
Fires Involving Batteries of Electric Bicycles, Personal Mobility Devices, Powerbanks and Laptops (2008 – 2015)

The Singapore Civil Defence Force (SCDF) responds to all reported fires in Singapore for firefighting and fire investigation. The archiving of detailed records for all these fires has enabled these studies for the purposes of public education and fire prevention.

The SCDF Fire Analysis Report series aim to make sense of similar fires seen over the years. Each report will provide details on the trends, patterns and other findings from the analysis of a specific type of fire or fire-related topic. Relevant examples of actual fire incidents will also be presented. In addition, fire safety tips or references to sources of information relating to fire prevention will be provided.

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Key Findings

- Batteries of consumer products were involved in about 52.7% of all battery fires in Singapore from 2008 – 2015. Among these, batteries of electric bicycles were the most prevalent, followed by powerbanks.
- About 90.6% of electric bicycle battery fires in Singapore occurred in the last 4 years.
- The first powerbank fire in Singapore was reported in 2013. In the following year, there were 6 cases.
- 62.5% of the powerbank fires occurred while the powerbank itself was being charged.
- Laptop battery fires were generally rare with 3 reported cases between 2008 and 2015. In all 3 cases, the laptops were operating on either the bed or sofa.

Battery Fires

There are 95 battery¹ fires² in Singapore from 2008 – 2015. As shown in **Figure 1**, there were slightly more fires involving batteries of consumer products than those of equipment with commercial and industrial applications. Amongst the consumer products, fires involving the batteries of electric bicycles were most prevalent, constituting 34.7% of all the battery fires reported between 2008 – 2015. This is followed by powerbanks at 8.4%.

¹ A battery comprises 1 or more cells where each is an electrochemical unit that can convert chemical energy to electrical energy [1]

