Year 11 and 12 Physics and Maths

Community Battery and Solar Data

Achieving net zero emissions

A collaboration between Noosa EEHub, Zero Emissions Noosa and the University of Southern QLD

For further information or to access more detailed data sets please contact hello@noosaeehub.com.au

Noosa Environmental Education Hub

Unit 1: Physics — Thermal, nuclear and electrical physics

Unit Standards

An understanding of heating processes, nuclear reactions and electricity is essential to appreciate how global energy needs are met. In this unit, students explore the ways physics is used to describe, explain and predict the energy transfers and transformations that are pivotal to modern industrial societies. Students investigate heating processes, apply the nuclear model of the atom to investigate radioactivity, and learn how nuclear reactions convert mass into energy. They examine the movement of electrical charge in circuits and use this to analyse, explain and predict electrical phenomena.

Contexts that could be investigated in this unit include technologies related to nuclear, thermal, or geothermal energy, electrical energy production, large-scale power systems, radiopharmaceuticals and electricity in the home; and related areas of science such as nuclear fusion in stars and the Big Bang theory.

Through the investigation of appropriate contexts, students understand how applying scientific knowledge to the challenge of meeting world energy needs requires the international cooperation of multidisciplinary teams and relies on advances in ICT and other technologies. They explore how science knowledge is used to offer valid explanations and reliable predictions, and the ways in which it interacts with social, economic, cultural and ethical factors.

Students develop skills in interpreting, constructing and using a range of mathematical and symbolic representations to describe, explain and predict energy transfers and transformations in heating processes, nuclear reactions and electrical circuits. They develop their inquiry skills through primary and secondary investigations, including analysing heat transfer, heat capacity, radioactive decay and a range of simple electrical circuits.

By the end of this unit, students will:

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- understand how the kinetic particle model and thermodynamics concepts describe and explain heating processes
- understand how the nuclear model of the atom explains radioactivity, fission, fusion and the properties of radioactive nuclides
- understand how charge is involved in the transfer and transformation of energy in electrical circuits
- understand how scientific models and theories have developed and are applied to improve existing, and develop new, technologies
- use science inquiry skills to design, conduct and analyse safe and effective investigations into heating processes, nuclear physics and electrical circuits, and to communicate methods and findings
- use algebraic and graphical representations to calculate, analyse and predict measurable quantities associated with heating processes, nuclear reactions and electrical circuits
- evaluate, with reference to empirical evidence, claims about heating processes, nuclear reactions and electrical technologies
- communicate physics understanding using qualitative and quantitative representations in appropriate modes and genres.

Science Inquiry Skills Identify, research, construct and refine questions for investigation; propose hypotheses; and predict possible outcomes (ACSPH001)

Design investigations, including the procedure/s to be followed, the materials required, and the type and amount of primary and/or secondary data to be collected; conduct risk assessments; and consider research ethics (ACSPH002)

Conduct investigations, including using temperature, current and potential difference measuring devices, safely, competently and methodically for the collection of valid and reliable data(ACSPH003)

Represent data in meaningful and useful ways, including using appropriate Système Internationale (SI) units and symbols; organise and analyse data to identify trends, patterns and relationships; identify sources of random and systematic error and estimate their effect on measurement results; identify anomalous data and calculate the measurement discrepancybetween experimental results and a currently accepted value, expressed as a percentage; and select, synthesise and use evidence to make and justify conclusions (ACSPH004)

Interpret a range of scientific and media texts, and evaluateprocesses, claims and conclusions by considering the quality of available evidence; and use reasoning to construct scientific arguments (ACSPH005)

Select, construct and use appropriate representations, including text and graphic representations of empirical and theoretical relationships, flow diagrams, nuclear equations and circuit diagrams, to communicate conceptual understanding, solve problems and make predictions (ACSPH006)

Select, use and interpret appropriate mathematical representations, including linear and non-linear graphs and algebraic relationships representing physical systems, to solve problems and make predictions (ACSPH007)

Communicate to specific audiences and for specific purposes using appropriate language, nomenclature, genres and modes, including scientific reports (ACSPH008)

Solar energy generation across regions

Lessons 3

Activity Rationale

Solar energy systems work by placing solar energy cells on the roof of a building and using these to capture energy from the sun. This energy is then converted into electricity.

