MODULE VI

Lesson Plan 2

Summary

Title

Batteries and differences between their technologies

Duration	45 minutes
The age range of students	10 to 14 years

Summary of the theme

This topic aims to present the main types of batteries available today, emphasising how they work. A battery will be built with a lemon to better explain and understand how they work.

Learning outcomes

Aim/Learning Objectives.

- Understand the basic operation of a battery.
- To know the electrical concepts of a battery.
- Current battery types.
- Implementation of a functional stack from a lemon.

Cross-cutting objectives

- Develop environmental awareness and ecological responsibility.
- To know how batteries work and the differences between the different technologies.
- Promote the use of clean and sustainable energies.

Connection with Sustainable Development Goals

This theme is aligned with SDG 7 "Ensure access to affordable, secure, sustainable and modern energy" - Target 7.2 By 2030, significantly increase the share of renewable energy in the energy mix; and Target 7.3 By 2030, double the global rate of improvement in energy efficiency.
This theme is aligned with SDG 12 "Ensure sustainable consumption and production patterns" - Target 12.2 By 2030, achieve sustainable management and efficient use of natural resources.

Implementation

Facilitation

- Make sure all resources are ready before the class.
- Make sure you always use recyclable or recycled materials.
- Promote an atmosphere of collaboration and respect for the environment.
- Remember that the students and the classroom may get a little dirty.

Resources / Materials needed

- Lemon.
- Zinc nails.
- Copper cable.
- Polymeter.

Ideas to continue

- Battery Recycling Project: Encourage students to investigate the impact of battery waste on the environment and design a small recycling campaign in their school. They can create posters, research proper recycling methods, and even calculate the energy savings from recycling batteries.
- Building Advanced Batteries: As an extension of the lemon battery experiment, students could explore building batteries using different materials (e.g., potatoes, salt water, or other fruits). Have them compare the voltage and efficiency of each battery type and discuss why different materials yield different results.
- Class Debate on Battery Use in Society: Divide the class into two groups: one arguing for the benefits of widespread battery use in modern society (e.g., for electric vehicles, mobile phones, etc.) and the other highlighting the environmental and ethical concerns (e.g., resource extraction, waste management). This activity fosters critical thinking and communication skills.

These activities will help students deepen their understanding of the role of batteries in modern society and encourage them to think critically about sustainability and energy use.

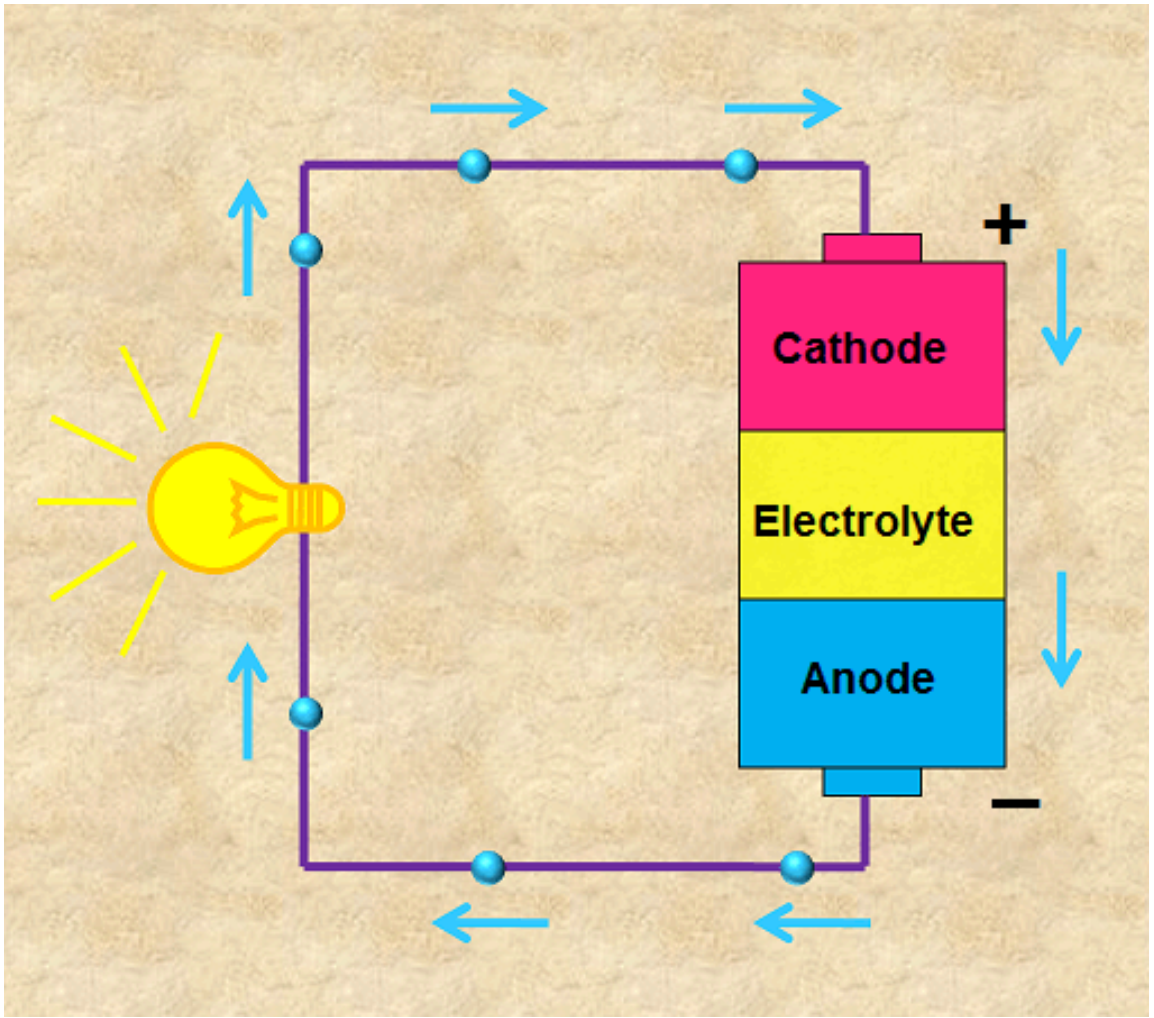
Source / Classroom materials and preparation

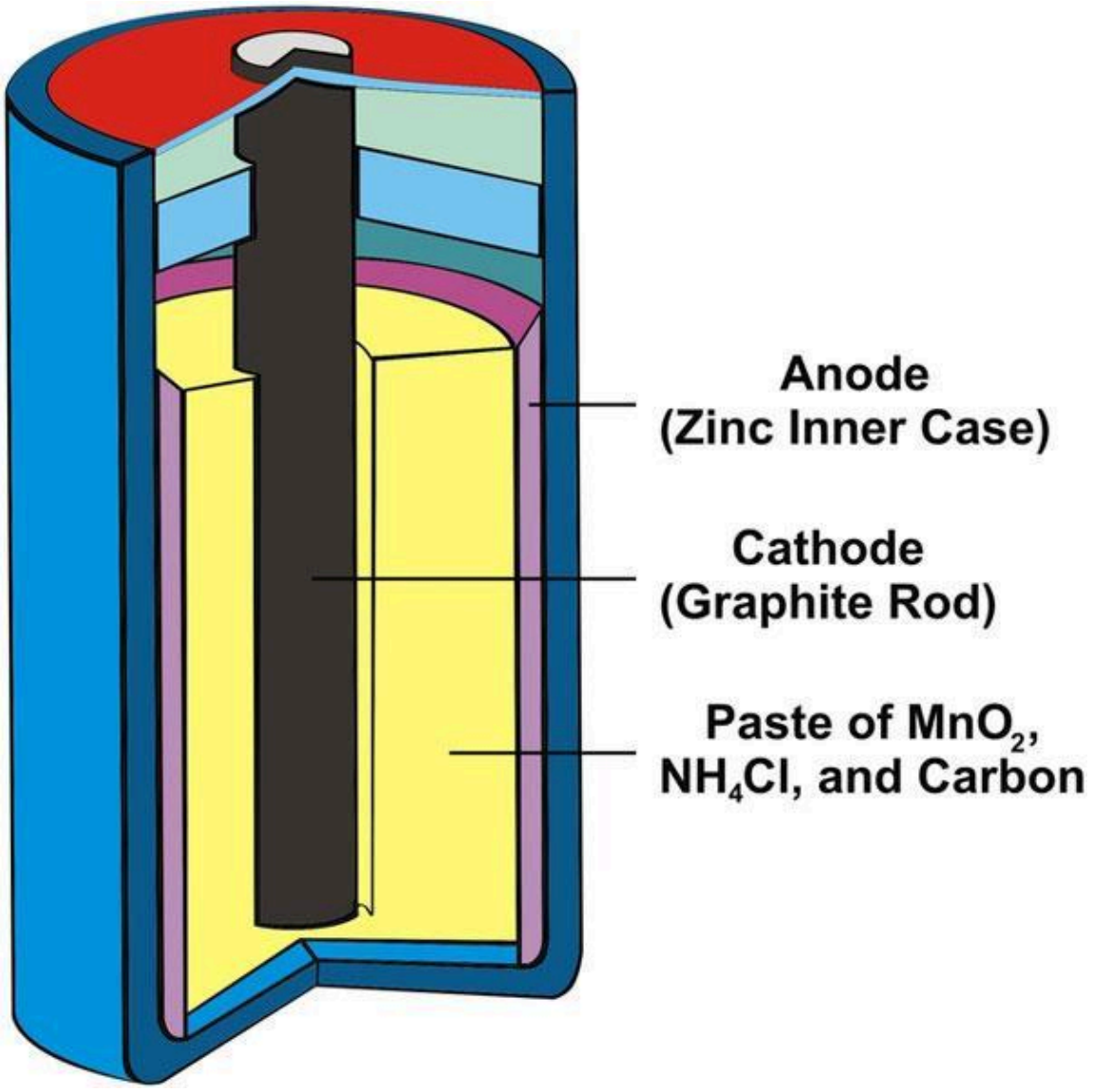
Videos used for the construction of the lemon stack:

https://www.youtube.com/watch?v=GhbuhT1GDpI

https://www.youtube.com/watch?v=yljtkcnWp4I

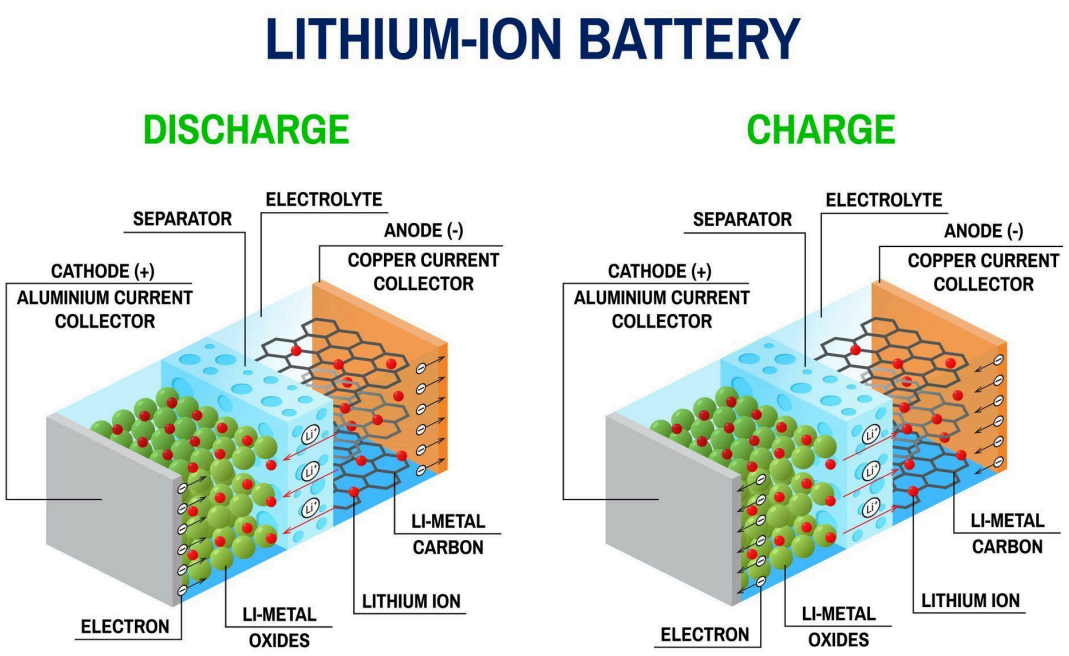
Topic outline

Timing	Step-by-step instructions
5 min.	Introduction to the subject: To present the topic's objectives, emphasise the importance of batteries in today's society. As a technological society, we consume much more electrical energy than previous societies, and not only do we need to have a backup for that energy, but we also use a lot of portable devices.
5 min.	The basic operation of a battery: Inside the batteries, a chemical reaction takes place, causing the anode (negative pole) to release electrons, which are directed to the cathode (positive pole).  https://www.physics-and-radio-electronics.com/blog/wp-content/uploads/2016/10/battery.png Note that, by convention, the direction of the current is set in the direction from the positive to the negative pole, but that is the opposite direction to the flow of electrons. The electrolyte allows the chemical reaction to be completed but does not allow the electrons to pass internally from the anode to the cathode; they are forced to go through the external electrical circuit.



https://blog.upsbatterycenter.com/wp-content/uploads/2014/04/dry-cell-battery.jpg

The fundamental difference between a cell and a battery is that, in a battery, when all the available electrons have passed from the anode to the cathode, the battery is said to be depleted and needs to be replaced. However, in a battery, this situation can be reversed by a process of "charging", which can be understood as the opposite process; the anode acts as the cathode and the cathode as the anode, and the initially available electrons can be recovered.

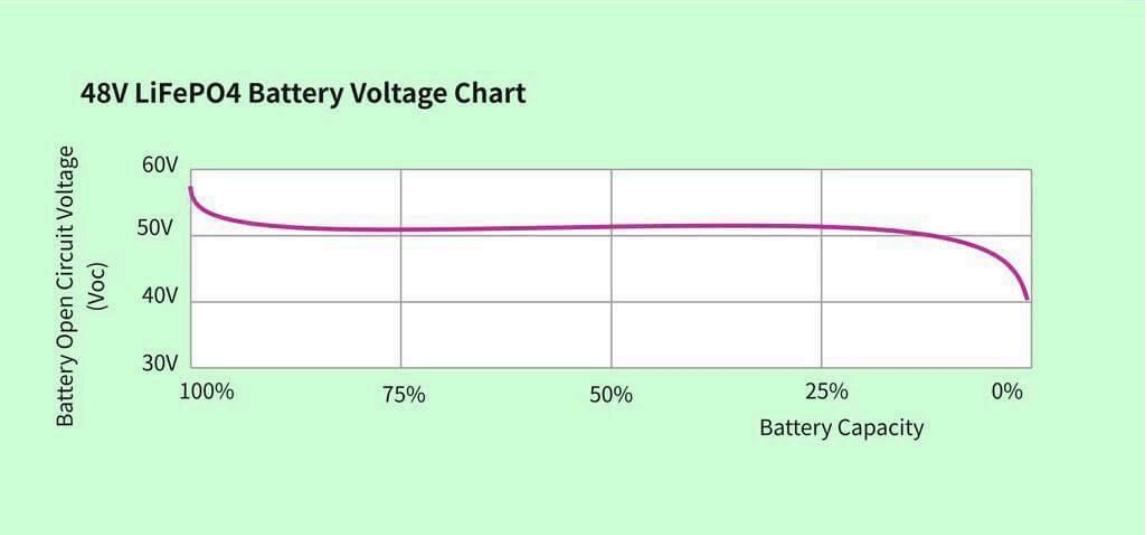


https://www.electricbee.co/content/images/2022/02/lithium-ion-battery-diagram-01.jpg

10 min.

