

The company is ENE Solar Systems Oy. The CEO is Juhani Kanerva and the company is located in Nakkila Finland. They produce electricity with renewable energy sources. Company is still young since it was established in 2015. ENE Solar Systems Oy is the customer for this thesis. Company's contact person was Juhani Kanerva.

2 ACCUMULATOR TECHNOLOGY

2.1 Definitions and general

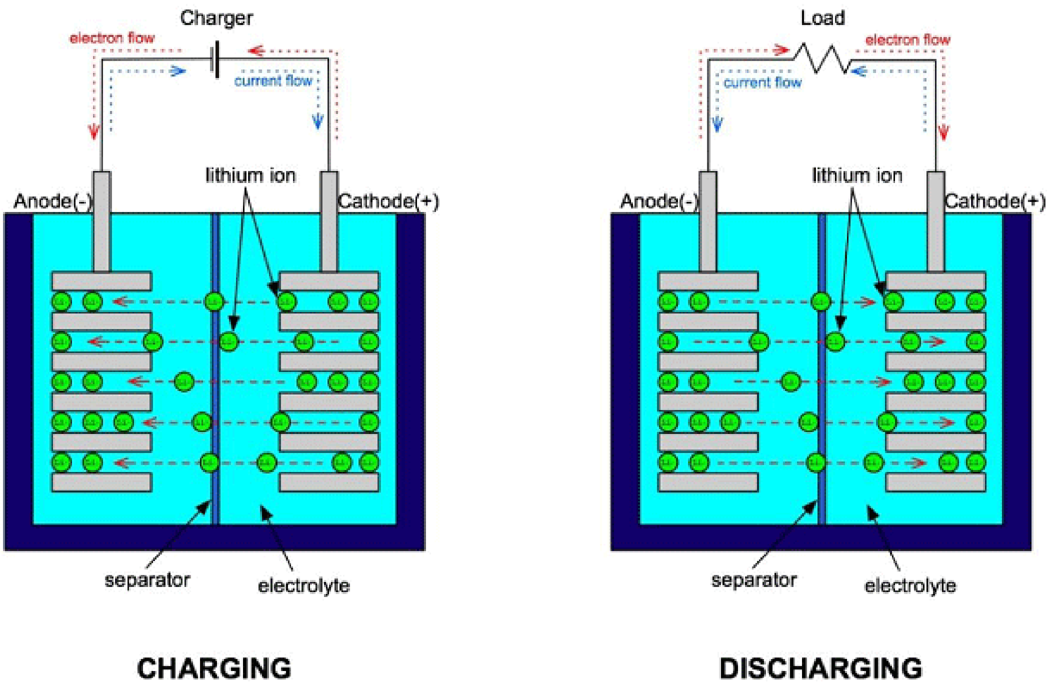
We must remember the difference between power [Watt] and energy [Joule]. Rule of thumb is that we can choose between high power density or high energy density [Watt hours] when we talk about batteries. E.g. super capacitors can deliver very high energy output for a short time, applications like laser devices. Fuels cells have on the other hand higher energy density but low power output. Lithium-ion batteries lies somewhere between these two which is the reason they are used in everyday consumer electronics like mobile phones, laptops and also in cars.



Picture 1.Power density vs. Energy density (Website of extreme tech, 2013)

2.2 Lithium-ion batteries

Lithium-ion battery is made of a negative anode and a positive cathode dissolved in electrolyte, between the anode and the cathode is a separator which prevents physical contact. In the electrolyte lithium-ions move from cathode to anode (charging) and vice versa when discharging. Current flow is changing also.



Picture 2.Lithium-ion battery. (Website of: Physics and society -blog, 2013)

"Since sun and wind are discontinuous energy sources and electric engines need to be powered, the success of these ecological renewals depends on efficient storage systems. In this respect, among the various possible alternatives, electrochemical batteries, and lithium batteries in particular, are the best choices, since they are able to convert stored chemical energy into electrical energy with high conversion efficiency and without toxic emission." (Scrosati, Abraham, Schalkwijk & Hassoun, 2013, 36).

2.2.1 Battery prices

Lithium-ion battery prices have come down about 14% per year since 2007. Hopefully prices will continue dropping even though demand for lithium is growing with all the electric vehicles built in the future. Even Tesla’s planned gigafactories would increase Lithium demand so high that mankind could consume earth’s lithium reserves in less than in two decades. (Website of Greentech media, 2015).

2.3 Lead-acid batteries

Lead-acid batteries are generally cheaper than lithium-ion batteries. These have been around longer than lithium-ion batteries. The reason that LA batteries are still used is the high surge current delivery which is necessary in starter motors in cars. These are still widely used as a backup power system such as cell phone towers and hospitals. Due to low cost they are also popular in free time activities such as summer cottages and boats.

Lead-acid batteries come in two main categories. SLI (Starting, Lightning, Ignition) i.e. car batteries with high surge current but they can’t withstand deep cycles. Deep cycling these SLI batteries will form crystallized lead sulfate which drops the battery’s performance eventually. Second is a deep cycle LA batteries. They can be used also in PV plants to store energy since they are deep cycled almost all the time.