Through the use of technology, the electricity generation data provided by solarschools. net enables students to obtain electricity generation data from schools in several geographical locations in Australia. By using this and data obtained from the Bureau of Meteorology, students can compare electricity generation between schools in the same region.

This activity has been designed to show real life applications of Mathematics. It can be used as a stand-alone activity.

Curriculum Links

QCAA Mathematics A Senior Syllabus (2008)
Core Topic:
Exploring and understanding data
Subject matter

- Use of summary statistics to draw and analyse conclusions, represent data and make inferences (SLEs 1–5).
- Interpretation and use of sample statistics (including sample means and medians) as estimates of parameters to predict underlying population values or of values in a model (SLEs 1–5).
- Interpret relationships between variables and make predictions by identifying and using trend lines (both linear and non-linear) (SLEs 6, 12, 13).
- Sample standard deviations and interquartile range as descriptors of spread (SLEs 7–12).

QCAA Senior Mathematics – General (v1.1 2019)
Unit 3: Bivariate data, sequences and change, and Earth geometry
Topic 1: Bivariate data analysis

Identifying and describing associations between two categorical variables

In this sub-topic, students will:

- Define bivariate data.
- Construct two-way frequency tables and determine the associated row and column sums and percentages.
- Use an appropriately percentaged two-way frequency table to identify patterns that suggest the presence of an association.
- Describe an association in terms of differences observed in percentages across categories in a systematic and concise manner and interpret this in the context of the data.

Identifying and describing associations between two numerical variables

In this sub-topic, students will:

Construct a scatterplot to identify patterns in the data suggesting the presence of an association.

Describe an association between two numerical variables in terms of direction (positive/negative), form (linear) and strength (strong/moderate/weak).

Calculate and interpret the correlation coefficient (*rr*) to quantify the strength of a linear association using Pearson's correlation coefficient, where covariance and standard deviation are determined, using appropriate technology.

Fitting a linear model to numerical data

In this sub-topic, students will:

Identify the response variable and the explanatory variable.

Use a scatterplot to identify the nature of the relationship between variables.

Model a linear relationship by fitting a least-squares line to the data.

Use a residual plot to assess the appropriateness of fitting a linear model to the data.

Interpret the intercept and slope of the fitted line.

Use, not calculate, the coefficient of determination (R2) to assess the strength of a linear association in terms of the explained variation.

Use the equation of a fitted line to make predictions.

Distinguish between interpolation and extrapolation when using the fitted line to make predictions, recognising the potential dangers of extrapolation.

Association and causation

In this sub-topic, students will:

Recognise that an observed association between two variables does not necessarily mean that there is a causal relationship between them.

Identify and communicate possible non-causal explanations for an association, including coincidence and confounding due to a common response to another variable.

Solve practical problems by identifying, analysing and describing associations between two categorical variables or between two numerical variables.

Australian Curriculum
Mathematics – General
Unit 3
Topic 1: Bivariate data analysis

The statistical investigation process:

Review the statistical investigation process; for example, identifying a problem and posing a statistical question, collecting or obtaining data, analysing the data, interpreting and communicating the results. (ACMGM048)

Identifying and describing associations between two categorical variables:

Construct two-way frequency tables and determine the associated row and column sums and percentages. (ACMGM049)
Use an appropriately percentaged two-way frequency table to identify patterns that suggest the presence of an association. (ACMGM050)

Describe an association in terms of differences observed in percentages across categories in a systematic and concise manner and interpret this in the context of the data. (ACMGM051)

Identifying and describing associations between two numerical variables:

Construct a scatterplot to identify patterns in the data suggesting the presence of an association. (ACMGM052)
Describe an association between two numerical variables in terms of direction (positive/ negative), form (linear/non-linear) and strength (strong/moderate/weak). (ACMGM053)
Calculate and interpret the correlation coefficient (r) to quantify the strength of a linear association. (ACMGM054)

