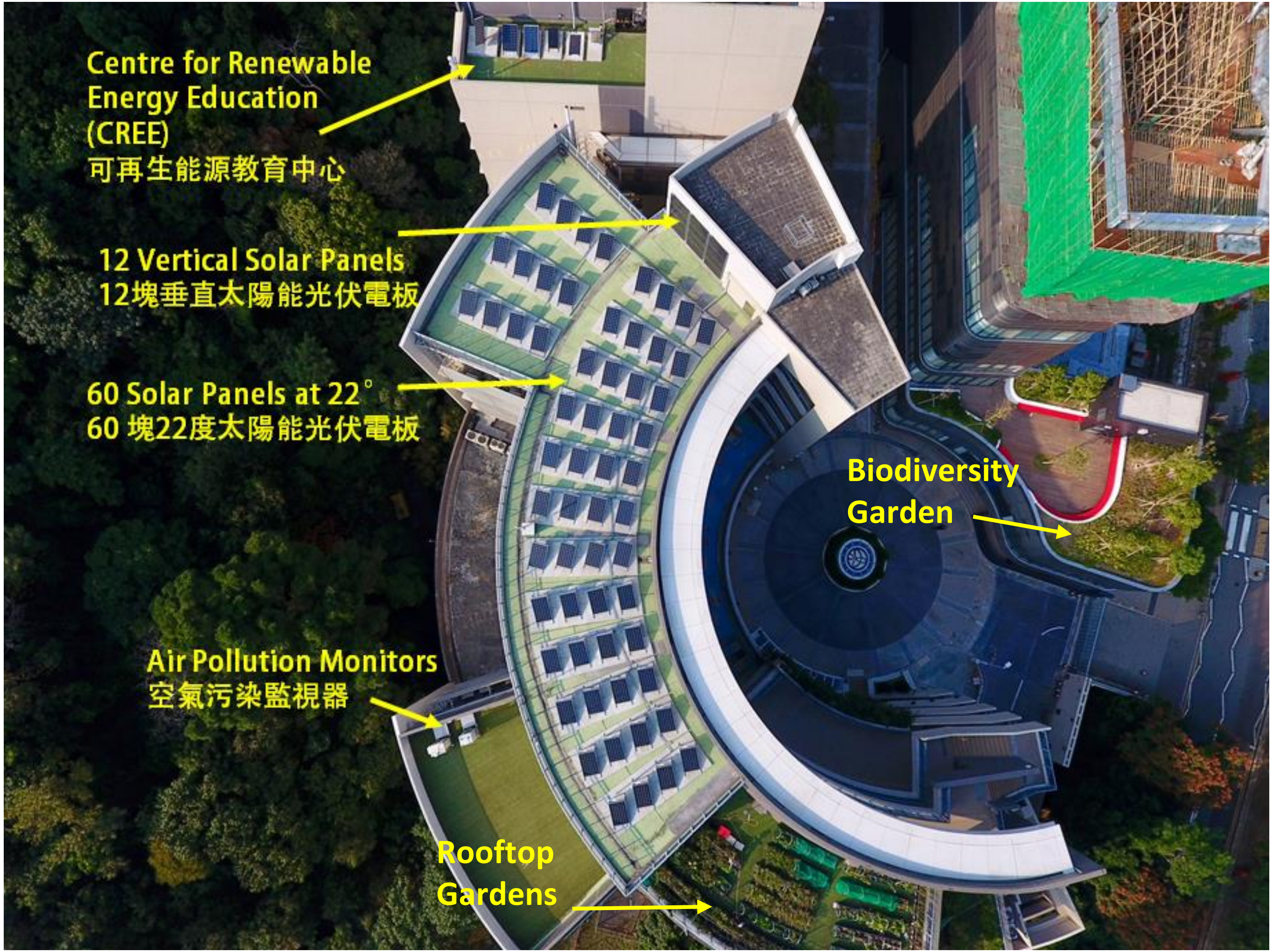
Sustainability at ISF
弘立書院的可持續發展計劃

What we do

Starting in 2013, we have invested in a number of school-wide initiatives around our facilities meant to raise awareness about sustainability issues and model how to tackle some solutions that might mitigate climate change...