Specific energy lies somewhere 33-42 Wh/kg

Energy density 60-110 Wh/l

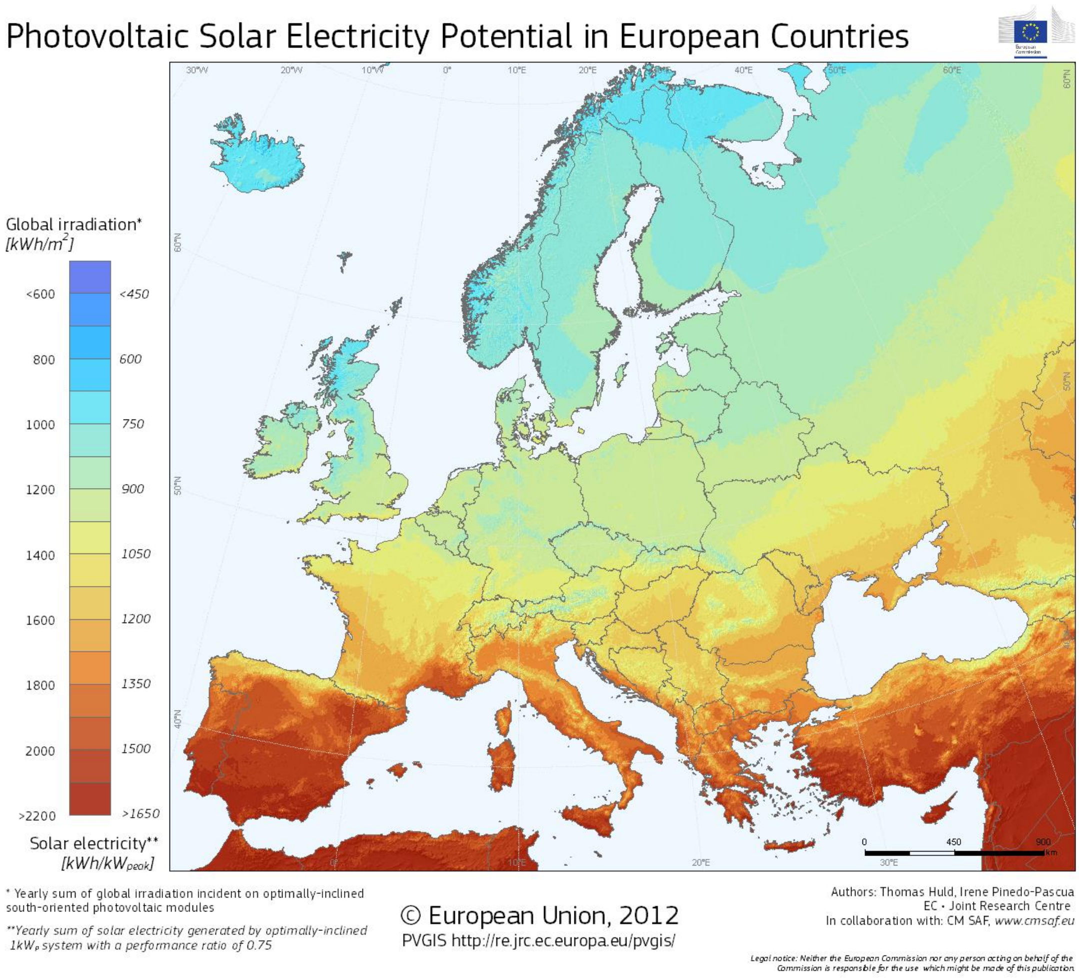
Specific power 180 W/kg

LA batteries can withstand also cold climates without losing all the capacity so they are feasible also in Finland. (Website of Power Sonic, 2015)

3 THE SUN

3.1 General

The sun is a huge star in the middle of our solar system. It is mostly hydrogen and helium. The power source is a fusion reaction in its core. Sun light or electromagnetic radiation is the main energy source on earth. It powers plant growth and causes winds. Sun light is necessary for humans to live on earth but still the full potential is not even closely collected that is emitted to earth. On the outer atmosphere sun's radiation is about 1400 W/m^2. On the earth's surface the radiation is around 1000 W/m^2. In Pori, Finland solar radiation is around 1150 kWh/m^2/year, which is about the same as northern parts of Germany.



Picture 3. PV potential in Europe (Website of European commission, 2015)

So coffee maker could be powered just by collecting the energy that the sun emits into a one square meter on earth on a sunny day. Of course many things will affect to this in real life, like position on earth and that we can't collect 100% of the sun light. But the area where sun shines on earth all the time is vast. And it's not necessary to build solar power parks everywhere on earth. Just using our existing rooftops when they are reasonable is enough.

3.1.1 Sun's position in the sky

We are able to calculate the sun's path in the sky. This allows us to use tracking panel systems for greater production.

Sun declination can be calculated with formula:

$$d = 23{,}45 * \sin(\frac{360}{365} * n) \qquad (3.0)$$

n=day number starting 21.1.

3.1.2 Sunrise and sunset

Time = Solar time + longitude correction-equation of time.

Pori airport coordinates are 61°27'41"N 021°47'52"E. Time zone longitude in Finland is 30°. Longitude correction in Pori airport is

$$\frac{30° - 21{,}7977°}{15} ° * 60min = 32{,}8min \qquad (3.1)$$

Declination $$d(21.1.) = 23{,}45 * \sin(\frac{360}{365} * -59) = -19{,}92821° \quad (3.2)$$

Sunrise and sunset moment (3.3)

a=-0,833 (takes into account sun diameter and refraction in atmosphere)

sin (-0,833°) = sin 61,4614°*sin (-19,92821°) + cos 61,4614°*cos(-19,92821°)*cos h

-->cos h=0,63429765

-->h=50,632° (sunset) or h=-50,632° (sunrise)

Solar times h=15*(Tsol-12)-->sunset 12+50,632/15=15,3755-->15:22,5, sunrise 12-50,632/15=8,6245-->8:37,5