Fitting a linear model to numerical data:

Identify the response variable and the explanatory variable. (ACMGM055)
Use a scatterplot to identify the nature of the relationship between variables. (ACMGM056)
Model a linear relationship by fitting a least-squares line to the data. (ACMGM057)
Use a residual plot to assess the appropriateness of fitting a linear model to the data (ACMGM058)
Interpret the intercept and slope of the fitted line. (ACMGM059)
Use the coefficient of determination to assess the strength of a linear association in terms of the explained variation. (ACMGM060)
Use the equation of a fitted line to make predictions. (ACMGM061)
Distinguish between interpolation and extrapolation when using the fitted line to make predictions, recognising the potential dangers of extrapolation. (ACMGM062)
Write up the results of the above analysis in a systematic and concise manner. (ACMGM063)

Association and causation:

Recognise that an observed association between two variables does not necessarily mean that there is a causal relationship between them. (ACMGM064)
Identify possible non-causal explanations for an association, including coincidence and confounding due to a common response to another variable, and communicate these explanations in a systematic and concise manner. (ACMGM065)

Solar energy generation within a region

What you need to do

1. Preliminary

1. Locate the data sets provided for solar generation data of period xxfor:

The J
The Leisure Centre
(*At times, generators may be turned off for maintenance).

2. Predict a relationship between daily hours of sunshine and daily solar energy generation.

Graph data

1. Draw up a table to record the data for each location:
Download the daily sunshine hours for the period defined

(http://www.bom.gov.au/watl/sunshine/).
Monthly solar energy generation (kWh).

(Note: 1kWh is a unit of energy which indicates that 1000W of power was generated in 1 hour)(http://solarschools.net).

2. Draw histograms and look for trends

1. Using a single grid, draw histograms of the sunshine and energy generation data.
Choose suitable scales for each data set separately.
Use the left vertical axis for monthly sunshine hours and the right vertical axis for monthly solar energy generation.
The horizontal axis should be the months.
Plot data in pairs of columns for each month: left hand column should be sunshine hours and right hand column should be solar energy generation data.
Use a legend to explain the columns.

2. Discuss any trends that you observe in the sunshine data.
3. Discuss any trends that you observe in the solar energy generation.
4. Using your graphs, is there a positive, negative or no correlation between sunshine data and solar energy generation data?

3. Draw a scatterplot and look for correlations

A better way of testing possible correlations would be to draw a scatterplot.

1. Using your graphing calculator (or pencil and paper), draw a scatterplot of sunshine hours versus solar energy generation. (Use the horizontal axis for the independent variable).
2. Using your scatterplot:
Is there any correlation between sunshine data and solar energy generation data?
If so, what is the relationship between the variables?

Extension - Use the Regression Analysis tools on your graphing calculator to find the relationship between the variables.

4. Compare data between sites

It would be reasonably expected that the two sites will be similar in their data given they are in a similar location however the size of the solar energy systems may be different.
Give an explanation as to why you think this could occur.
How did the solar energy generation compare over the two sites?
What possible explanations could you give for these results?

5. Research factors influencing solar energy generation

Table 1: Data relating to monthly temperature and rainfall

2.

School	Month Highest Temp.	Highest temp (oC)	Month Lowest temp.	Lowest Temp (oC)	Range of Temp (oC)	Month Highest Rainfall	Highest Rainfall (mm)	Month lowest Rinfall	Lowest Rainfall (mm)

Using the data recorded in Table 1, compare the weather experienced by each of the schools during the twelve month period.

Sunshine hours

1. Use Table 2 to record the following data and calculations for each location:
Average daily sunshine hours for each month of the year

(http://www.bom.gov.au/watl/sunshine/)
Minimum average daily sunshine hours
Maximum average daily sunshine hours
Median (Q2) average daily sunshine hours
Quartile 1 (Q1) and quartile 3 (Q3) average daily sunshine hours
Interquartile range (IQR)

Table 2: Data relating to average daily sunshine hours for each month

Year	Average daily sunshine hours for each month		
Month	School 1	School 2	School 3
Feb			
Mar			
Apr			
May			
Jun			
Jul			
Aug			
Sep			
Oct			
Nov			
Dec			
Maximum			
Minimum			
Median (Q2)			
Q1			
Q3			
IQR			

2. On one set of axes, construct box and whisker plots using the average daily sunshine hours for each month data from these three locations.