Centre for Renewable Energy Education (CREE)
可再生能源教育中心
12 Vertical Solar Panels
12塊垂直太陽能光伏電板
60 Solar Panels at 22°
60 塊22度太陽能光伏電板
Air Pollution Monitors
空氣污染監視器
Biodiversity Garden
Rooftop Gardens

Grade 3 classrooms
三年級的教室

Classroom is using 100% solar power
教室已100%使用太陽能電力

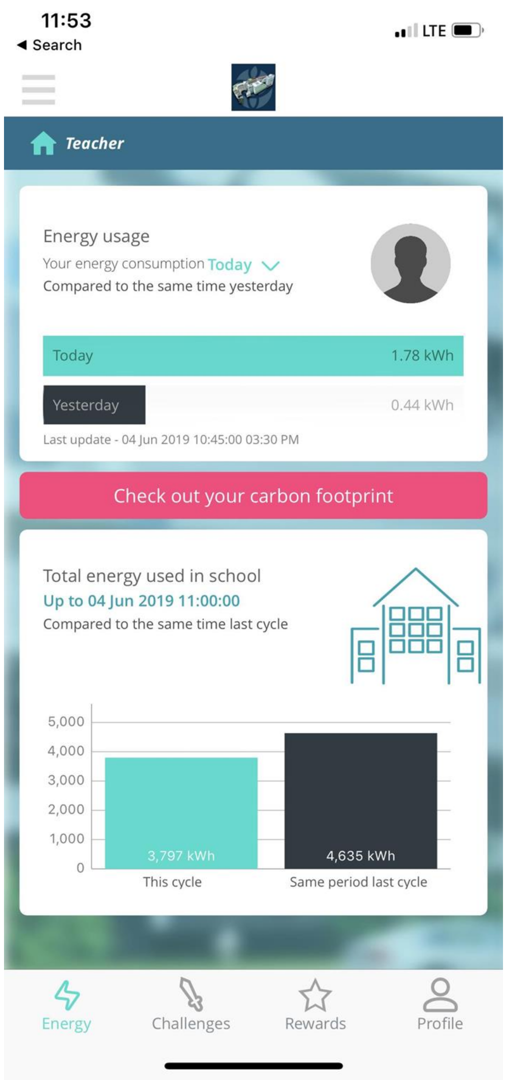
Warning – battery low, take action to prolong use of renewable power and defer use of the external grid
警告 – 電池電量低，採取可延長可再生能源的方法及推遲使用外部電網

Classroom is using 100% external grid power (fossil fuel)
教室100%使用外部電網 (化石燃料)

CREE (Center for Renewable Energy Education)
可再生能源教育中心


CREE System
Select Diagram: System Information
CREE MONITORING SYSTEM
Real Time System Data
Power Output of Mono PV Panel (Tracker): 47 W
Power Output of Poly PV Panel: 77 W
Power Output of Thin Film PV Panel: 39 W
Power Output of Mono PV Panel: 113 W
Power Output of Flexible PV Panel: 6 W
Power Output of Wind Turbine: 0 W
Power Output of Hydro Power Generator: 0 W
Consumption
Pump: 55 W
Real Time Weather Data
Module Temperature of Mono PV Panel (Tracker): 47.4 °C
Module Temperature of Mono PV Panel: 53.1 °C
Module Temperature of Poly PV Panel: 49.1 °C
Module Temperature of Thin Film PV Panel: 52.8 °C
Module Temperature of Flexible PV Panel: 46.9 °C
Solar Irradiance: 847.3 W/m2
Ambient Temperature: 36.7 °C
Water Heater Temperature (Top): 55.1 °C
Water Heater Temperature (Bottom): 62.3 °C
Real Time Control Status
Pump 1 ON
Pump 2 ON
Hydro Power OFF
Water Tank OFF