Equation of time 21.1. is -11,5 min

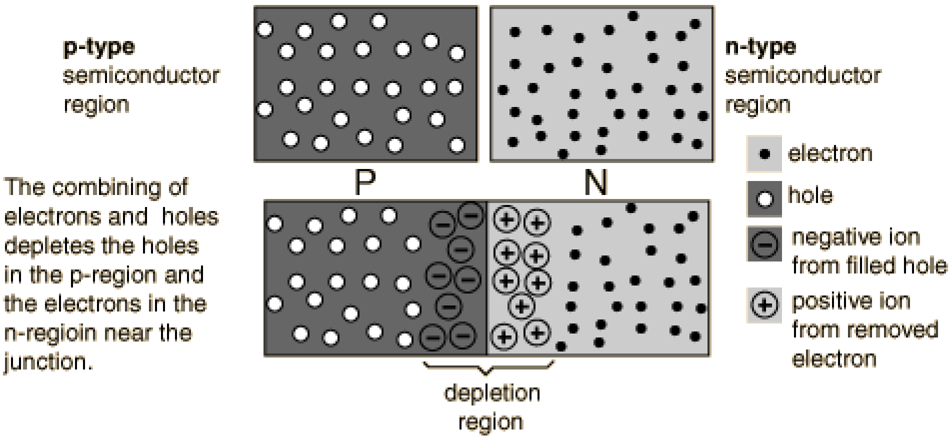
Sunrise time=8:37,5+0:32,8-(-0:11,5)=9:22

Sunset time=15:22,5+0:32,8-(-0:11,5)=16:07

4 SOLAR POWER

4.1.1 A p-n junction

A p-n junction is a spot where p-type and n-type semiconductors meet. Material can be silicon for example. P-side must be doped with impurities to give it excess electrons and the n-side with impurities to give it holes that are opposite of electron's charge. These electrons and holes can move freely because they are both in excess quantities. When these p- and n-semiconductor touch it allows to electron and holes to meet and fulfill each other's leaving behind positive and negative ions. Ions then gather near the region where the materials meet.



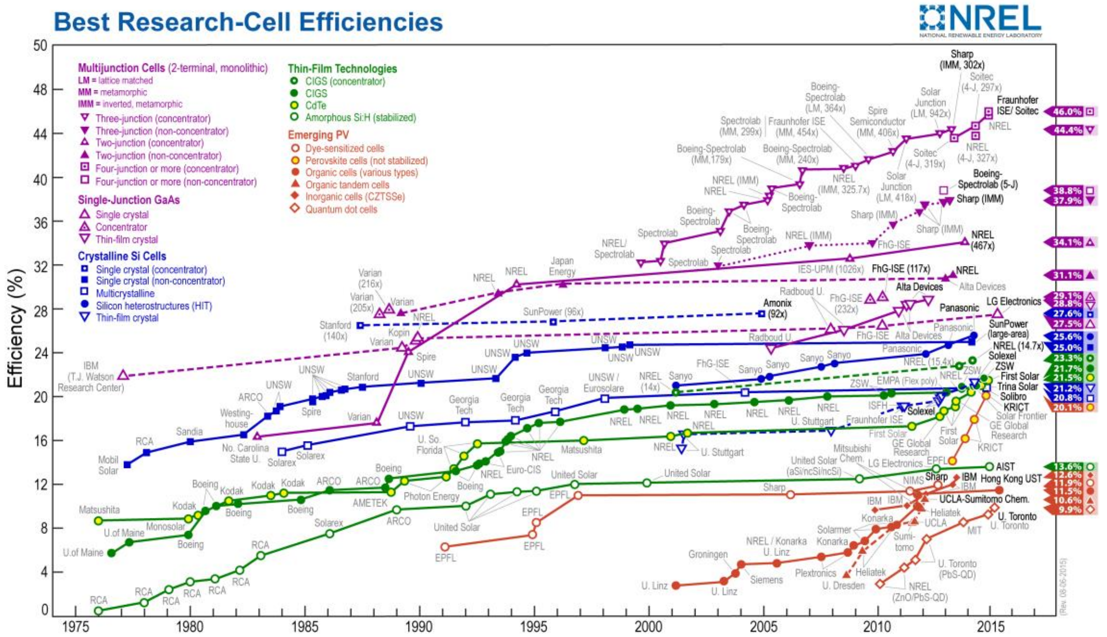
Picture 4. A p-n junction and depletion zone. (Website of Hyperphysics, 2015)

When sun light hits the panel, it will dislodge an electron. Thus creating both an electron and a hole, which are both free to move. The electric field pushes electron from the p-type material to the n-type and the holes vice versa. This flow of negative and positive charges is called voltage. If we now connect the p- and n- type semiconductors with a wire and allow electrons and holes travel we get a current. So we have working circuit that can power devices.

4.1.2 Photo voltaic

PV is a technology where sun’s electromagnetic radiation is collected with a panel and through p-n junction phenomena converted to direct current (DC). Our electric grid is using alternating current (AC) so we need an inverter. Converter feeds the alternating current to the grid or straight away to home’s devices or heating for example. But usually we want measure the output of our solar panel system so we use an electricity meter to track the production. A meter is necessary if we feed the power to the grid.