Solar energy output data

1. Use Table 3 to record the output trends you would expect from each solar energy system throughout the year. Justify your answers (consider the average daily sunshine hours for each month and the changes between the dry and wet seasons).

Table 3: Data relating to average daily sunshine hours for each month

Site	Output trend expected

2. Obtain the solar energy output data for a twelve month period for each of the sites using the www.solarschools.net.

   Graph the data on Figure 1 below or use a spreadsheet (use different colours for different sites.

School names:

Extra Activities for Battery Data

Contact Noosa EEHub for access to real data sets from the Batteries installed at either facility (The J or The Leisure Centre)

Graph the data relating to the battery storage and output.

Do you have a home solar photovoltaic system? Let's assess the size of the battery required to power your home solar system.
Typically, a battery system is used to transfer the time of use from day time hours (when electricity is cheaper) to night time hours where there are heavier tariffs for coal fired electricity use. Achieving a balance between the amount of solar you store in the battery and the amount you allow for use from the solar system is a household decision.
As a base the below table can be used as an example of this storage approach.

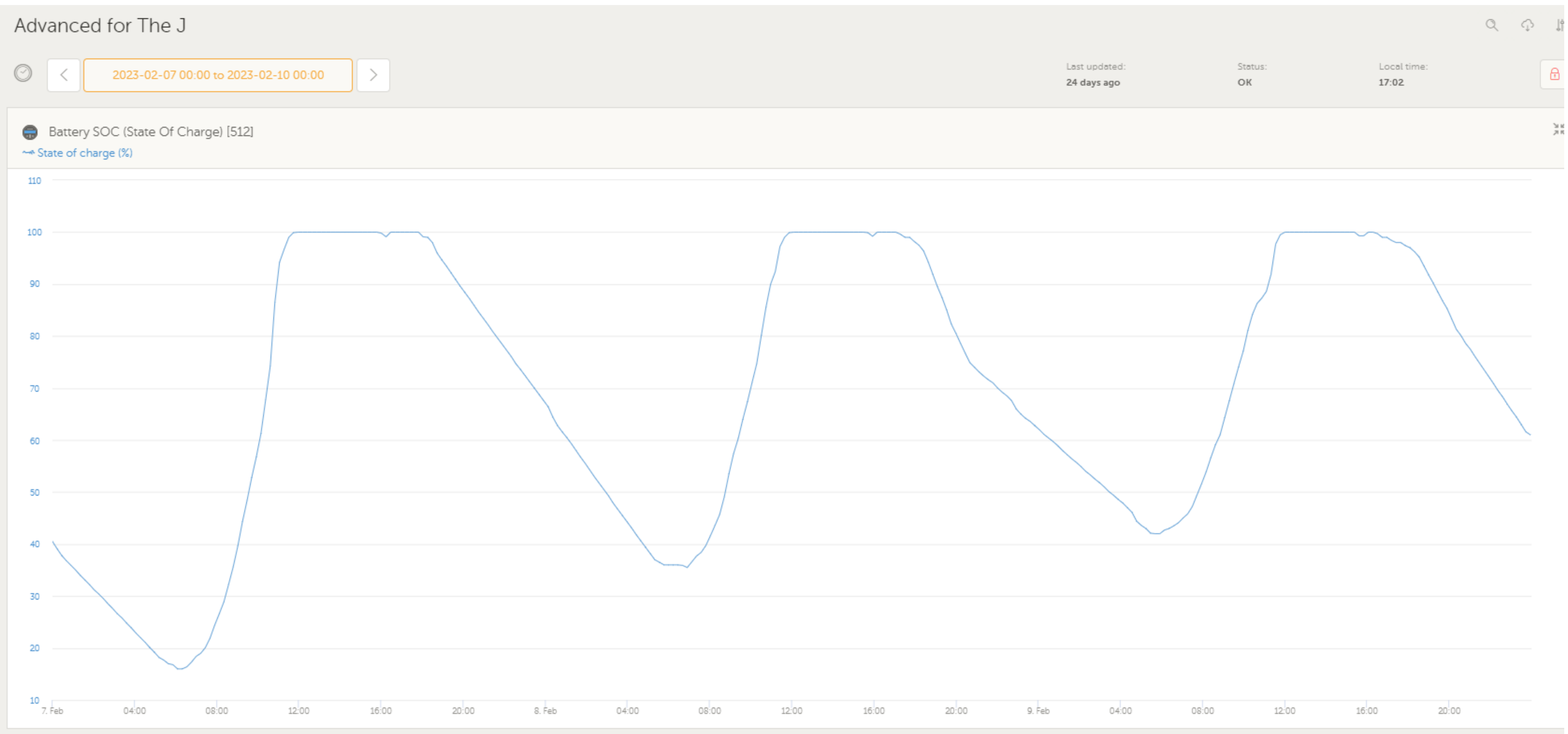
Your daily energy consumption	Self-Consumption Ratio for Different Solar System Sizes				
	2kW Solar	3kW Solar	5kW Solar	7kW Solar	10kW Solar
5-10kWh	30%	25%	17%	13%	9%
11-15kWh	48%	38%	26%	20%	15%
16-20kWh	57%	46%	34%	26%	20%
21-25kWh	66%	53%	40%	32%	24%
26-30kWh	73%	59%	44%	37%	28%
31-40kWh	82%	67%	50%	42%	34%