弘立書院
THE ISF ACADEMY
Login
Building G
Building B
Building R
Enabled by
g·hub
AR mode


11:53
◀ Search
LTE
Teacher
Energy usage
Your energy consumption Today
Compared to the same time yesterday
Today 1.78 kWh
Yesterday 0.44 kWh
Last update - 04 Jun 2019 10:45:00 03:30 PM
Check out your carbon footprint
Total energy used in school
Up to 04 Jun 2019 11:00:00
Compared to the same time last cycle
5,000
4,000
3,000
2,000
1,000
0
3,797 kWh
4,635 kWh
This cycle
Same period last cycle
Energy
Challenges
Rewards
Profile

The effect of charging regime on the lifespan of two lithium battery chemistries

Marco Ip, ISF Academy

Abstract

Our electricity system is making a transition to more renewable sources and batteries have an important role to play. However, batteries still have to overcome certain problems including, safety, low energy density (energy per unit weight) and short lifetime. Lithium ion batteries, developed in the 1980s, have some advantages compared to other types of battery - they are rechargeable, safer, lighter and have a longer life span. At ISF Academy, we are using lithium ion batteries for a solar microgrid and teach students about reducing their energy demand.

One factor that affects the lifetime of a battery is the way it is charged and discharged (the "charging cycle"). I worked with Ampd Energy in Hong Kong to investigate the impact of the charging cycle on the lifetime of two different types of lithium ion batteries - NCA and NCM made by two different manufacturers EVE and BAK.

Why Lithium ion batteries are successful

Three main factors in the success of a battery chemistry are weight, ionisation energy and cost. The anode, cathode and electrolyte in a battery are chosen based on their chemical and physical properties and their contribution to the above three factors.

The main advantage of lithium is its low atomic weight (7), which is why lithium ion batteries are so light and why they are widely used in mobile phones and electric vehicles. Lithium has an electron configuration of $1s^2 2s^1$. The lone electron in the 2s orbital means that it has a very low ionisation energy, which results in the easy production of lithium ions. Although lithium batteries have a high thermal risk due to the high reactivity of lithium, by removing the valence electron of lithium, it becomes a lithium cation which now only has a full 1s orbital and is much more stable. This makes Lithium ion batteries safer. ("Is Lithium-Ion the Ideal Battery?").

The battery cells tested

EVE battery: NMC (Lithium Nickel Manganese Cobalt oxide)
(cathode 6-2-2 relative chemical composition)

BAK batteries: NCA (Lithium Nickel Cobalt Aluminum oxide)
(cathode 8-1-1 relative chemical composition)

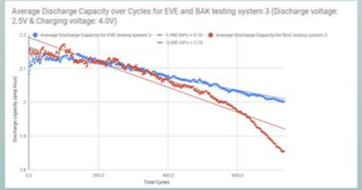


Figure 1: charge 2.5V, discharge 4.0V

Figure 2: charge 2.5V, discharge 4.2V

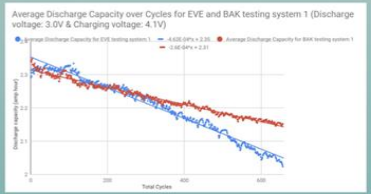


Figure 3: charge 3.0V, discharge 4.1V

Positive electrode materials

NMC: (LiNiMnCoO2)
The manufacturer EVE uses the ratio 6:2:2 for Ni:Co:Mn. "Nickel is known for its high specific energy but poor stability; manganese has the benefit of forming a spinel structure to achieve low internal resistance but offers a low specific energy. Combining the metals enhances each other strengths." ("BU-205: Types of Lithium-Ion"). The advantages of NMC are its safety, a relatively high energy density of 150–220Wh/kg, a typical lifespan of 1000-2000 cycles and a cost of ~$420 per kWh.