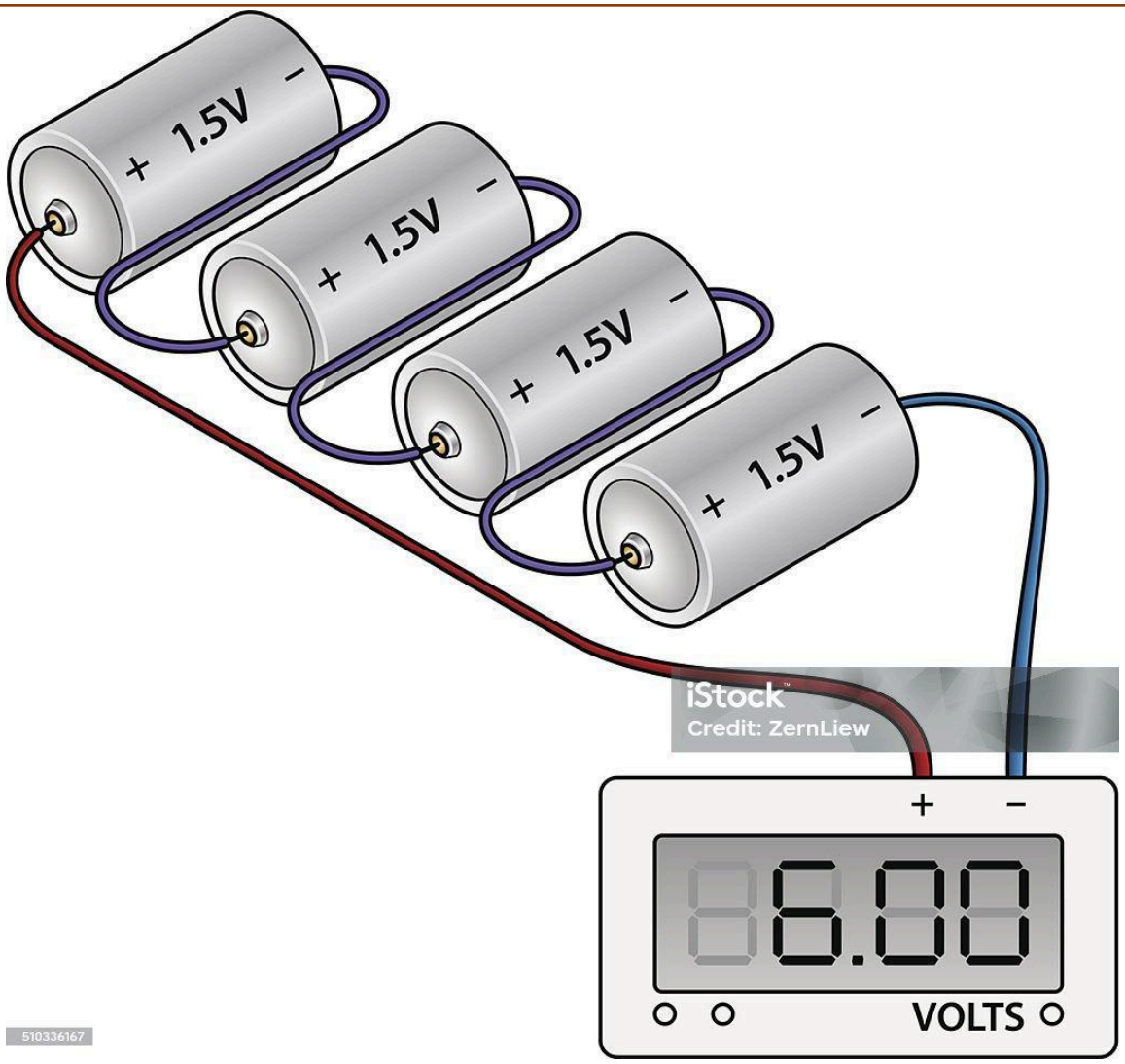
Electrical concepts of a battery:

The electrical parameters of a battery are voltage, peak current, and capacity. The voltage of a battery is assumed to be a parameter that remains constant but varies as the battery is depleted.



https://appbattery.com/wp-content/uploads/2023/12/48V-lifepo4-battery-voltage-chart.jpg

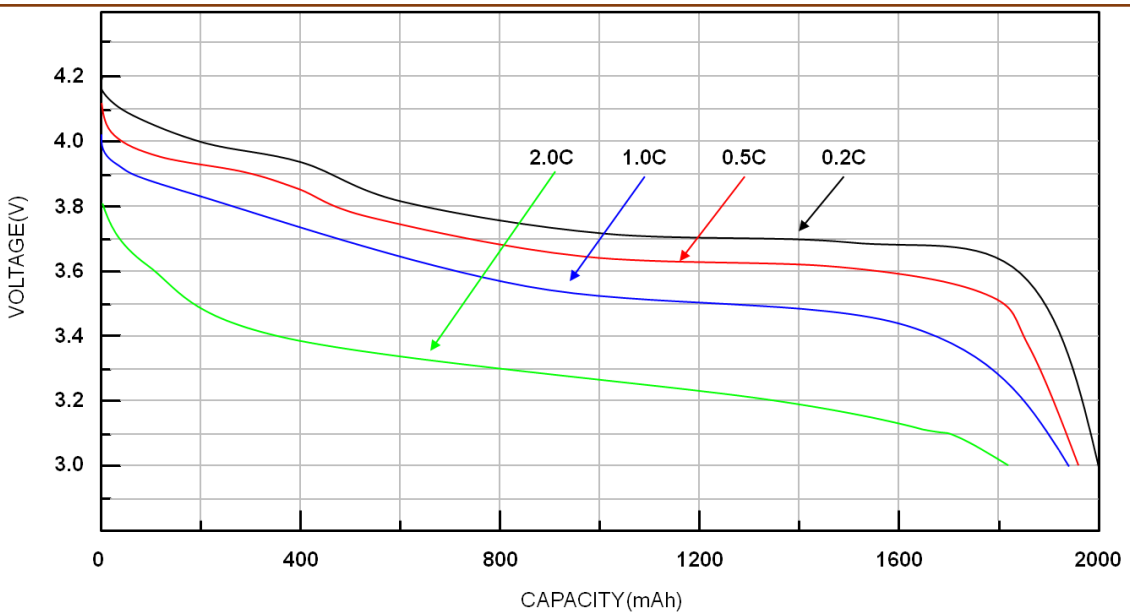
The battery's voltage value depends on the cell type (basic unit) used for the battery's construction. For example, we can find voltages of *1.4*, *1.5*, *3*, *3.6, etc.*... depending on the chemical reaction taking place in the cell. To achieve higher voltage values, several cells are connected in series.



https://media.istockphoto.com/id/510336167/es/vector/diagrama-de-conexi%C3%B3n-de-bater%C3%ADa.jpg?s=1024x1024&w=is&k=20&c=5TjyK7f5EWc_PUQd08vu7_lk58ftJmsE75SlNivth1w=

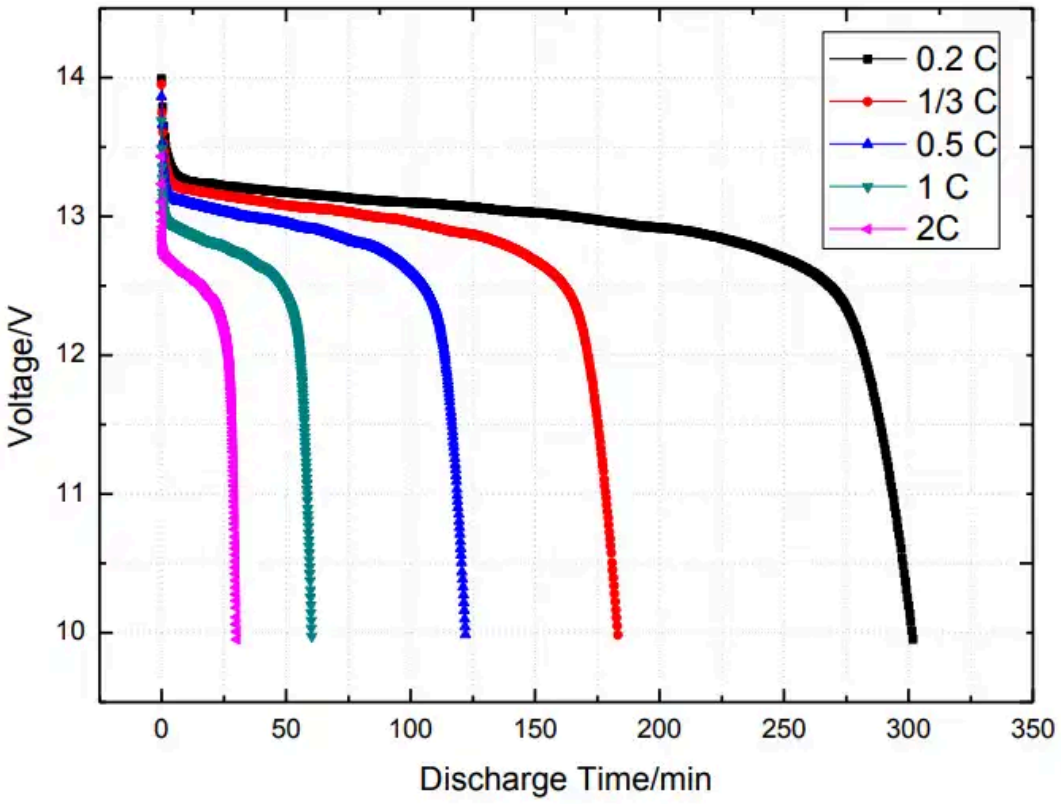
About current, batteries cannot supply an infinite current; they are limited to a maximum value that manufacturers advise never to exceed. This value is related to the capacity of the battery, defined as the capacity to supply a constant current over time, and is typically measured in Ah. For example, a 1,200 mAh battery can supply 1.2 A for 1 hour.