² Excluding fire involving batteries of motor vehicles

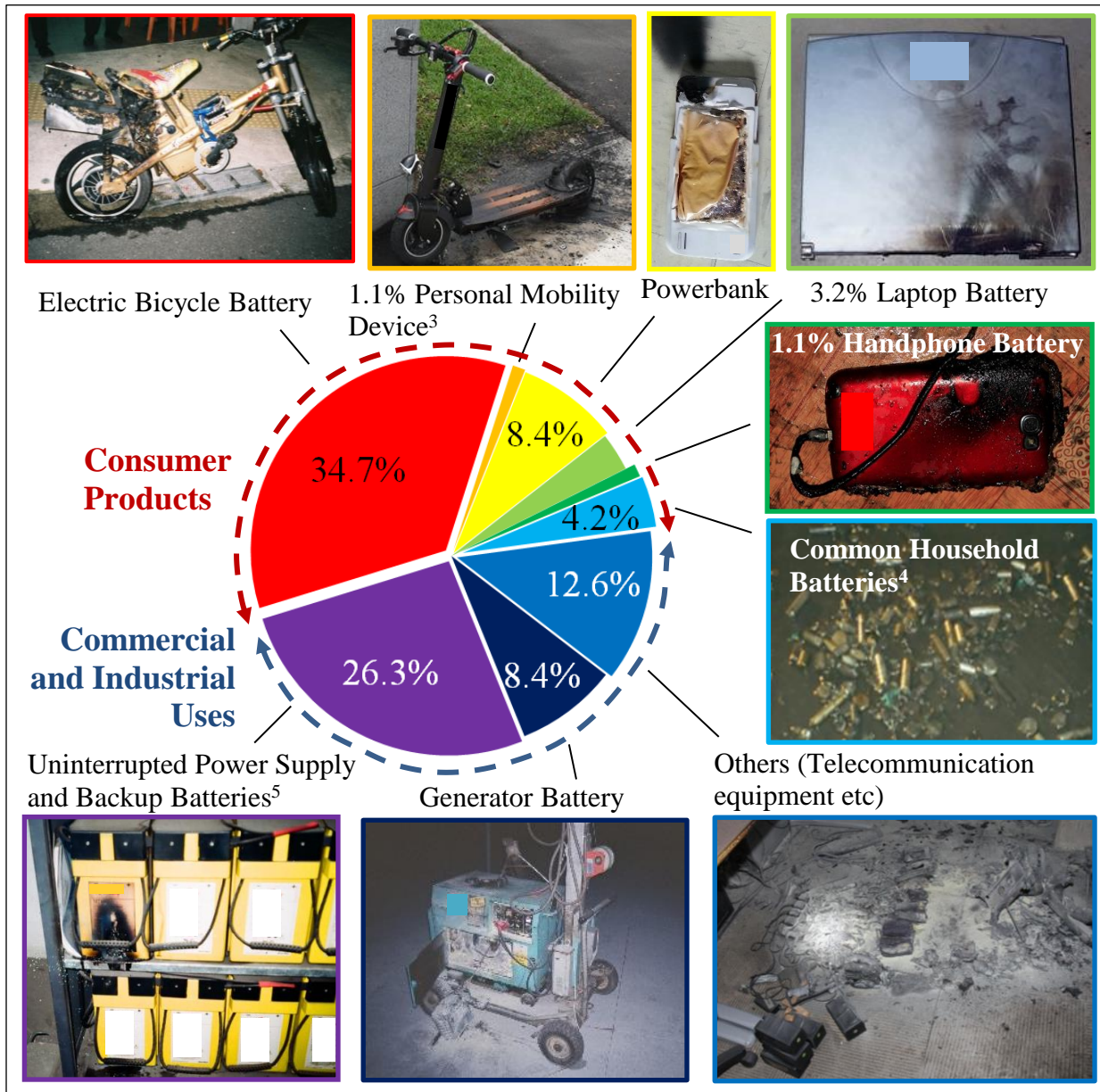


Figure 1: Breakdown of Battery Fires (2008 – 2015)

³ Personal Mobility Device includes skateboard, kick-scooter, electric scooter, hoverboard and e-wheel in accordance to the definition provided by Land Transport Authority [2]

⁴ Common Household batteries include non-rechargeable (primary⁶) and rechargeable (secondary⁷) batteries that are typically cylindrical (AA, AAA, D, etc.) or button in shape (LR41, LR44, etc.)

⁵ Uninterrupted Power Supply and backup batteries are emergency power supplies activated when utility is cut off. Large units are typically used to provide standby power to telecommunications installations [3]

⁶ Primary batteries can only be used once and not rechargeable [4]

⁷ Secondary batteries are rechargeable after repeated use. Different combinations of chemicals used in secondary batteries include Lead Acid, Nickel-Cadmium (NiCd), Nickel-Iron, Nickel Metal Hydride (NiMH), Silver Oxide, Nickel-Zinc, Hydrogen Electrode, Zinc/ Manganese Dioxide and Lithium-Ion (Li-ion) [5]

Most of the battery fires reported involved rechargeable batteries, also known as secondary batteries, which are often used in portable electronics devices and electric vehicles [6]. In this report, fires involving the batteries of electric bicycles, powerbanks and laptops will be examined.

Electric Bicycles

According to Singapore Customs, there were 21,599 electric bicycles imported into Singapore in 2015 and this is over 19 times the number imported in 2008 [7] as shown in **Table 1**.

Year	2008	2009	2010	2011	2012	2013	2014	2015
Number of electric bicycles imported ⁸	1,107	1,991	2,215	3,018	3,371	3,830	6,213	21,606

Table 1. Number of electric bicycles imported into Singapore (2008 – 2015)

Electric bicycles that have power assistance, either through a throttle or when pedalling (also known as ‘pedal assist’ or ‘pedelec’), are commonly referred as electric bikes or ‘e-bikes’ [8]. The pedelec and the ‘throttle assist’ or ‘on-demand’ are 2 broad types of electric bicycles. A pedelec does not have a throttle but as the cyclist pedals, the motor augments with a certain amount of power. The amount of power to be added can usually be adjusted, in accordance to the preference of the cyclist [9]. The ‘throttle assist’ allows the cyclist to control the power through the throttle. The cyclist may choose to pedal or sit back and he is able to vary the power [10]. Electric bicycles that allow direct drive (motor to cut in without pedalling and throttle control for acceleration) are not approved for use in Singapore [11].

