



World Fire Congress

2024 | UNITED STATES

Fire Risk of Emerging Technologies

Steve Kerber, PhD, PE





Fire Risk of Emerging Technologies

Steve Kerber, PhD, PE

World Fire Congress

May 8, 2024



Balancing Sustainability and Fire Resiliency



Lithium-ion battery adoption and the fire service

ESS – Marine – EV – Consumer Products - Medical



All powered devices are candidates for lithium-ion electrification.

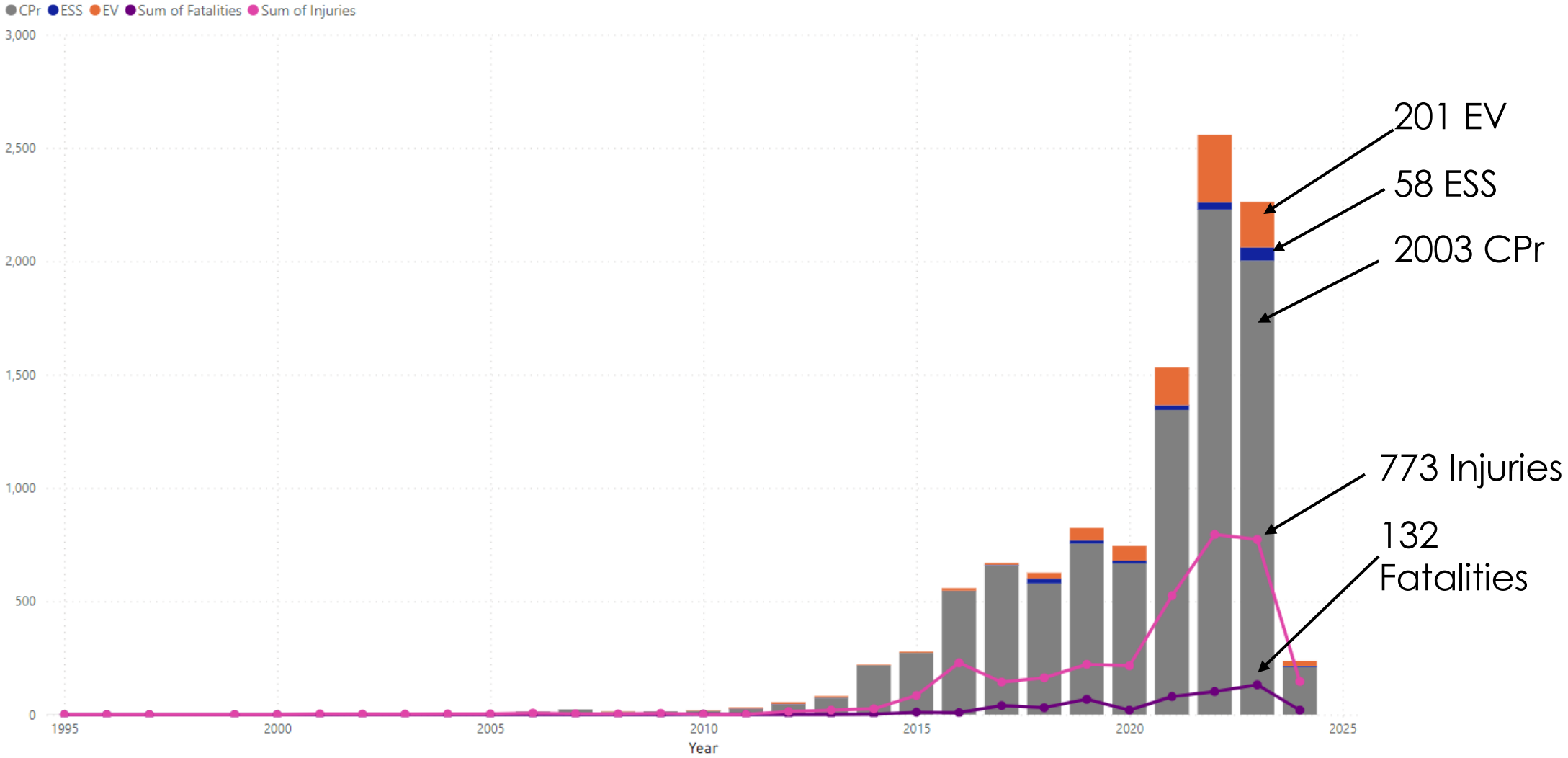
Many challenges throughout the life cycle