Manufacturers relate the maximum current of the battery to the capacity of the battery through the parameter "*C*", which indicates the percentage of the capacity. For example, if the 1,200 mAh battery has a parameter C=2, we can obtain a current of 2.4 A at its output ($2 \cdot 1{,}200 - 10^{-3}$). It is usual for batteries to have different "*C*" parameters for charging and discharging; they are usually charged at less current than they can be discharged. Although the battery voltage is assumed to be constant, it can vary depending on the current, the higher the current, the lower the voltage.



https://www.batterypowertips.com/wp-content/uploads/2021/06/Battery-voltage-capacity-and-C-rate.png

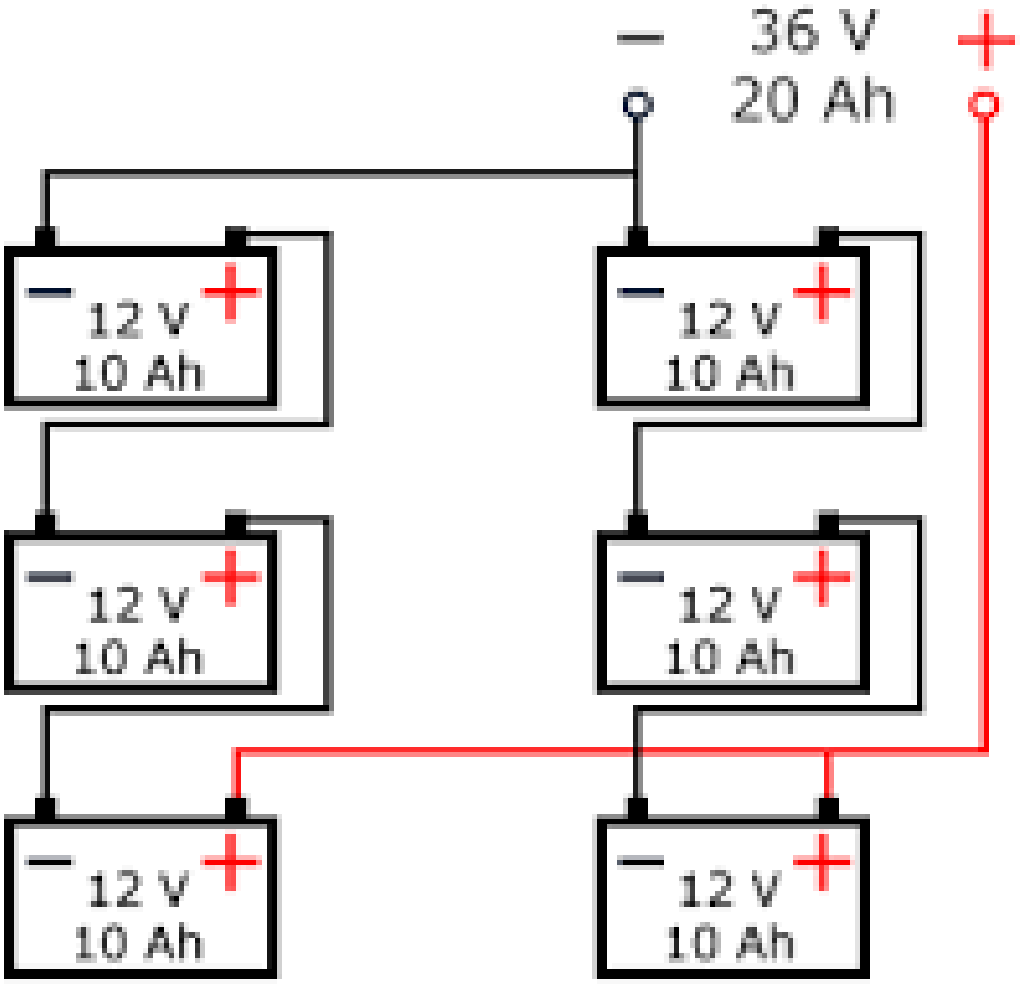
It is also worth noting that the battery runs down faster when discharged with more current. For example, those mentioned above 1,200 mAh battery will last 1 hour if discharged at 1.2 A ($1.2 \cdot 1 = 1{,}200 \cdot 10^{-3}$), half an hour if discharged at 2.4 A ($2.4 \cdot 0.5 = 1{,}200 \cdot 10^{-3}$), and 4 hours if discharged at 300 mA ($300 \cdot 10^{-3} \cdot 4 = 1{,}200 \cdot 10^{-3}$).



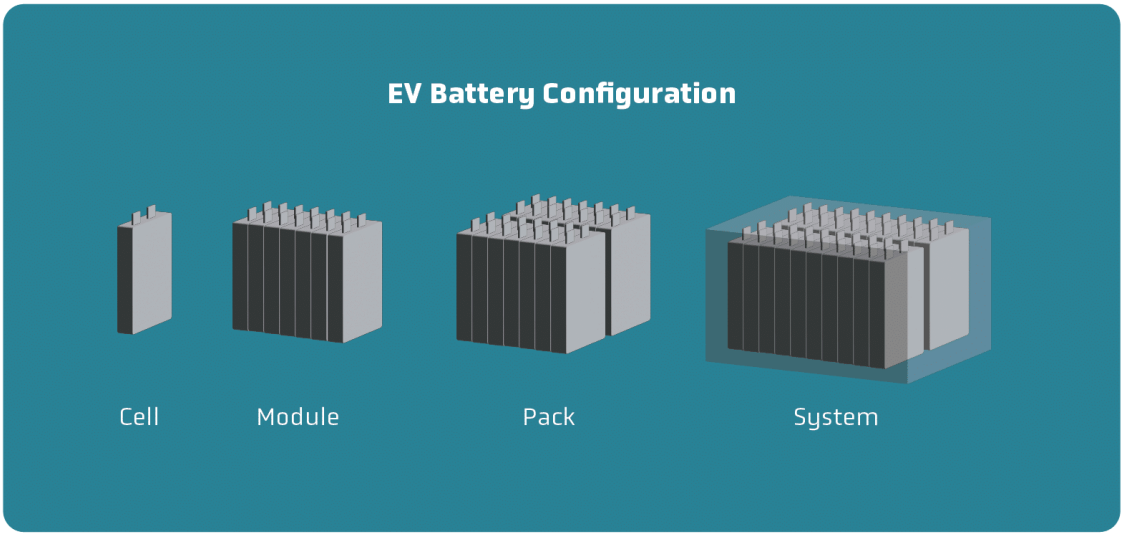
https://www.bravabatteries.com/wp-content/uploads/2022/11/Different-Rate-Discharge-Curve.webp

As mentioned with the voltage, if you want to increase the current that the battery can supply, you would have to connect more batteries, in this case, in parallel, to increase the total current. Hybrid connections, both series and

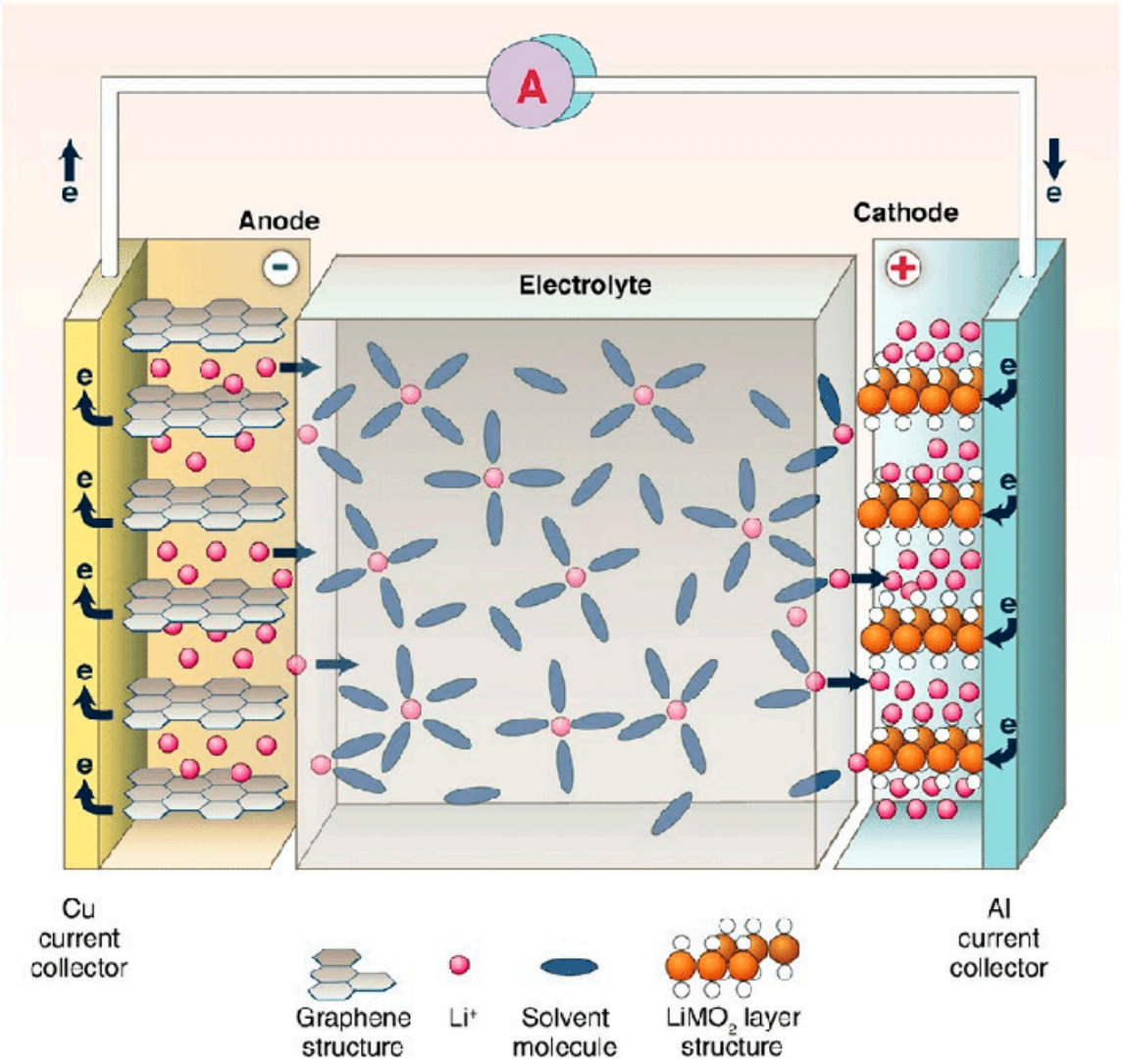
parallel, are normally made to obtain the necessary parameters for each application.