The batteries used in electric bicycles vary from model to model. Some electric bicycles use lead acid batteries, whereas newer models generally NiMH, NiCd and/or Li-ion batteries [12,13]. Typically, the battery is mounted on the bicycle at the body frame or above the rear wheel [14] as seen in **Figure 2** and **Figure 3**.

⁸ Figures shown are with reference to calendar year. The figures given in Singapore Customs’ newsletter: Making an Exception: Motorised Bicycles and Motor Vehicle Manufacture, on the other hand, were with reference to financial year.



Figure 2. Battery mounted on the bicycle frame



Figure 3. Battery positioned above the rear wheel

Electric Bicycle Battery Fires

There were 32 incidents of fire involving the batteries of electric bicycles from 2008 – 2015, about 90.6% of the fires occurring in the last 4 years (see **Figure 4**). As seen in **Figure 5**, 50.0% of the fires occurred while the batteries were being charged while 31.3% of the fires occurred when the electric bicycles were stationary and not in use.

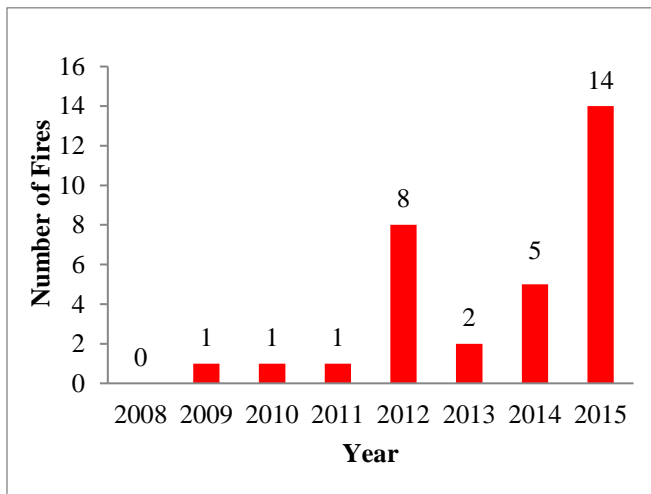


Figure 4. Breakdown of electric bicycle battery fires (2008 – 2015)

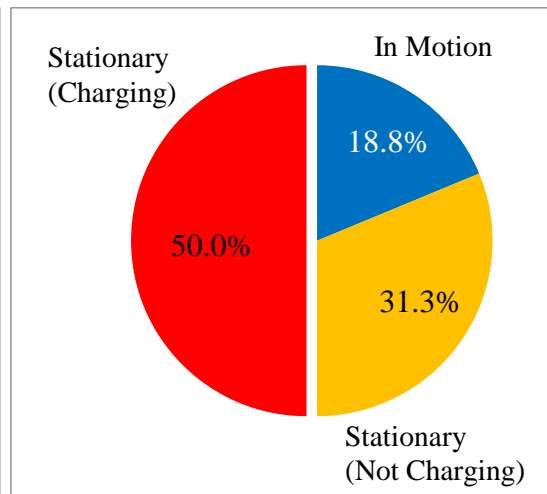


Figure 5. State of electric bicycle at the time of fire (2008 – 2015)

Most of the fires (59.4%) spread beyond the electric bicycle (see **Figure 6**). On closer examination of these cases where there was fire spread, most were noted to have taken place in the living room and common area such as the corridor and void deck. The remaining cases occurred in storerooms and a kitchen. The proximity of the electric bicycle batteries to combustibles is a contributing factor to the fire spread.