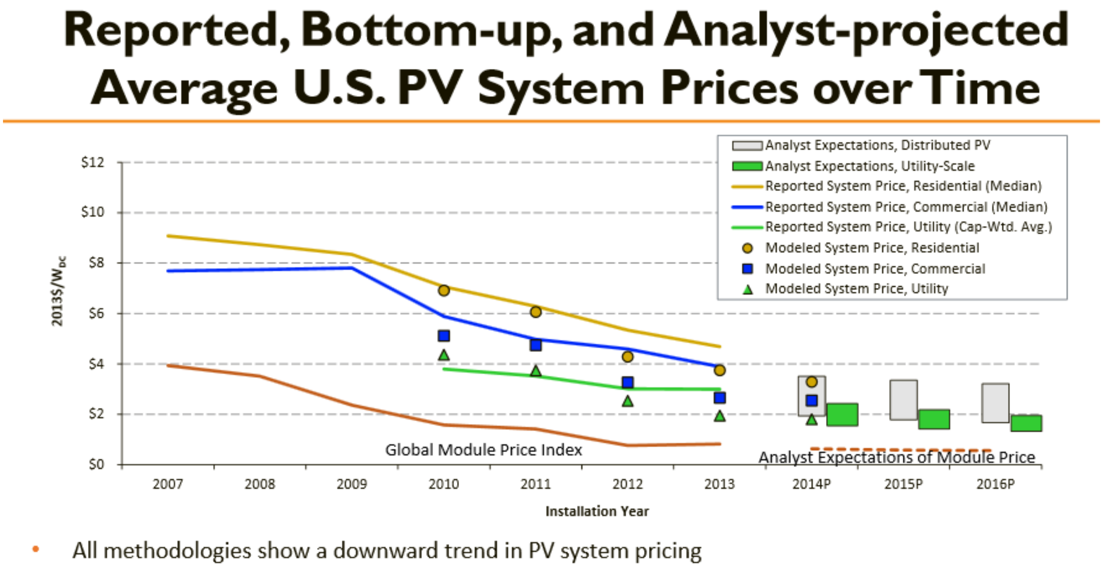
PV panels have got more efficient during recent years. Best efficiency is up to 46% with multijunction cells with concentrator. But these kinds of systems are usually too expensive for home use. More reasonable priced and simpler technology with crystalline silicon cells that are more common are about 20-25% efficient. (Website of NREL, 2015)



Picture 5. Best research cell efficiencies. “This plot is courtesy of the National Re-newable Energy Laboratory, Golden, CO.” (Website of NREL, 2015)

4.1.3 PV system pricing trends

From 1998 to 2013 PV system prices have fallen by 6-7% per year on average in US. (Website of NREL, 2014)



Picture 6. PV prices in us $/W ((Website of NREL, 2014)

Prices are definitely going down and projected price drops hopefully happen even after graph's projected 2016. It's true that when considering large scale solar power plants prices are even lower. But those prices are business offers and usually kept secret. But prices usually tend to fall and it will make solar power even more viable in Finland. Other opportunity is that the price of electricity will rise and thus increase profit from the panels and therefore decrease payback time.

4.2 Solar thermal

One efficient way to utilize energy from the sun is to collect thermal power. In Finland half of the energy demand in houses is heating. Heating demand divides in to three sub groups which are space heating, air condition and domestic hot water. (Website of Porvoon Energia, 2015). One of the best solutions to use solar thermal is to heat domestic hot water.

In order to thermal collectors to work they require direct sun light so cloud coverage will diminish the operation. In Finland we can get domestic hot water about 8-10 months a year with evacuated tube collectors. (Website of Sundial, 2015)

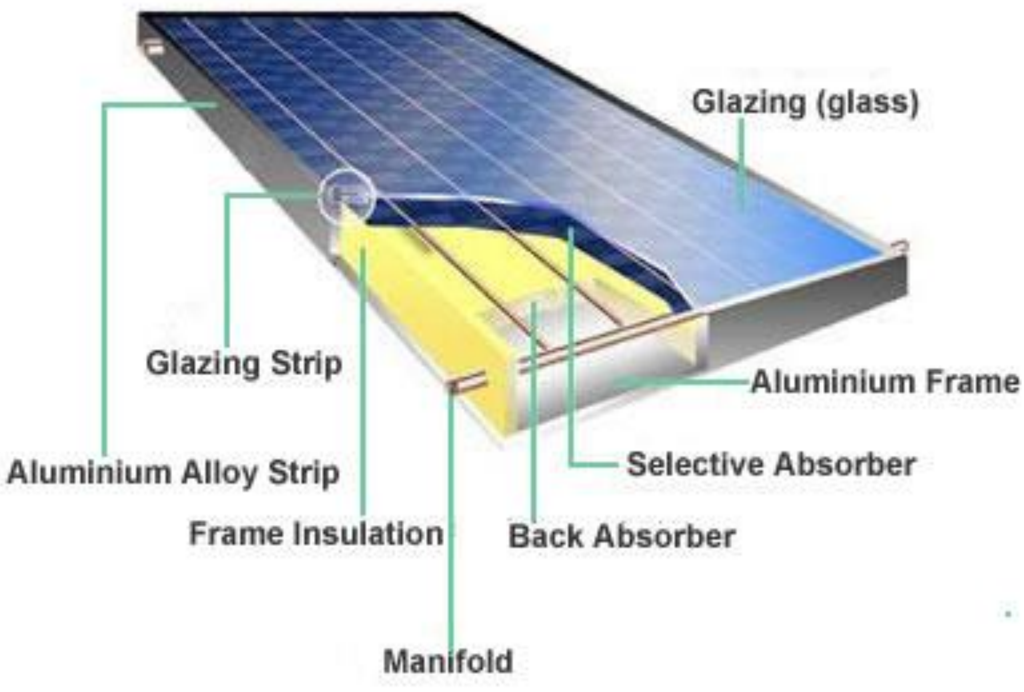
4.3 Solar thermal collectors

We have many technologies to collect solar thermal energy. Easiest ways are to use flat plate collectors and more advanced way is to use evacuated tube collectors. Even self-built systems are fairly easy to build and quite effective. For example, heating pool water with solar thermal energy. With long black water pipe that runs on a dark roof under a transparent plastic cover connected to a pump, the pump can be simple hand operated version and water could circulate in the pipe and in the pool. Even this kind of very simple solution can heat up the water enough during the summer in Finland.