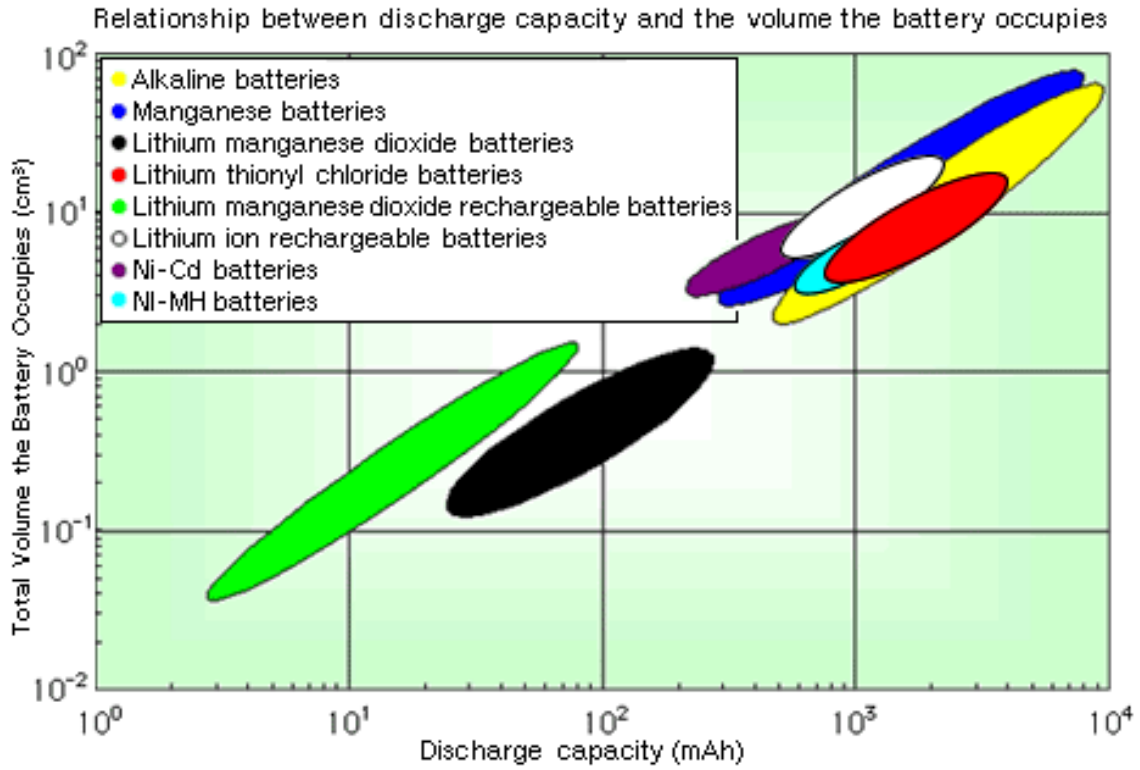


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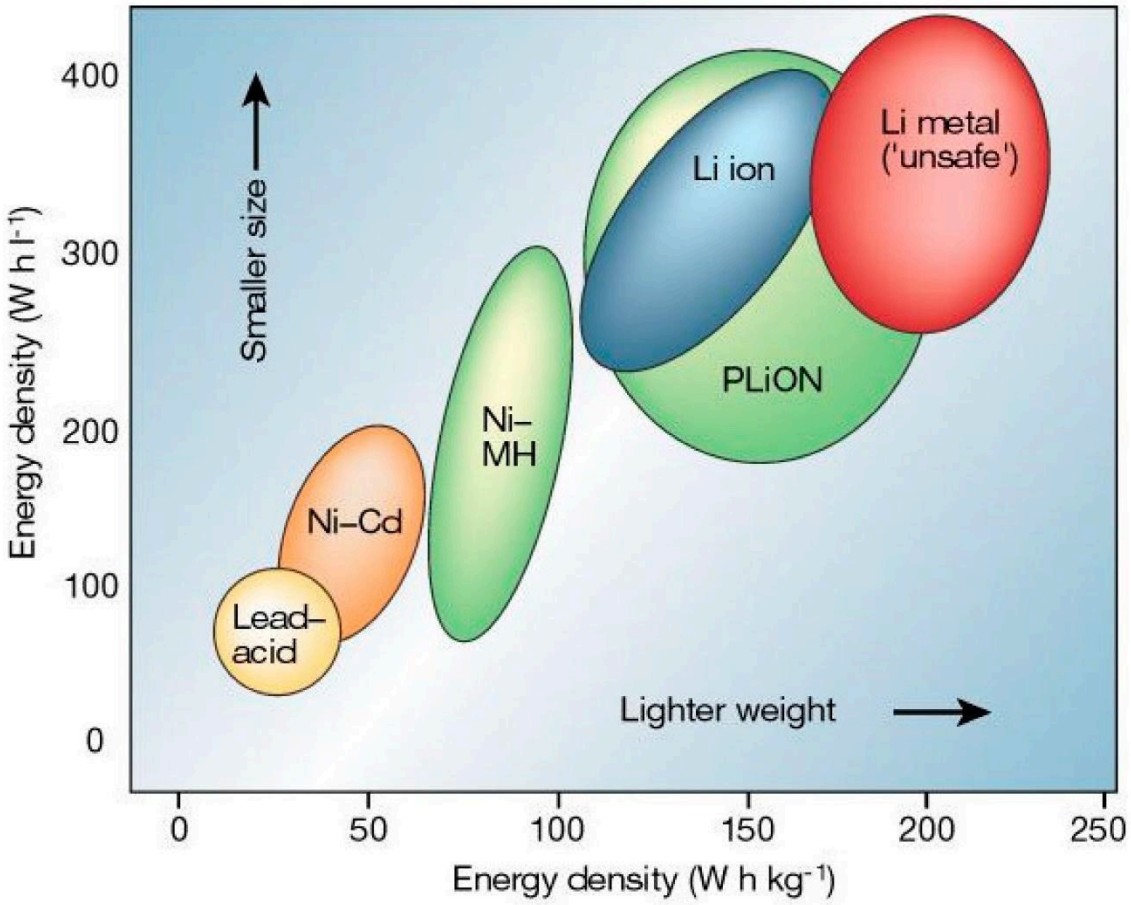
https://www.quantumscape.com/wp-content/uploads/2023/12/EV-Battery-Config.png

10 min.	Battery types: Battery types are classified according to the chemical reaction that takes place inside the battery to generate the flow of electrons. For example, the picture below shows a reaction scheme in a lithium-ion battery (lithium ions move within the electrolyte from the anode to the cathode).  https://www.researchgate.net/publication/332326791/figure/fig2/AS:746140047790080@1554905058079/Schematic-diagram-of-an-intercalation-Li-ion-rechargeable-battery-Most-commercially.png Each type of battery has better specifications than others; for example, the following image shows a comparison between the battery's volume and capacity, depending on the type of battery.



https://biz.maxell.com/en/primary_batteries/cap_vol_illust.gif

Another interesting comparison would be the volumetric energy density concerning the energy density by weight shown in the image below.