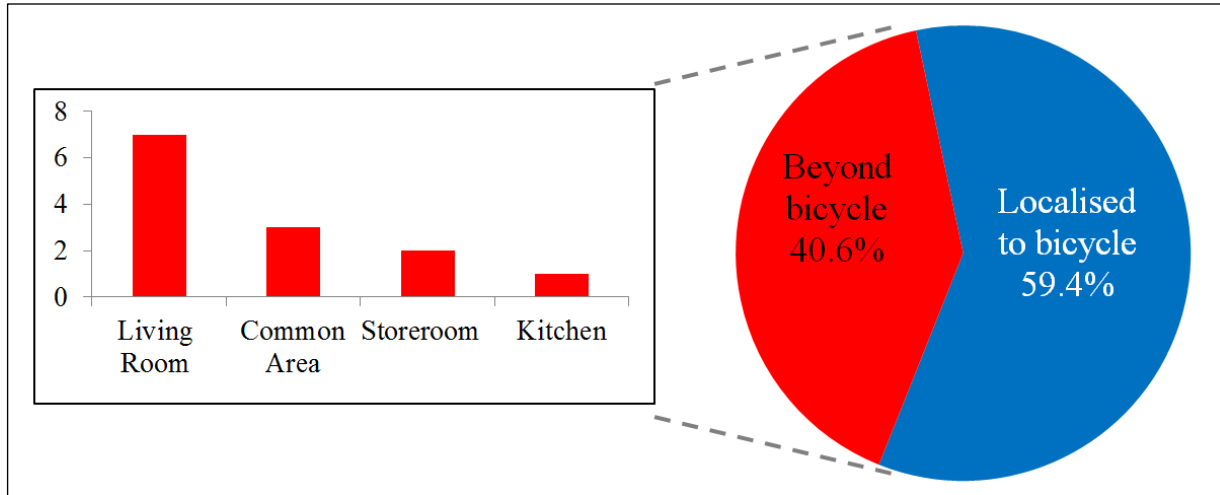


Figure 6. Breakdown of locations of electric bicycle battery fire occurrences (2008 – 2015)

Personal Mobility Devices

Hoverboard, e-wheel, skateboard and scooter are collectively termed as personal mobility devices (PMD) as seen in **Figure 7**. These devices have soared in popularity only in recent years.



Figure 7. Personal Mobility Devices (left to right): e-wheel, hoverboard, electric skateboard and electric scooter

2015 saw the first fire involving the batteries of a PMD (electric scooter) reported to SCDF. That was also the only PMD battery fire for that year. On the day of the incident, the rider was using the device as a mode of travel when it stopped operating abruptly. The rider dismounted and noticed smoke emitting from the rear of the scooter which developed into a fire moments later. He doused the fire successfully with a bottle of water that he was carrying. On closer examination, the fire appeared to have originated from the cylindrical lithium batteries found in the scooter rear (See **Figure 8**).



Figure 8. An electric scooter and the batteries affected in the fire

Powerbanks

Portable energy storage devices or portable battery chargers, commonly referred to as powerbanks, are back-up battery packs that can charge the batteries of electronic devices such as handphones, tablets and gaming devices when connected through a cable (see **Figure 9**). Some powerbanks are made for specific handphone models and can be attached directly onto the handphones without the use of cables during charging such as the battery case and power sleeve seen in **Figure 10** and **Figure 11** respectively.



Figure 9. A powerbank with built-in cylindrical Li-ion batteries

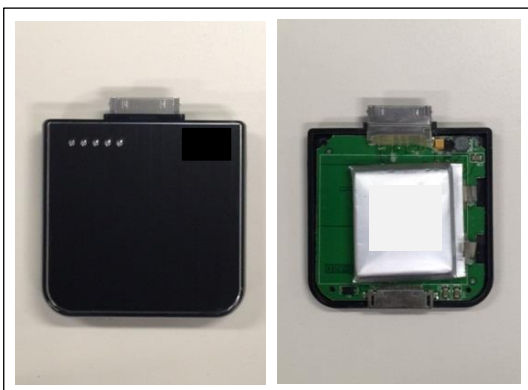


Figure 10. A battery case for handphones powered by a pouch type Li-ion battery



Figure 11. A power sleeve for handphones with a built-in pouch type Li-ion battery

Within the powerbanks, the built-in batteries are diverse in types. These built-in batteries may range from cylindrical shape (see **Figure 9**) to pouch⁹ type (see **Figure 10** and **Figure 11**) with various combinations of battery chemicals. Generally, Li-ion batteries are more commonly employed in the powerbanks sold locally.