For modern house integrated systems with large heat storage and vacuum tube collectors are many possibilities to design and construct. If a house has a circulating water heating system, solar thermal system can be installed afterwards to lower oil or electricity consumption.

4.3.1 Flat plate collector

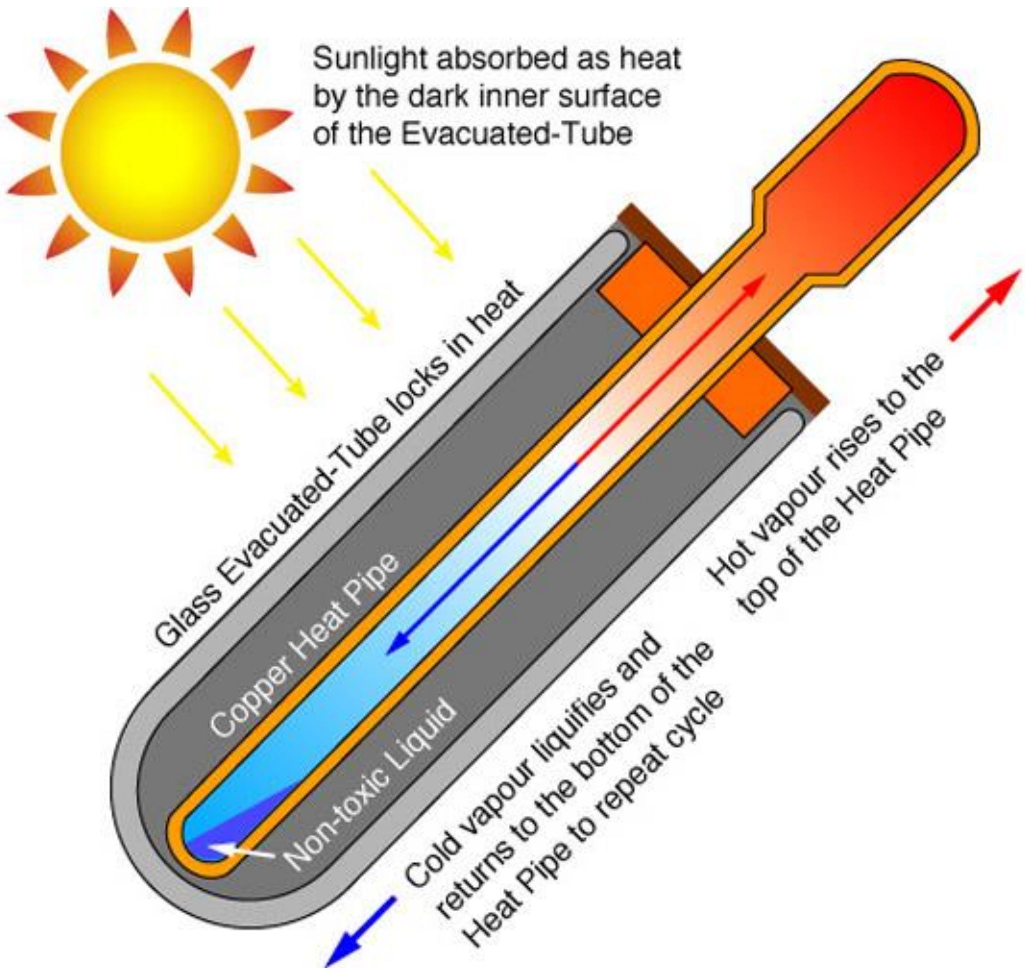
First type is a flat plate collector. It is a flat box which has a glass on top, absorber and insulator underneath and inside or under the absorber usually copper pipe where water is circulating. Usually these panels are the cheapest option but not the most efficient. Almost always multiple panels are installed to achieve optimal performance. These panels are suitable for home use.



Picture 7. Flat plate cut away. (Website of solarfeeds, 2010)

4.3.2 Evacuated tube collectors

Second type is evacuated tube collectors. The evacuated tube is made from glass that lets sun light penetrate easily. In the middle is a copper tube that is painted black or dark blue. The copper tube absorbs the solar radiation and heats up. In the copper tube is water with glycol mixture to prevent freezing. All the tubes are installed in angle which allows cool liquid water to flow in to the bottom of the copper tube and when the water heats and turn into a hot vapor it will rise to the top where the heat is collected and liquid is condensed back to the system. Vacuum works as a powerful insulator and only little heat is lost due to heat radiation.



Picture 8. Cut out of evacuated tube collector. (Website of sunmaxxsolar, 2015)

Evacuated tube collectors are most efficient way for consumers to heat their houses. It can be also installed for businesses. This kind of system is more expensive but also outperforms flat plate collectors.

4.3.3 Concentrated systems

One option for solar thermal is to collect it with concentrated systems. Idea is to focus certain area's sun radiation into a smaller spot. It can be done with multiple mirrors or parabolic reflective materials.