NCA: (LiNiCoAlO2)
The BAK manufacturer BAK uses the ratio of 8:1:1 for Ni:Co:Al. NCA has a typical energy density of 200-260Wh/kg, a lifespan of around 500 cycles and a cost of ~$350 per kWh. ("BU-205: Types of Lithium-Ion.") Although it has a high energy capacity, its short lifespan means that the maintenance cost is also very high. This model is a development of the NC battery, the addition of Aluminium makes it more stable. ("BU-205: Types of Lithium-Ion.")

Data Collection

The data for my project was provided by Ampd Energy in Hong Kong. Ampd produce and market large Li ion batteries for infrastructure and other uses. They were interested to determine which battery chemistry and which manufacturer performed better and what affects the charging cycle has on the expected lifetime of the battery cell.

The cells were charged and discharged continuously using a charging rig. The rig cycles a cell through four stages; charge, rest, discharge, rest, and then repeats. The charging cycle is defined by the charging and discharging voltages which are selected at the start. During my work I observed about 600 cycles and 3 different charge/discharge regimes.

I chose to examine how the discharge capacity declined over time as this is an indicator of the expected life of the battery.

Charging and Discharging process

Rechargeable batteries are both galvanic and electrolytic depending on the state of charge. In the ISF Academy, the solar power harnessed from the rooftop is stored within batteries through the electrolytic cell, which converts electricity to potential chemical energy, a non-spontaneous redox reaction. The batteries supply power to some classrooms and to the cafeteria's frozen storage on weekends, where chemical energy is converted into electricity through a spontaneous redox reaction driven by the galvanic cell.

Essentially, the reaction in the electrolytic cell (charging) can be reversed by the reaction in galvanic cell (discharging), and vice versa, meaning that the reactants and products constantly switches back and forth. ("Can Redox Reactions Be Reversed?")

The electrolyte contains lithium cations, meaning that they are missing an electron. When the battery is completely drained, all the lithium ions stay on the positive electrode. When the battery is plugged to a electric source, the lithium ions starts moving towards the negative electrode in order to gain electrons (reduction reaction happens). ("About.") In this state, the battery is an electrolytic cell, meaning that it converts electrical energy into chemical energy. The redox reaction is not spontaneous and electrical energy is required in this process. The reaction is exothermic.

Once all the lithium ions have gained an electron in the negative electrode and therefore gained energy, the battery is at a full state of charge. If the battery is then used in a circuit, a pathway would form and therefore the electrons that have been built up in the negative electrode will flow through the negative electrode to the positive electrode. The flow of electron creates a current and charges the device. This causes the lithium to lose electrons (oxidation reaction happens), becoming cations again and moving towards the positive electrode. ("About.") Note that in this state the battery is a galvanic cell which converts chemical energy into electrical energy. The redox reaction is spontaneous and electricity is not required to start it. The reaction is endothermic.

Conclusions

The figures show the decreasing capacity of the BAK and EVE cells for three different charge/discharge cycles. The slope of the line of best fit indicates the rate of decay of the cells' capacity which is an indicator of its lifespan.