Global trend of lithium-ion battery incidents



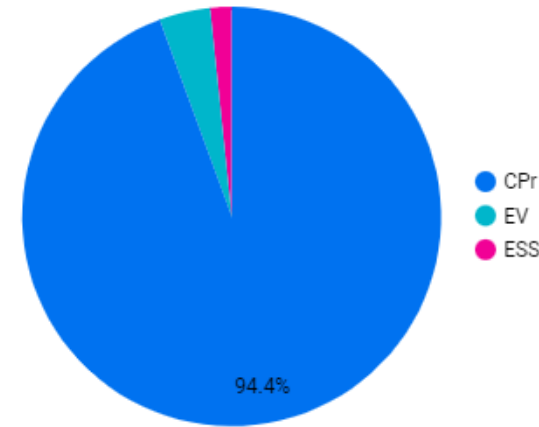
Lithium-ion battery thermal runaway incidents



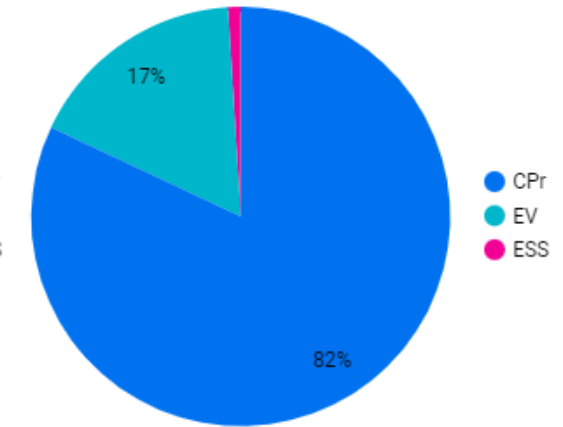
North America's biggest challenge

Most injury and fatality incidents involve consumer products*

Injuries by Product Type

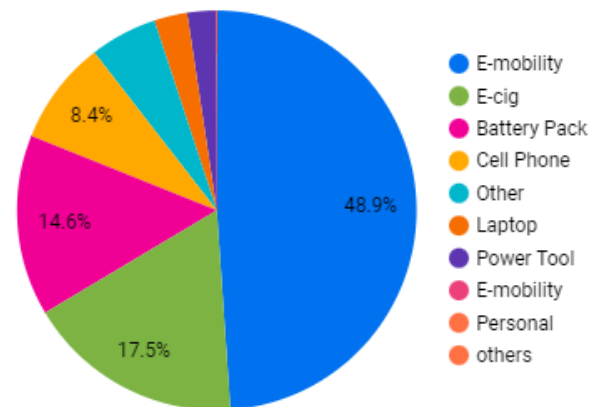


Fatalities by Product Type

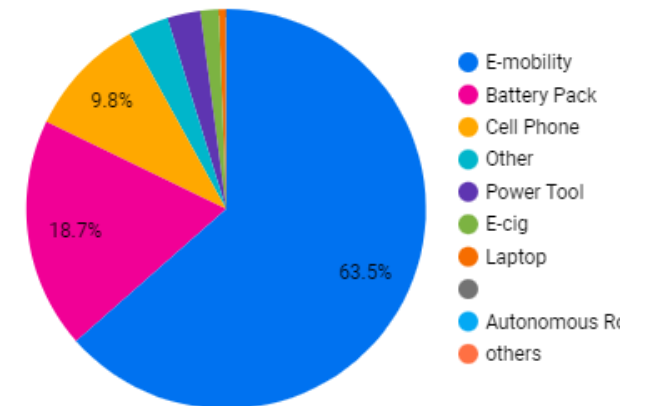