Picture 9. Picture of concentrated solar power. (Website of SEIA, 2015)

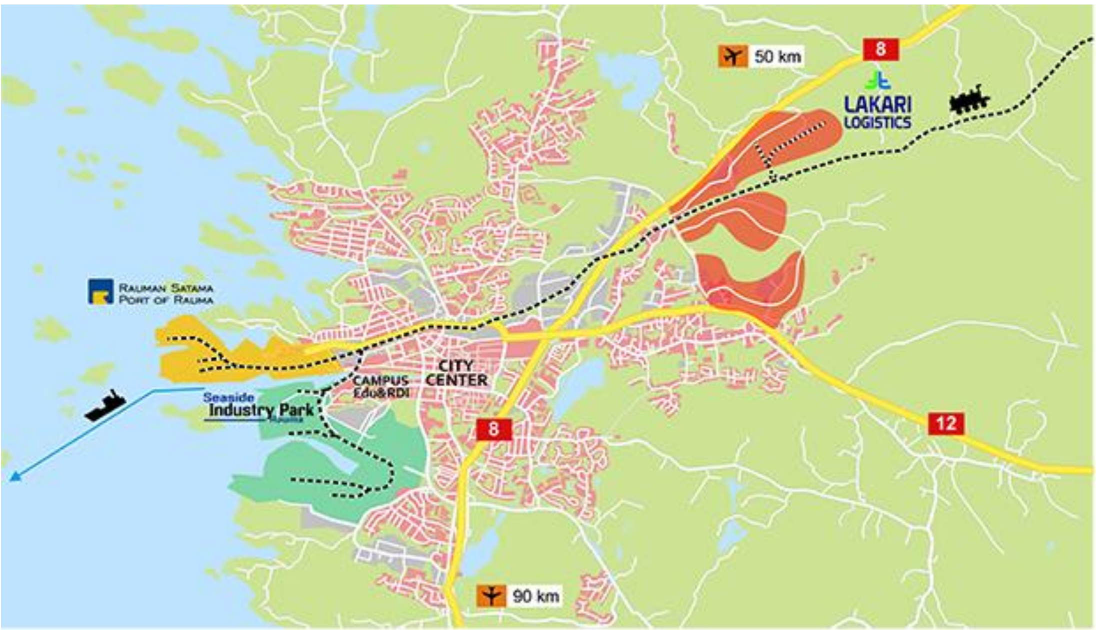
The parabolic reflective material concentrates the solar energy to the tube. Inside the tube is flowing water that transfers the heat. These systems can be scaled up and they are fairly cheap to install. Concentrating solar plants can be so powerful that they can run steam generators to produce electricity.

5 BATTERIES IN A SOLAR POWER PLANT

5.1 Design of the solar power plant

The Solar plant is 8,7MWp. It contains about 27 000 panels which would be in a fixed angle of 20° with 6 meter distance between rows. Total area is 20 ha for the plant. Annual production is 8,5 GWh with fixed system and 10,5 GWh with one-axis tracker. First design plant is supposed to be installed in Rauma's Lakari technology area. The construction should start in 2016.

The plant would be biggest solar power plant in Finland and also noticeable in Nordic countries. The plant's internal electricity consumption is approximately 12 000 kWh/a, which could be stored into a smaller battery. All figures may change since it's only a design at the moment. The project is called Solar Park Rauma.



Picture 10. Location of Lakari area marked in orange. (Website of lakariarea, 2015)

5.2 Feasibility of the battery

An excel file was created to estimate the yield of the battery. It seems that it isn't feasible in any way. Cost of the battery is just too high and the electricity price is too low. Calculation has been created so that it mimics the real hourly estimation of sun shine and power accumulates in the battery. The minimum price that the battery starts to sell can be adjusted. So it basically transfers the selling point to the better priced hours.

P	Q	R	S	T	U	V	W	X	Y	Z	AA	AB	AC
€/MWh	39,00	Lower limit PRICE to produce to battery					0,00	(MWh) Sales minimum from batteries					
€/MWh	39,00	Limit PRICE to sell from battery											
MWh	1,00	battery capasity (as AC OUTPUT)							TOT € SUN	TOT € BAT	TOTAL SOLI	EXTRA DUE BAT	
MW	8,70	LIMIT MAX AC system Power							257828,72	70664,58	328493,30	7404,40	
							Myynti	Myynti	€/year	€/year	€/year	€/year	

Picture 11. Excel file's input screen.

The parameters that can be adjusted are: Lower limit price to produce to the battery, Limit price to sell from the battery, Battery capacity, Limit max AC system power and Sales minimum from batteries which means the minimum capacity left on the battery that is not sold.

In the following calculation following values are used. Battery price 0,8 €/Wh when capacity is 1 MWh and plant size is 8,7 MWp. It seems that the optimum price to sell from the battery is 39 €/MWh, annual extra profit would be 7404,40€. Expected life time of the batteries is 15 years. Battery would cost 800 000€. Extra profit from the battery would be roughly 15a*7404,40€=111066€. Real hourly prices from Finland Nord Pool 2014 spot market are used to evaluate the feasibility. Hourly production was obtained from the website of PVWatts.com. Weather conditions were from Tampere, since Rauma or Pori didn't have their own weather data available.