Powerbank Fires

As shown in **Table 2**, the first powerbank fire was reported in 2013 and this number increased to 6 the following year. It was noted that 62.5% of all reported powerbank fires took place in bedrooms as depicted in **Figure 12**. It was also noted that there were more instances of fire (62.5%) occurring when the powerbanks were being charged as illustrated in **Figure 13**; with 3 cases happening when the powerbanks were charging on the bed. 2 cases involved powerbanks charging on study tables. There were no reported fires involving powerbanks when they were being used to charge another device.

Year	2008	2009	2010	2011	2012	2013	2014	2015
Number of powerbank fires	0	0	0	0	0	1	6	1

Table 2. Annual number of fires involving powerbanks (2008 – 2015)

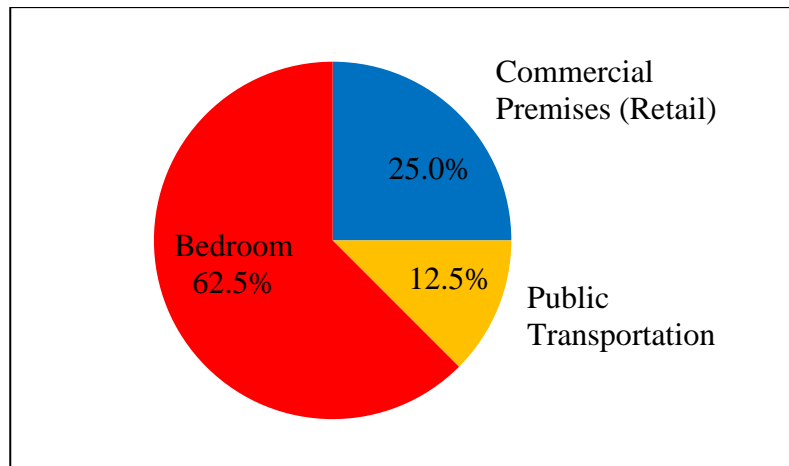


Figure 12. Breakdown of locations where fires involving powerbanks occurred (2008 – 2015)

⁹ The pouch type batteries have conductive foil-tabs welded to the electrodes and brought to the outside in a fully sealed manner. They have applications in consumer, military and automotive applications. No standardised format exists; each manufacturer designs its own. [15]

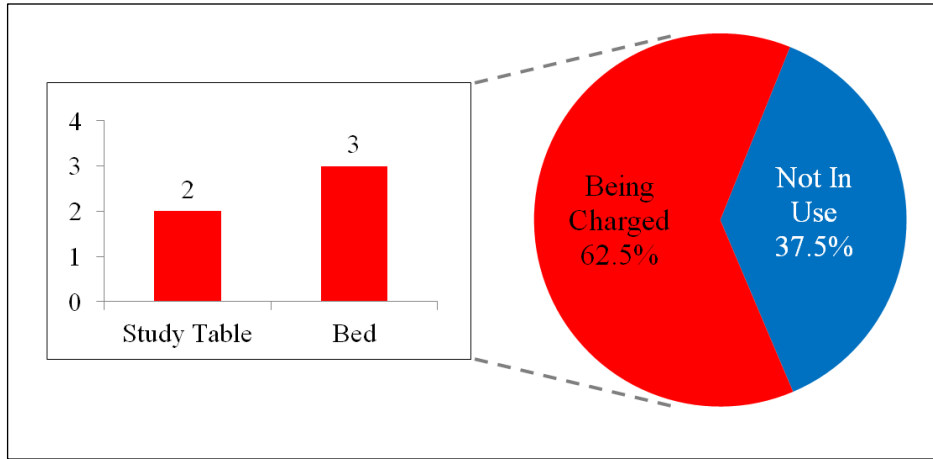


Figure 13. State of powerbanks at the time of fires (2008 – 2015)

Laptop Fires

Laptop fires are generally rare with only 3 reported cases between 2008 – 2015 as shown in **Table 3**. It was observed that in all 3 incidents, the laptops were operating on either a bed or a sofa as seen in **Figure 14**. The upholstery may have significantly reduced the heat dissipation rate by the laptop.