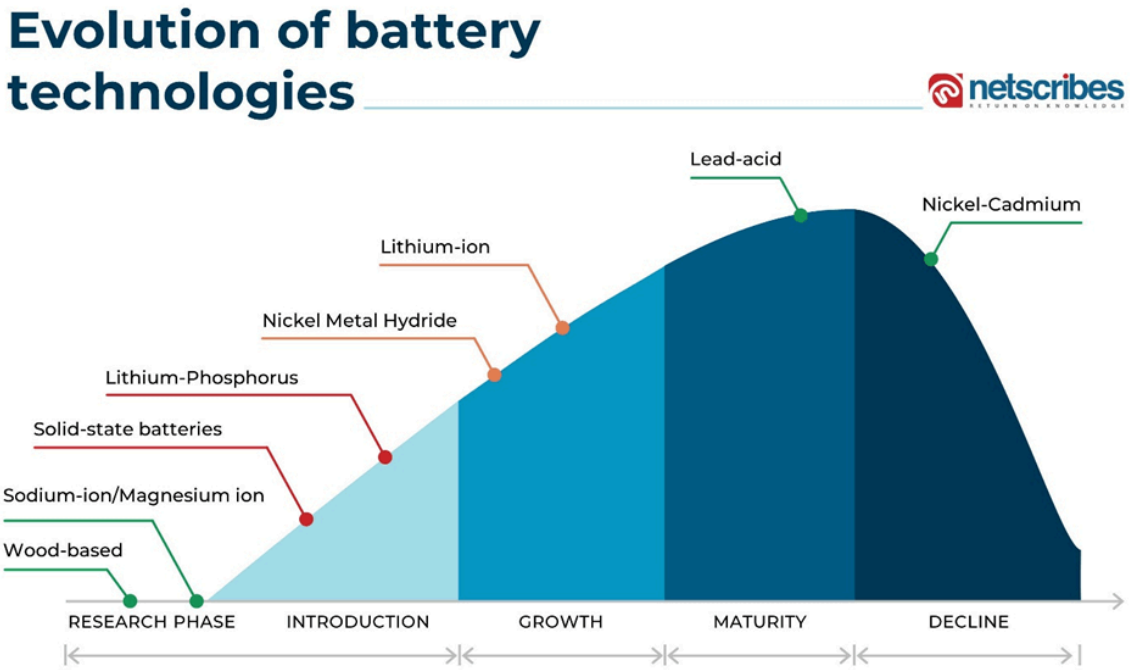
https://www.mdpi.com/energies/energies-12-01074/article_deploy/html/images/energies-12-01074-g001.png

Despite the above, the parameters that make the most difference between the different types of batteries would be the number of charge-discharge cycles that can be done to the battery, and the *Depth of discharge* (DOD) that

can be done in those cycles. Depth of discharge indicates how much capacity we can use (of the battery) without causing excessive degradation of the battery; for example, a depth of discharge of 80% means that we will discharge the battery (at most) to 20% (starting from a fully charged battery). Battery life is related to this very important parameter since, for example, we can find lead acid batteries that allow only 500 discharge cycles with a DOD of 100%, 1,000 cycles with a DOD of 60%, and up to 1,400 cycles with a DOD of 40% (https://www.victronenergy.com.es/upload/documents/Datasheet-Lead-carbon-battery-ES.pdf).

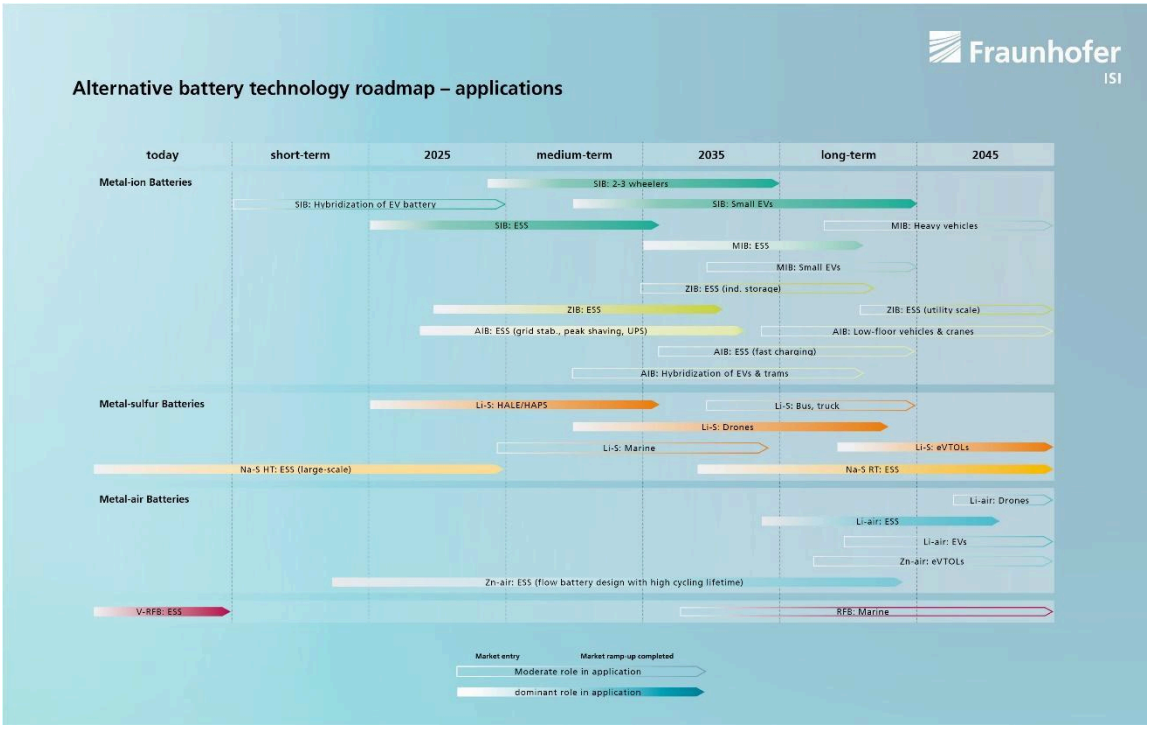
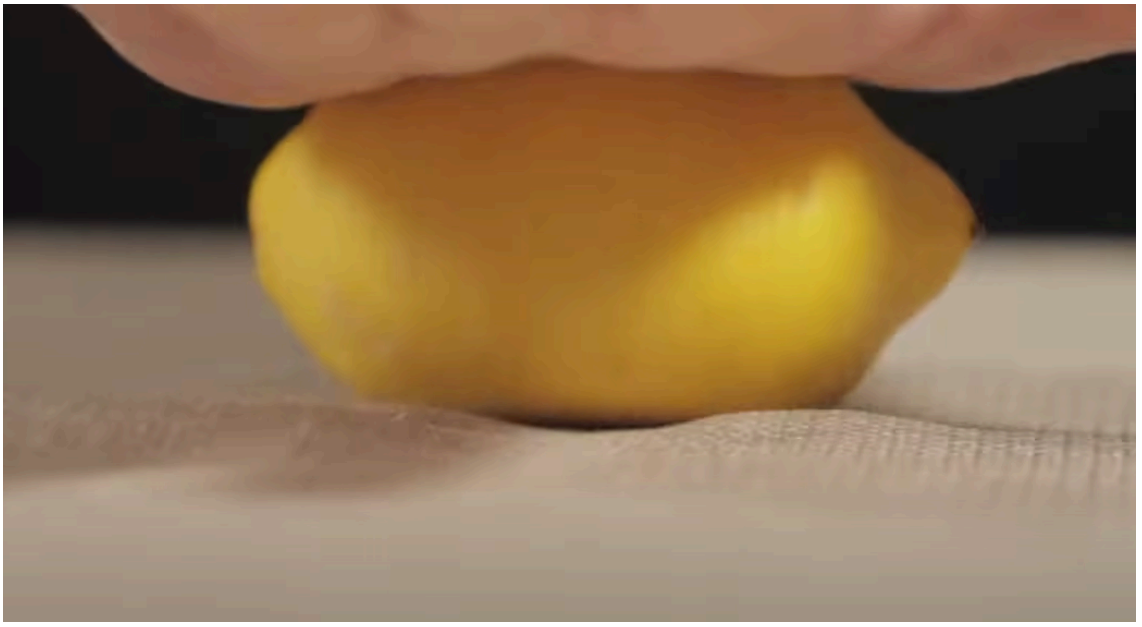
To compare other technologies, lithium batteries from the same manufacturer would allow 2,500 cycles at 80% DOD, 3,000 cycles at 70% DOD, and up to 5,000 cycles at 50% DOD (https://www.victronenergy.com/upload/documents/Lithium_Battery_Smart/15958-Manual_Lithium_Smart_Battery-pdf-es.pdf); while the values for AGM batteries would be 300 cycles at 100% DOD, 700 at 60% DOD, and 1,000 at 40% DOD (https://www.victronenergy.com.es/upload/documents/Datasheet-AGM-Super-Cycle-battery-ES.pdf).