5.3 Production rates

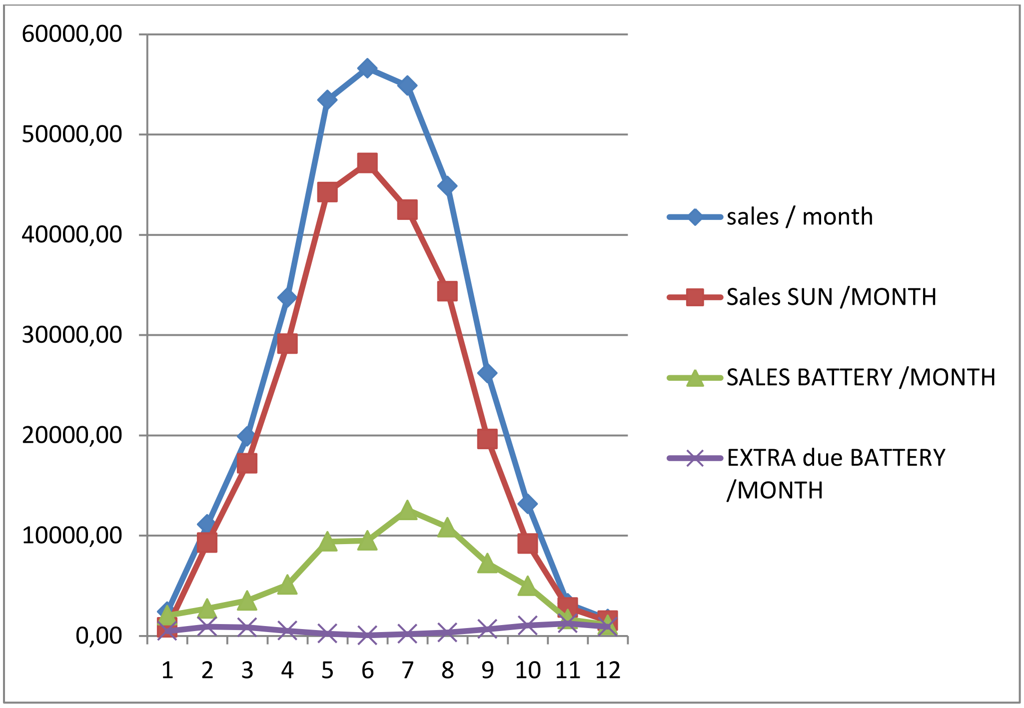


Chart 1. Production of the solar power plant €/month.

From the chart above can be seen clearly the very small extra profit from transferring low priced hours to the high priced hours even though the battery would sell quite a lot.

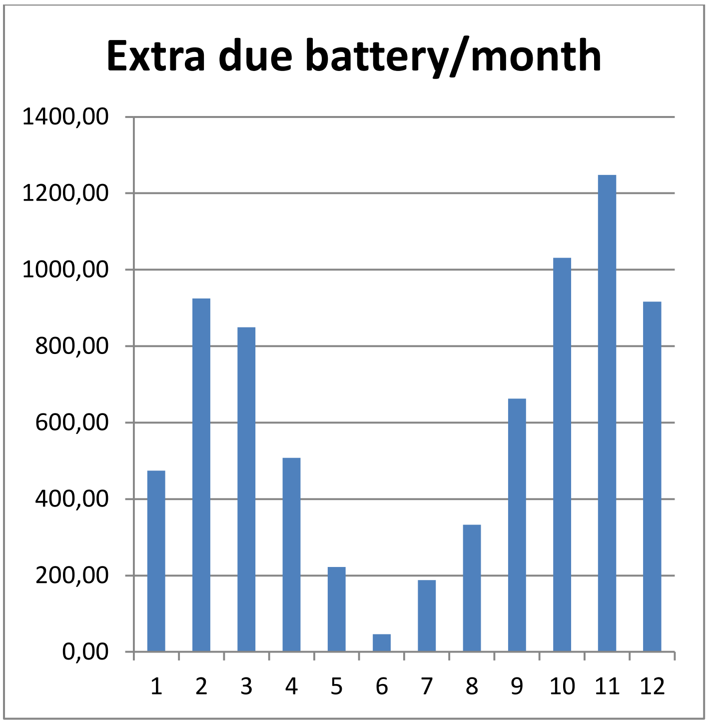


Chart 2. Extra profit in euros due battery/month.

This chart presents more clearly the time when the battery would give the highest extra profit. It is not during the summer or winter but the optimal profit is during spring and autumn. But the extra profit is still quite low.

5.4 The excel file

The base of the excel file was PVWatts online calculator. (Website of PVWatts calculator, 2015) It provided lot of data and was able to simulate DC and AC output hourly over the year. Hourly based pricing was from Nord Pool's website and the data used was from year 2014 since it was a full year. One positive thing in Finland is that cell temperatures stay relatively low over the year compared to southern countries and it increases cell efficiency. Beam irradiance means power from direct sun light and diffuse irradiance means scattered sun light for example if sun is behind cloud coverage. Ambient, cell temperature and wind speed are considered.