Year	2008	2009	2010	2011	2012	2013	2014	2015
Number of fires involving batteries of laptops	2	0	1	0	0	0	0	0

Table 3. Annual number of fires involving batteries of laptops (2008 – 2015)



Figure 14. Laptop battery fires occurred on the bed or sofa

From the Case Files

Case #1: December 2011, Kallang

The occupant was woken up by his domestic helper in the morning when the latter detected a burning smell and a crackling sound from the electric bicycle battery which was being charged in the living room. When he headed out to investigate, he saw that the electric bicycle was already on fire. He quickly switched off the power supply at the socket to the charger and extinguished the fire with buckets of water. He then evacuated his family and called SCDF for assistance. Due to the fire, the seat and battery compartment of the electric bicycle were damaged (see **Figure 15**).



Figure 15. The seat and battery compartment of the electric bicycle were damaged

Case #2: October 2013, Ang Mo Kio

It was 8 in morning when the occupant woke up to use the restroom. While he was in the restroom, he heard an ‘explosion’ coming from the living room of the 1-room HDB flat. Subsequently, he heard his 3 roommates shout ‘fire!’ and as he went out to investigate, he found themselves trapped in the kitchen due to the smoke and fire near the main door. 2 of his roommates escaped by jumping off the kitchen window of their HDB unit on the 2nd floor. He and the last roommate climbed out of the kitchen window and stood on the ledge. Some Town Council workers in the vicinity saw what happened and helped to pitch a ladder to assist in the evacuation.

As a result of the fire, the contents of the HDB flat were damaged (See **Figure 16**). The cause of fire was determined to be accidental and of electrical origin at the battery of an electric bicycle which was charging near the main door (See **Figure 17**).



Figure 16. The contents of the HDB flat were damaged

Figure 17. The burn patterns were consistent with fire origin near the main door where the battery of an electric bicycle was being charged.



Case #3: June 2014, Bishan

In the evening, a homemaker heard ‘popping’ sounds from her daughter’s room. When she went in to investigate, she saw pockets of fire at the left side of the bed. She made attempts to put out the fire using buckets of water but was unsuccessful and she evacuated. Investigations revealed that her daughter had left her powerbank to be charged on her bed since morning and that was the only device that was energised in her bedroom. As a result of the fire, contents of the room were damaged (see **Figure 18**). Other parts of the unit sustained heat and smoke damage (see **Figure 19** and **Figure 20**). Burnt remains of the powerbank were recovered in the Area of Fire Origin (see **Figure 21**).



Figure 18. The contents of the room were damaged



Figure 19. Other parts of the unit sustained heat and smoke damage



Figure 20. Other parts of the unit sustained heat and smoke damage



Figure 21. Burnt remains of the powerbank were recovered in the Area of Fire Origin

Case #4: July 2014, Woodlands

The occupant was in the kitchen when her granddaughter alerted her that smoke was seeping out from one of the bedrooms. After she retrieved the key to open the door, she saw the bed on fire. Her attempts to put out the fire were futile and she called SCDF for assistance. As a result of the fire, the bed was damaged. The walls and flooring in the room sustained heat and smoke damage (see **Figure 22**). Investigations revealed that a powerbank was left charging on the bed and the burnt remains of the powerbank were recovered from the determined Area of Fire Origin (see **Figure 23**).