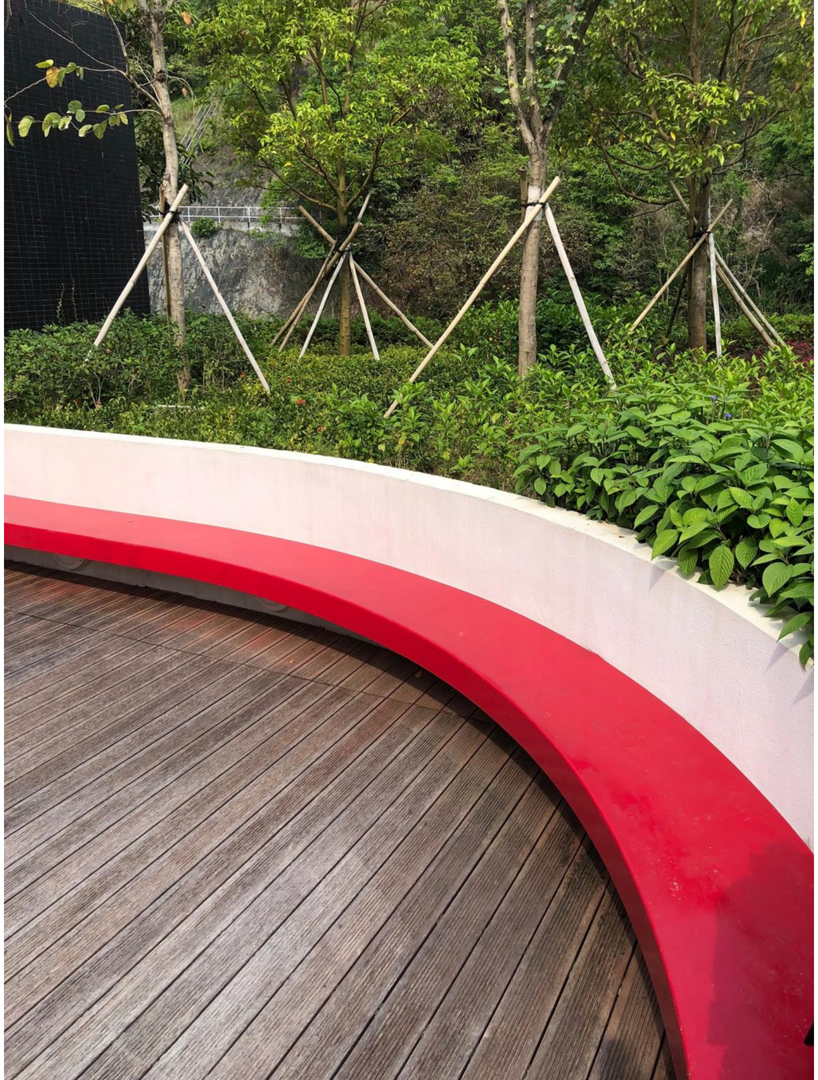
The EVE cell performs better than BAK in regime 1 and 2 (low discharge voltage), but worse in regime 3 (high discharge voltage).

Comparing the two regimes in figures 1 and 2, the only difference is the discharging voltage. The slope of the lines is higher for both BAK and EVE in figure 2 which suggests that the higher discharging voltage causes the lifespan to deplete faster. The capacity of the BAK cells depletes faster than the EVE cells in both cases. Another interesting point is how in testing system 1, the capacity of the BAK cell starts to decay at a much faster rate at around 610 cycles. This supports the secondary research I have done which indicates that cells with the NCA chemistry usually have around 500 cycles.

Clearly charge and discharge voltage effects the lifespan and different cell chemistries perform differently under different duty regimes but it is difficult to generalise based on this data.

References and acknowledgements:

Biodiversity Garden
生物多樣性花園



Recycling
資源回收

Indoor Air Pollution
室內空氣污染

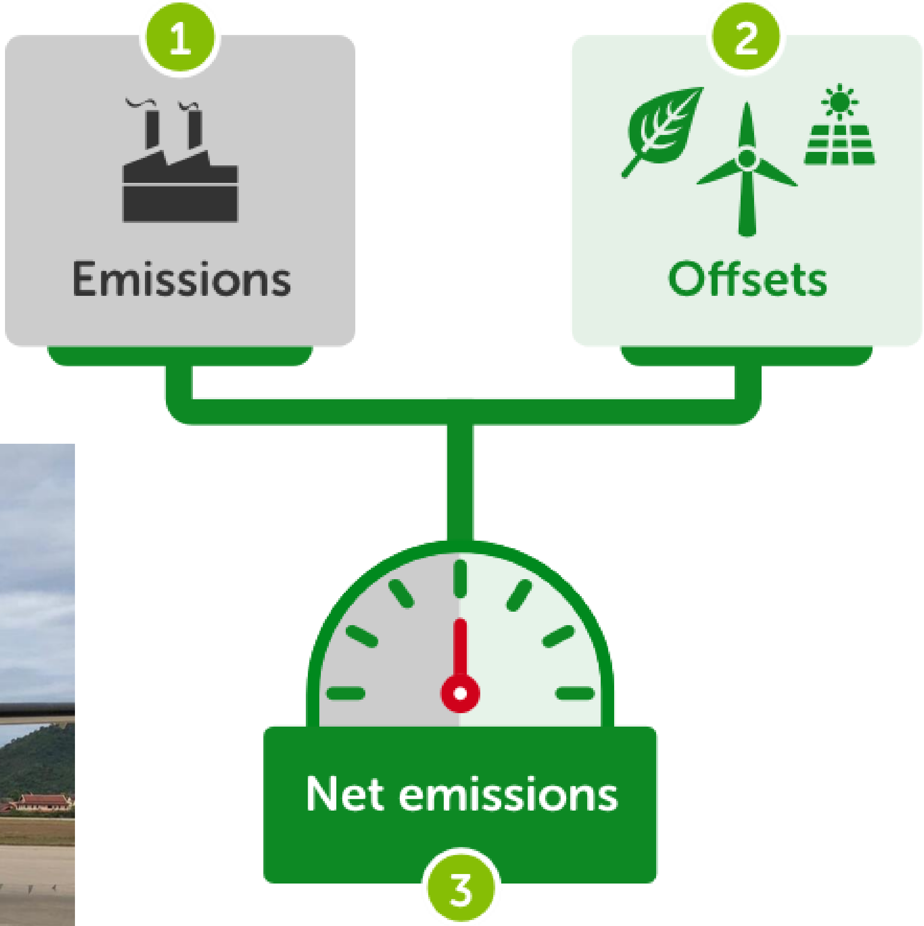
Outdoor air pollution
戶外空氣污染

Green Rooftops

Textile waste - upcycling, art, clothing re-design
紡織品回收 -
升級再造變成藝術
衣物重生

Carbon Offsetting

Students going out on ELP!