6	Month	Day	Hour	Beam Irradiance (W/m^2)	Diffuse Irradiance (W/m^2)	Ambient Temperature (C)	Wind Speed (m/s)	Plane of Array Irradiance (W/m^2)	Cell Temperature (C)	DC Array Output (W)	AC System Output (W)
7	1	1	0	0	0	-2,3	5,2	0	-2,3	0	0
8	1	1	1	0	0	-2,4	6,2	0	-2,4	0	0
9	1	1	2	0	0	-2,1	5,8	0	-2,1	0	0
10	1	1	3	0	0	-1,6	5,5	0	-1,6	0	0
11	1	1	4	0	0	-0,9	5,1	0	-0,9	0	0
12	1	1	5	0	0	-0,3	4,8	0	-0,3	0	0
13	1	1	6	0	0	0,6	4,4	0	0,6	0	0
14	1	1	7	0	0	1,1	4,1	0	1,1	0	0
15	1	1	8	0	0	1,3	3,8	0	1,3	0	0
16	1	1	9	0	0	1,4	3,4	0	1,4	0	0
17	1	1	10	0	7	1,6	3,1	6,789	-0,161	58760	7605,825
18	1	1	11	0	14	1,2	3,3	13,426	-0,342	116298	64090,016
19	1	1	12	0	18	0,7	3,4	17,271	-0,718	149833	97004,711
20	1	1	13	0	14	0,3	3,6	13,427	-1,174	116707	64490,805
21	1	1	14	0	8	0,3	4,3	7,759	-1,15	67434	16121,209
22	1	1	15	0	0	0,2	5	0	0,2	0	0
23	1	1	16	0	0	0,2	5,7	0	0,2	0	0

Chart 3. Representation of data used.

The excel file is hourly based over a year which makes it over 8700 lines or roughly 750 pages long calculation and hence it is not presented in full here by the request of ENE Solar Systems Oy.

The file itself was built with IF clauses and real life simulation was pursued. The file will remain as a valuable tool for ENE Solar Systems Oy.

6 CONCLUSIONS

Earth have reached in 2014 400 ppm CO2 in atmosphere when 350 ppm is our sustainable target figure. We were at 350 ppm in 1986. (Website of ESRL, 2015) The world needs to change this direction if people wish to have this planet as we know it. It requires drastic changes in current ways to produce energy. Transportation needs to aim for greater public transportation systems instead of private car ownerships. Or we need to find a sustainable way to replace combustion engines. In order all this to happen there must be political power behind the movement. Earth simply can't tolerate countries like China and India to have equal amount of cars per capita as western countries have.

Option is renewable energy sources for energy production. For transportation it could be electric vehicles or hydrogen driven engines. But for electric vehicles energy storage has still some pretty serious difficulties compared to combustion engines. The same thing goes for energy storage for large scale. This thesis was a research about feasibility of using lithium-ion batteries in solar power park. It seemed that it is still not feasible and payback time would be so huge that it exceeds system's life time almost ten times.

If electricity price would be three times higher and the cost of lithium-ion batteries would go down to 0.33€/Wh it would be plus minus zero.

15a*3*7400€/a=333 000€

Where:

7400 €/a is a rounded number of maximum annual extra profit from the battery.

3 is electricity price multiplier.

If system price would be 0.1€/Wh or price of the electricity would be 7.2 times higher, the result would be the same. But these numbers are rather large and it is very unlikely that electricity price would go up so much in any scenario. One option could be that batteries support solar and wind energy production, this way some industrial applications could operate around 8 months per year in Finland independently.

In future lithium air battery could be so efficient that it could solve energy storage problems. It has almost the same energy density as gasoline, in theory at the moment. But research is still going to take at least 10 more years. The idea is that the battery borrows oxygen from the air and combines an oxygen molecule with lithium ion on the catalyst, this reaction releases energy. Recharging releases the oxygen atoms back to the atmosphere. It still faces some big issues like poor efficiency and capacity retention. Causes for these problems are still unknown but scientists are researching these problems. IBM Battery 500 is a project where the goal is to create a battery that could run a normal vehicle 500 miles with a single charge. Lithium air battery is a strong candidate for that task. (The website of YouTube. IBM Battery 500: A look inside a lithium-air battery –video. 2015).

7 REFERENCES

Scorsati, Abraham, Schalkwijk, Hassoun. 2013. Lithium batteries : Advanced Technologies and applications. Page 36.

The website of ESRL. 2015. Referred 3.10.2015.
http://www.esrl.noaa.gov

The website of European comission. 2015. Referred 4.10.2015.
http://re.jrc.ec.europa.eu

The website of Extreme tech. 2013. Referred 4.10.2015
http://www.extremetech.com

The website of Green tech media. 2015. Referred 5.10.2015
http://www.greentechmedia.com

The website of Hyperphysics. 2015. Referred 10.10.2015
http://hyperphysics.phy-astr.gsu.edu/

The website of Lakariarea. 2015. Referred 18.11.2015
http://www.lakariarea.fi/

The website of NREL. Photovoltaic System Pricing Trends. 2014. Referred 15.10.2015
http://www.nrel.gov/docs/fy14osti/62558.pdf

The website of NREL. 2015. Referred 20.10.2015
http://www.nrel.gov

The website of Physics and society –blog. 2013. Referred 20.10.2015
https://physicsandsocietybc.wordpress.com

The website of Porvoon Energia. 2015. Referred 25.10.2015
http://www.porvoonenergia.fi

The website of Power Sonic. 2015. Referred 18.11.2015.
http://www.power-sonic.com/

The website of SEIA. 2015. Referred 29.10.2015
http://www.seia.org/

The website of Solarfeeds. 2010. Referred 1.11.2015
http://www.solarfeeds.com

The website of Solarplaza. 2013. Referred 5.11.2015
http://www.solarplaza.com

The website of Sundial. 2015. Referred 10.11.2015
http://www.sundial.fi

The website of Sunmaxxsolar. 2015. Referred 11.11.2015
http://www.sunmaxxsolar.com

The website of Teslamotors. 2015. Referred 29.9.2015
http://www.teslamotors.com/powerwall

The website of YouTube. 2015. IBM Battery 500: A look inside a lithium-air battery -video. Referred 18.11.2015 https://www.youtube.com/