Figure 22. As a result of the fire, the bed was damaged. The walls and flooring in the room sustained heat and smoke damage



Figure 23. Burnt remains of the powerbank were recovered from the determined Area of Fire Origin

Causes of Battery Fires

Battery fires can be caused by faulty electrical circuitry that may lead to battery short-circuiting. The high current drawn by faulty electrical circuitry can generate sufficient heat to ignite the devices or materials in close proximity [16].

Another cause of battery fires is overheating and this was the reason for recalls of batteries used in some electric bicycles, powerbanks and laptops in Singapore and other countries [17,18,19,20,21,22,23]. In the case of powerbanks, it was reported that poor design can make the powerbank prone to excess heat build-up in the battery and this could possibly ignite the chemicals within, leading to smoke and fire [24].

Li-ion batteries, which are common in many consumer devices have been in the limelight since its involvement in a few fire incidents on-board aircrafts [25,26]. Airlines have also imposed certain restriction for passengers to carry-on or checking-in such batteries [27,28]. Some airlines have even prohibited specific PMDs such as the hoverboard due to concerns that the batteries capacity is not labelled accurately for airlines to determine if the devices can be taken on-board safely [29].

Li-ion batteries were also part of major product recalls for the fire hazards it posed [30,31]. One of the fire risks identified in a research regarding Li-ion battery is that the electrolyte¹⁰ used in a Li-ion battery is hydrocarbon-based as opposed to a water-based electrolyte contained in NiMH or NiCd batteries. Leakage or venting of Li-ion batteries will release flammable vapours [32]. The release of flammable gases is also the most significant ignition hazard associated with batteries pointed out in the Ignition Handbook [33]. The Li-ion battery may also short-circuit due to faults or damage in the separators¹¹ which may be caused by mechanical injury, overcharging, or exposure to heat. Such short-circuits can cause temperature increase in the battery which will, in turn, accelerate the internal chemical reaction; and further add to the heat which could lead to the combustion of battery materials [35].

Prevention of Battery Fires

Proper Storage

Batteries, including used ones, carry electrical charge and can start a fire when in contact with other batteries or conductors. Proper storage or taping the terminals of batteries when not in use could also prevent fire occurrences [36]. Batteries should also be stored in room temperature,

¹⁰ Besides the anode (negative electrode) and cathode (positive electrode), the electrolyte is the other key component in a battery which serves as the medium for transfer of charge, as ions, inside the battery between the anode and cathode. [1]

¹¹ A separator is used to separate the anode and cathode electrodes mechanically inside the battery. [34]

avoid prolong direct heat exposure and kept away from combustible or flammable materials as a safety precaution [37].

Check for Damage or Deformities

Visually examine batteries for signs of mechanical damage or deformities. When a battery is damaged or bloated, the risk of a fire occurring when it is charging increases [38]. Refrain from using damaged batteries as charging these batteries may lead to overheating [37].

Avoid Overcharging

Do not overcharge batteries as some older battery models do not have a power cut-off sensor installed and overcharging may lead to fire [37]. Overcharging, be it an once-off severe overcharge or repeated minor overcharge, may also cause permanent damage to the battery, leading to battery swelling, venting and other thermal or electrical events [39].

Allow Heat Dissipation

Electronic devices like laptops have air vents at the bottom or side and placing it on upholsteries and the like may block these vents [40]. Fires due to blockage of air vents in laptops by blankets and pillows have occurred; and these fabrics and upholsteries will further fuel the fire. The use of electronic devices, including charging of its batteries, on hard flat surfaces like a table or desk would allow for more optimal dissipation of heat [41].

Always adhere to the instruction provided by the manufacturers of your electric bicycle, powerbank or laptop. For powerbank, some information on its safe use can be found at the SPRING Singapore website [42,43,44]. It is advisable to check the 'Safety Alerts and Tips' section of the SPRING Singapore website regularly for any latest product safety recall or advice [45].

Caution!

For batteries and battery chargers, the use of imitation can lead to compatibility issues. The use of substitute batteries and chargers that are not designed for the product should be avoided as it can result in overheating or fire [46,47].

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