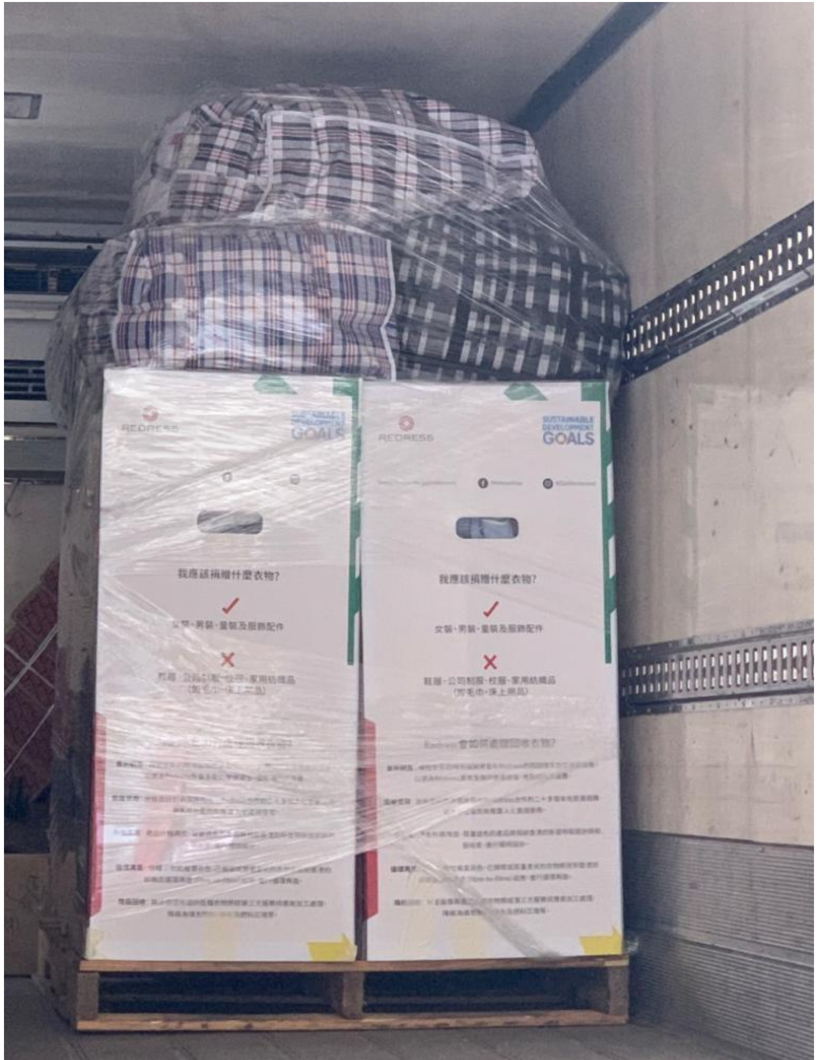


Student-focused Events

School-wide events that are often initiated and mostly organized by student to raise awareness about various sustainability-related issues...

Textile Waste - Student Clothing Drive

REDRESS



Swimming with Plastic Week (Oct 21-25)!

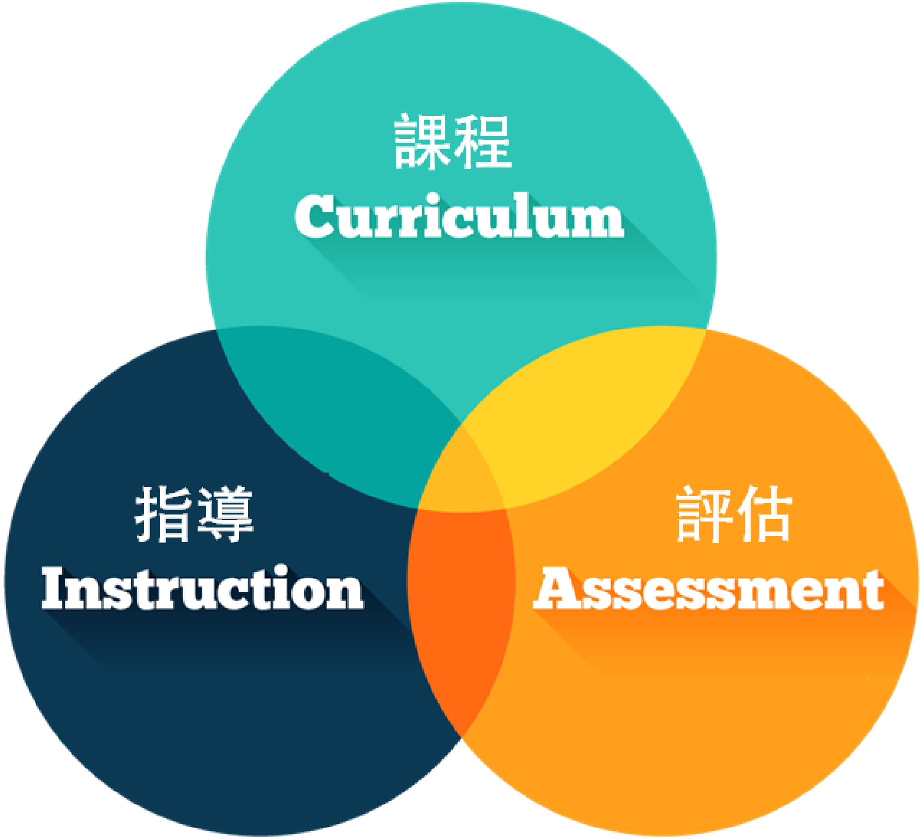
How we do it

After/while optimizing our resources, we are mobilizing a large team to both carry out the day-to-day implementation as well as how these efforts reach students at the curriculum level to ultimatly influence personal practices...

Sustainability Audit
可持續發展審核

Sustainability Council
可持續發展委員會

Sustainability Stewards
可持續發展護育者



Green Guardians
環保守護者