Battery technologies are constantly changing, with new ones appearing over time. In the image below, you can see some of the technologies and their degree of maturity.



https://www.netscribes.com/wp-content/uploads/2022/10/image-2.png

In conclusion, regarding the different battery technologies, and not to go into too much detail, the main functional difference is in the number of cycles and the allowable depth of discharge; however, there is also a big difference in the weight and volume that each type of battery has and occupies for a specific capacity (a fact to take into account for, for example, mobile applications).

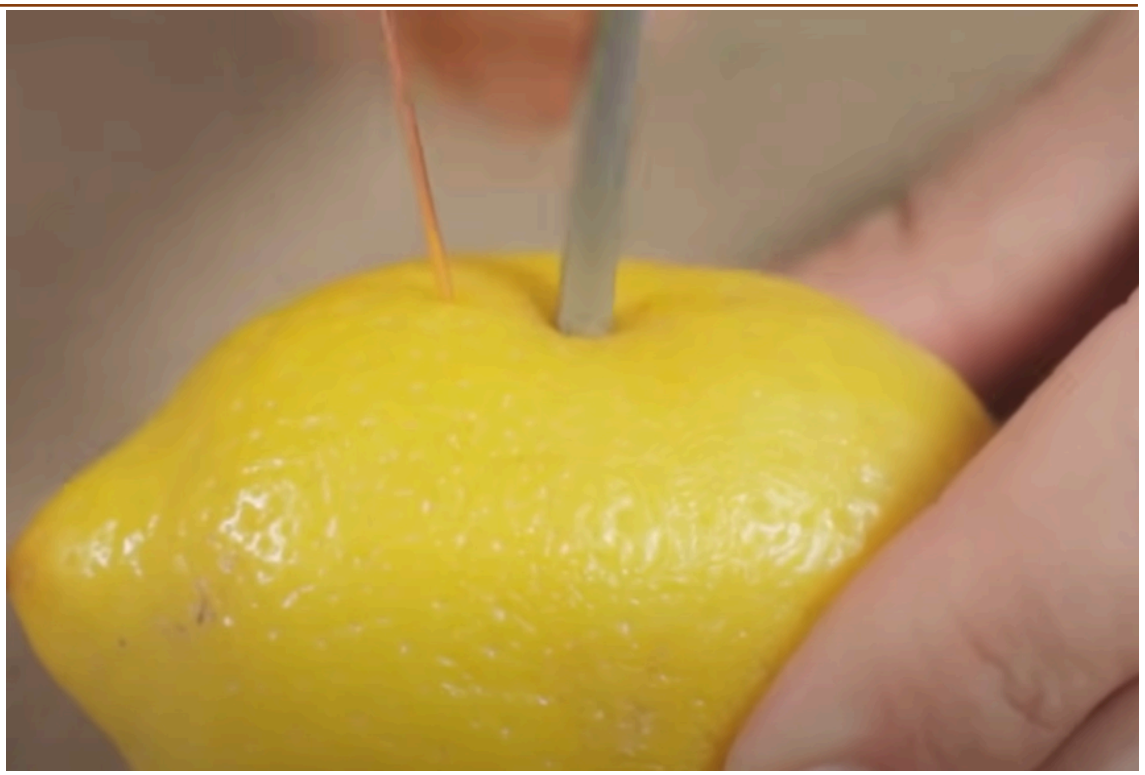
	The following image shows a possible evolution of batteries, where technologies that have not yet been developed but are expected to be applied in the future are shown.  https://www.isi.fraunhofer.de/en/blog/themen/batterie-update/alternative-batterie-technologien-lithium-ionen-potenziale-herausforderungen/jcr:content/fixedContent/pressArticleParsys/wideimage/imageComponent/image.img.jpg/1724654958781/applications-alternative-battery-technologies-roadmap.jpg
15 min.	Implementation of a functional stack: For the implementation of a lemon-based stack, the steps in the video are as follows: https://www.youtube.com/watch?v=GhbuhT1GDpI The typical phrase is: "*If life gives you lemons, make lemonade*"; but here it will be changed to: "*If life gives you lemons, make a cell battery*". - Concept: The electricity is not in the lemon; the lemon is the electrolyte. - We roll the lemon to break up the inner plant tissues and juice the inside. - 

- Insert a zinc or galvanised nail into one side of the lemon.