In the case of the two demonstration systems and their battery storage the key points to note are:
The J Noosa Junction:
- There are 6x 5kW Victron Multiplus II inverters (2 per phase) installed.
- This comprises 12x 5kWh Pylontech LiFePO4 battery modules creating 60kWh hours of storage and a usable draw down of 57.6kWh.
- The batteries supply the "essential circuits" during a grid failure. Meaning not all the site will have power but the communications, main lights, main power points etc will work.
- The site cannot sell the batteries power to the grid as Energex has requested a "hard export limit" of 0kW. This is becoming very common on larger installations as the grid reaches saturation point from decentralised loads such as rooftop PV or behind the meter batteries.

The Leisure centre is the same except it has 8x 5kWh modules giving it 38.4kWh of usable storage.

At the evacuation centres some residual energy is stored in the batteries for out of hours use and in case of a disaster.

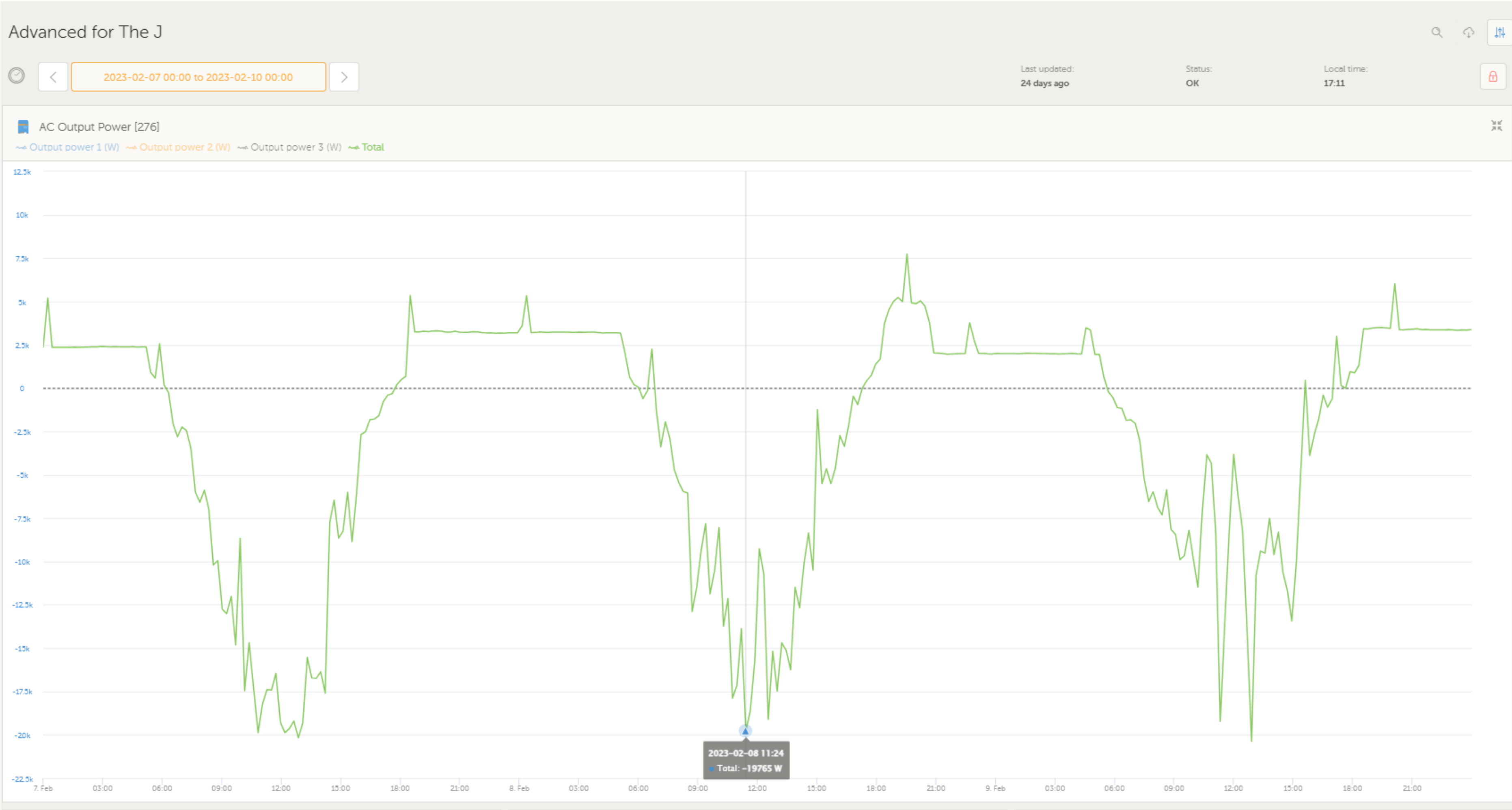
- Battery state of charge graph (3 days) - increasing during the day (solar hours) and decreasing at night:



- Total Power in and out of the Victron Inverters (3 days) - showing a night base load of aprox. 4kW (only the loads being backed up by the batteries), and aprox 20kW peak being fed by the 30kW solar + battery system into the remaining loads on site during the day (in excess of the supply to the loads being backed up by the batteries).

<image.png>

This second graph shows that the solar & batteries were capable of supplying all the energy to the loads located after the victron inverters (back up loads), and the excess was sent back to the other loads on site (peaking 20kW) during the day.



Then during the night, the backed up loads would use approx. 65% of the battery capacity, as shown in the first graph, before the sun was out again.

For more information about The J’s installation please review the slide stack presentation PDF.

Power requirements of a solar charging system

Introduction

This series of research activities explores the use of solar panels to charge and operate LED lights in the context of providing sustainable energy. Students are guided to measure input and output power of a solar charging system that can be used during sunlight hours as well as in dark conditions. The solar charger uses modern technologies including supercapacitors as an energy storage device. Students research the performance of the system to provide a sustainable supply of electrical energy for lighting multiple LEDs.

The design and construction of the solar charger is described in detail and it is recommended that this be prepared in advance of distribution to students. Soldering is required to ensure the integrity of the components in the system.

Assessment is left for the school to develop but there are opportunities for research and investigation instruments.

Curriculum Links:

Science in Practice (QLD - 2015)

Solutions to humanity's energy and resource challenges are likely to come from the application of science and technology. Students should develop an awareness of the consequences of using resources by considering their short- term and long-term impacts as well as their sustainability.

Research

Research whether solar photovoltaic systems are the most efficient renewable energy source for Australian houses. (C/P)

Investigate

The role that non-renewable and/or renewable energy plays in developing economies (E/P)
Exploring the development of a specific technology

Research questions

1. How many LEDs can the solar charger light up while in direct sunlight?
2. How many LEDs can light up without the solar panel in direct sunlight?
3. How long does an LED light up when connected to the capacitor?
4. How long do multiple LEDs stay on for when connected to the capacitor?

Resources

LED (red 1.8 - 2.2V @ 20mA (0.02A)
Solar panel (solar Panel 3V 500mA)
IN4004 Diode (1N4004 1A 400V Diode)
Zener Diode (zener Diode, 2.4V 0.5 W)
Capacitor (15F Supercapacitor 2.7 V)
Connecting leads (alligator clips)
Prototype board (recommended)

Sources

RS Online
Jaycar Electronics
Scientrific Pty Ltd

Safety

All components used in this circuit have specific polarity orientations and maximum specifications that must be followed. Failure to correctly orient the components will lead not only to the circuit not working but also could destroy the component. In some cases this could occur in a quite spectacular fashion.

Working safely with the supercapacitor

1. **The positive and negative terminals must be correctly connected to positive and negative power supply.**
   Failure to do so will lead to destruction of the capacitor through an explosion. This is potentially dangerous! To avoid this possibility only supply polarised capacitors to students with a reverse polarity protection diode soldered to the positive terminal of the capacitor as shown in the diagrams below. This diode also protects the solar panel from reverse current flow and un-wanted discharge of the storage capacitor.
2. **The supercapacitor must never be charged above its rated voltage.**
   Failure to limit the voltage on the supercapacitor will destroy the capacitor. However it may not be as spectacular as the reverse polarity situation. The voltage on the supercapacitor is limited in two ways:

The solar panel has a maximum supply voltage of 3.0V. The protection diode has a voltage drop of 0.7V. The maximum voltage applied to the capacitor would be 2.3V which is less than the rated voltage of 2.7V.

In the event that the supply voltage exceeds 3.0V then the voltage on the capacitor will be limited by the Zener diode connected in parallel. The zener voltage is fixed at 2.4V which is less than the capacitor maximum voltage of 2.7V.

3. **A short circuit should not be applied across the capacitor.**
   A short circuit will not destroy the capacitor but the conductor causing the short will become very hot and may cause burns if touched.
4. **Touching across the terminals of a charged supercapacitor will generally not cause an electric "shock" due to the low voltage and the high resistance of the skin.**

3

Considering the safety issues described above it is strongly recommended that the key components of protection diode, supercapacitor and Zener diode are soldered correctly on to a prototype board before distribution to students. This will avoid issues of incorrect polarity and excessive voltages on the supercapacitor.