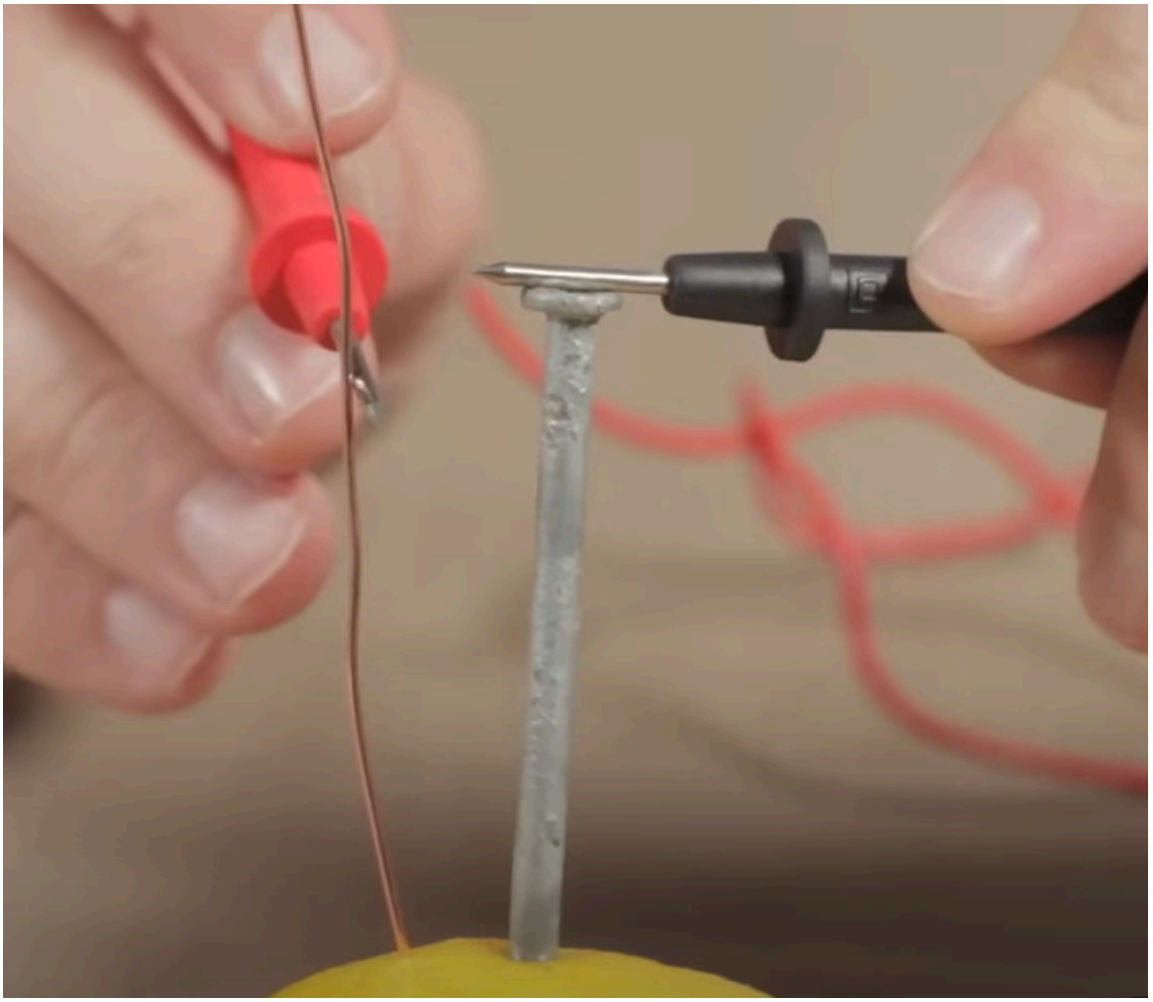


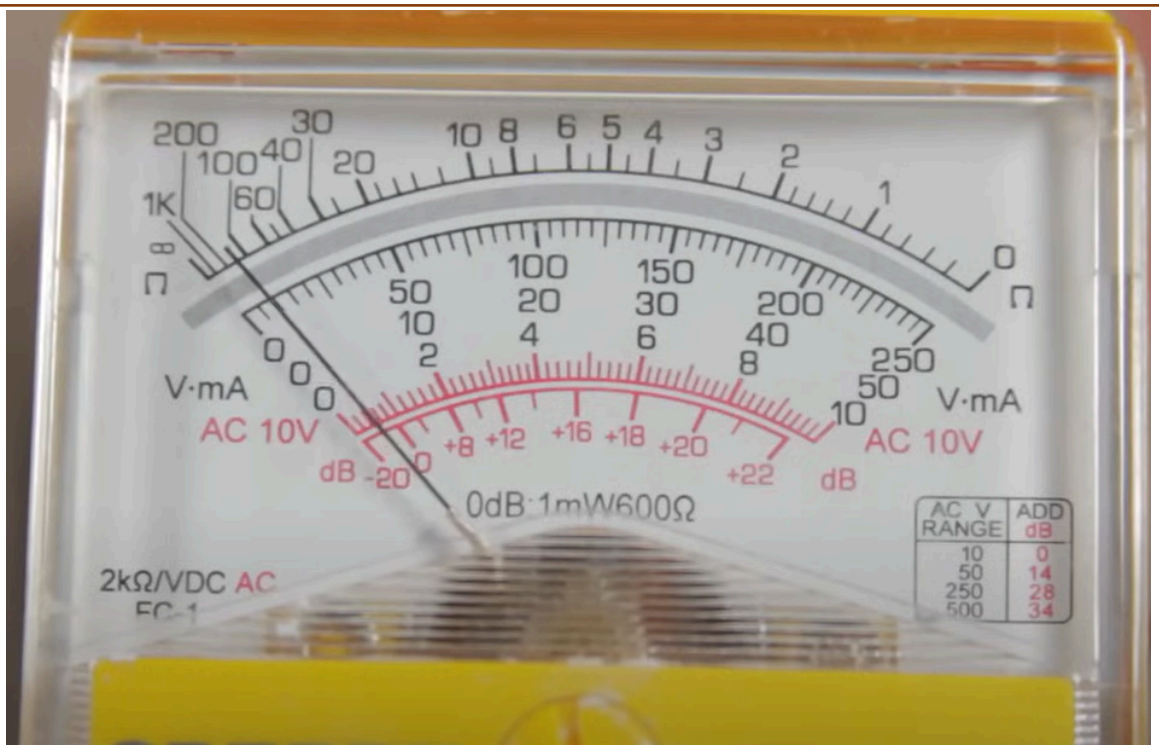
- Insert a copper nail or a piece of copper wire on the other side.



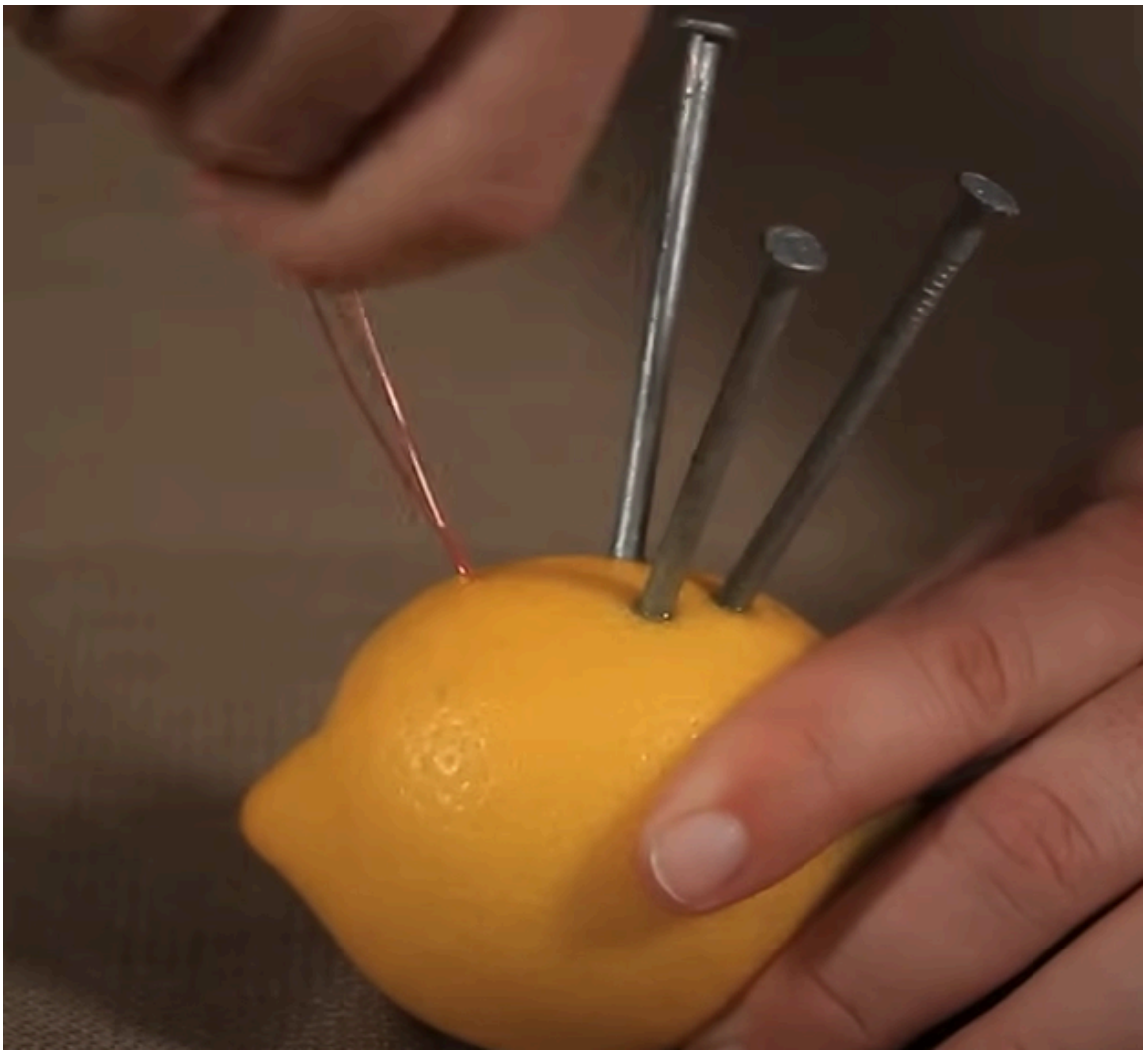
- 

At this point, we can check the voltage on our battery using a multimeter.





- Copper is the cathode (negative electrode), and zinc is the anode (positive electrode). The electrolyte is citric acid from lemon.
- To increase the voltage of our battery, we could connect several batteries in series, but it is sufficient to increase the amount of zinc and copper.





- The largest battery of this style (2,307.8 V) can be seen at: https://www.youtube.com/watch?v=IMc7HQj3gVE






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Formative evaluation

For this theme, essentially a single formative assessment tool is proposed:

- Group discussion:
  Description: Divide students into groups to discuss specific topics and then share their findings with the class.

  Example: Ask each group to find information on a particular technology, such as depth of discharge, number of cycles, weight, and size, and then compare the data with their peers.

Feedback

This example is proposed (you can adapt/modify):

Net Promoter Score (NPS) is a widely used tool to measure the loyalty and satisfaction of customers or, in an educational context, students. It measures the likelihood that students will recommend the subject or course to others.
How to analyse and apply NPS is explained below:

Development of the NPS question:

- Main question: "On a scale of 0 to 10, how likely are you to recommend this topic to other students?
- Follow-up questions: "Why did you select this score?" and "How can we improve this issue?

Collection of responses:

- Digital surveys: Use online tools such as Google Forms, SurveyMonkey, or Typeform to collect student responses.
- Paper surveys: Paper questionnaires are handed out at the end of the lesson for students to complete. A template for collecting responses with paper surveys is shown in the Annex.
- Interactive applications: Interactive applications such as Quizziz, Mentimeter, or Kahoot! are used to collect answers in real-time.

Classification of responses:

- Promoters (Score 9-10): Students are very satisfied and likely to recommend the subject.
- Passive (score 7-8): Satisfied, but not enthusiastic students; they could easily change their minds.
- Detractors (Score 0-6): Dissatisfied students who are unlikely to recommend the subject; they could provide constructive criticism.

Calculation of NPS:

- Formula: NPS = % of promoters - % of detractors.

- Score interpretation: NPS ranges from -100 to +100. A positive score (above 0) is generally good, and a score above 50 is excellent.

Analysing and using comments:

- Review the comments to understand the reasons behind the scores.
- Identifies patterns and specific areas for improvement among detractors and passives.
- Use the promoters' positive comments to reinforce the positive aspects of the issue.

Annexes

Include in this section all resources to be used/printed/used during the development of the topic (including formative assessment). Examples: Plans, Maps, Tables, Questionnaires, Graphs, etc.

QUESTIONNAIRE TO COLLECT FEEDBACK ON THE TOPIC

On a scale of 0 to 10, how likely would you recommend this subject to other students?

0	1	2	3	4	5	6	7	8	9	10

Not likely at all — Extremely likely

Why did you choose that score?

How could this issue be improved?