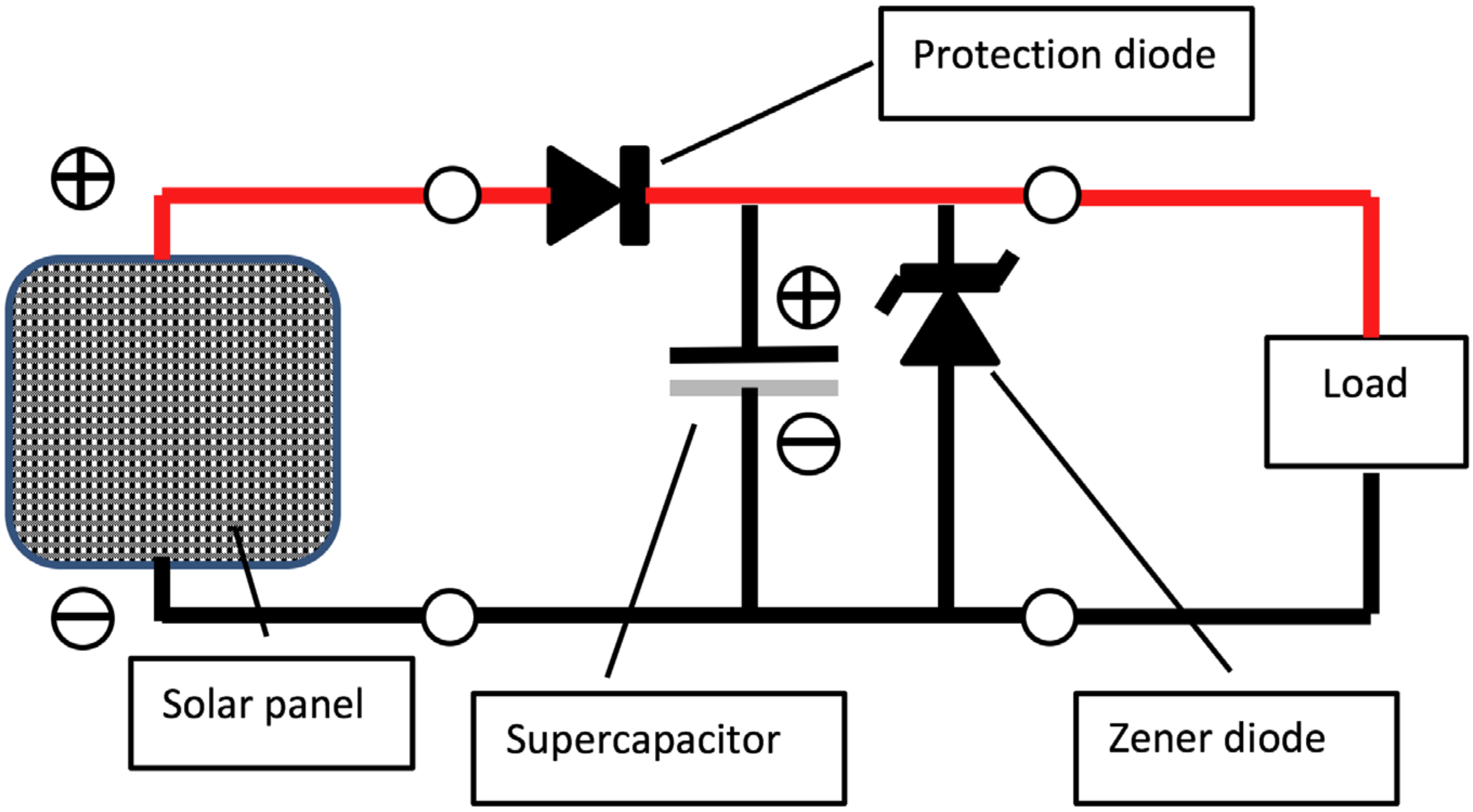
Design

The solar cell has an energy output that is stored in the capacitor. The capacitor is a temporary storage of charge and is functionally similar to a re-chargeable battery. The capacitor has a capacitance (Farads F) which is a measure of the quantity of charge per volt that can be stored in it.

The protection diode allows current to flow in one direction from the solar cell to the capacitor. It prevents reverse flow so that charge cannot return to the solar panel.

The Zener diode is connected across the capacitor so that the maximum voltage of the capacitor cannot be exceeded as well as providing a limit on the maximum output voltage for the load devices.

The load can be any electrical device but in this case the load will be an LED.



Load specifications
LED (red 1.8 - 2.2V @ 20mA (0.02A)

Solar charger
Solar panel (solar Panel 3V 500mA)
IN4004 Diode (1N4004 1A 400V Diode)
Zener Diode (zener Diode, 2.4V 0.5 W)
Capacitor (15F Supercapacitor 2.7 V)

Connections
Connecting leads (alligator clips)
Prototype board (recommended)

Construction

Build this circuit with the three components (Diode, Capacitor and Zener diode) mounted and soldered on a prototype board for ease of handling. This also eliminates the possibility of students connecting components with incorrect polarity.
Solder all components and solder colour coded leads to the input and output rows.

Each of the three components can only be mounted one way correctly with respect to positive and negative terminals. Otherwise the circuit will not work and the components may be destroyed.
Capacitor has clear markings that point to the shorter negative terminal.