Most consumer products incidents involve e-mobility devices

Injuries by Consumer Product Type



Fatalities by Consumer Product Type



*EV data inflated by fatalities as a result of crash



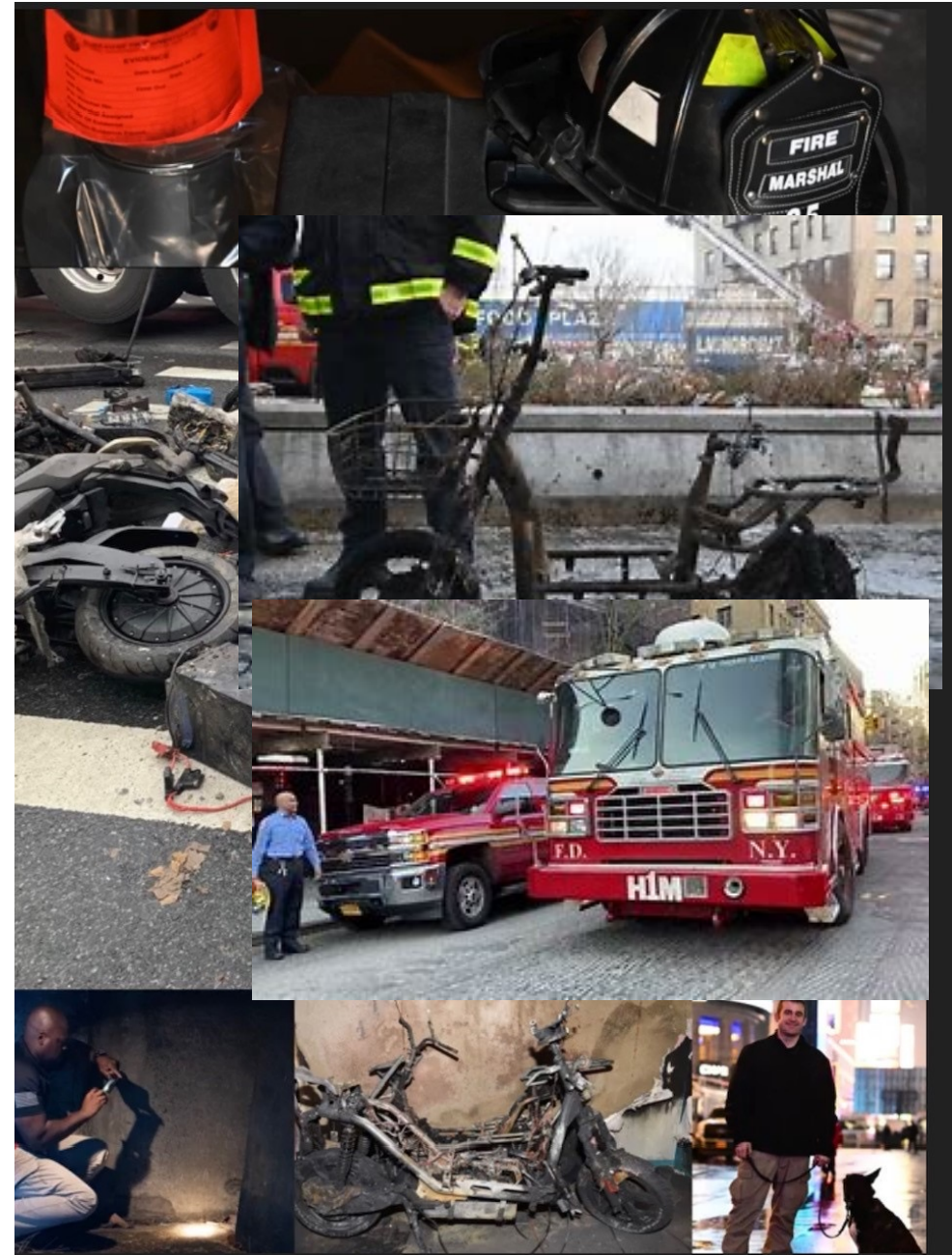
Bureau of Fire Investigation

Lithium Ion Fire Stats

(As of 12/31/2023)

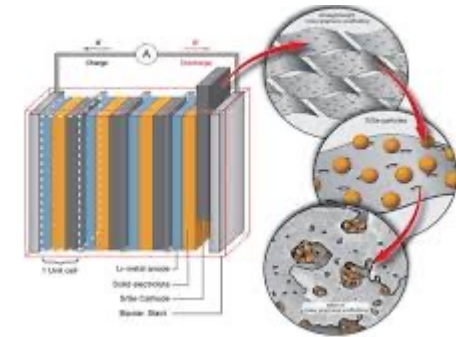


	<u>Investigations</u>	<u>Injuries</u>	<u>Deaths</u>
2019	30	13	0
2020	44	23	0
2021	104	79	4
2022	220	147	6
2023	267	150	18

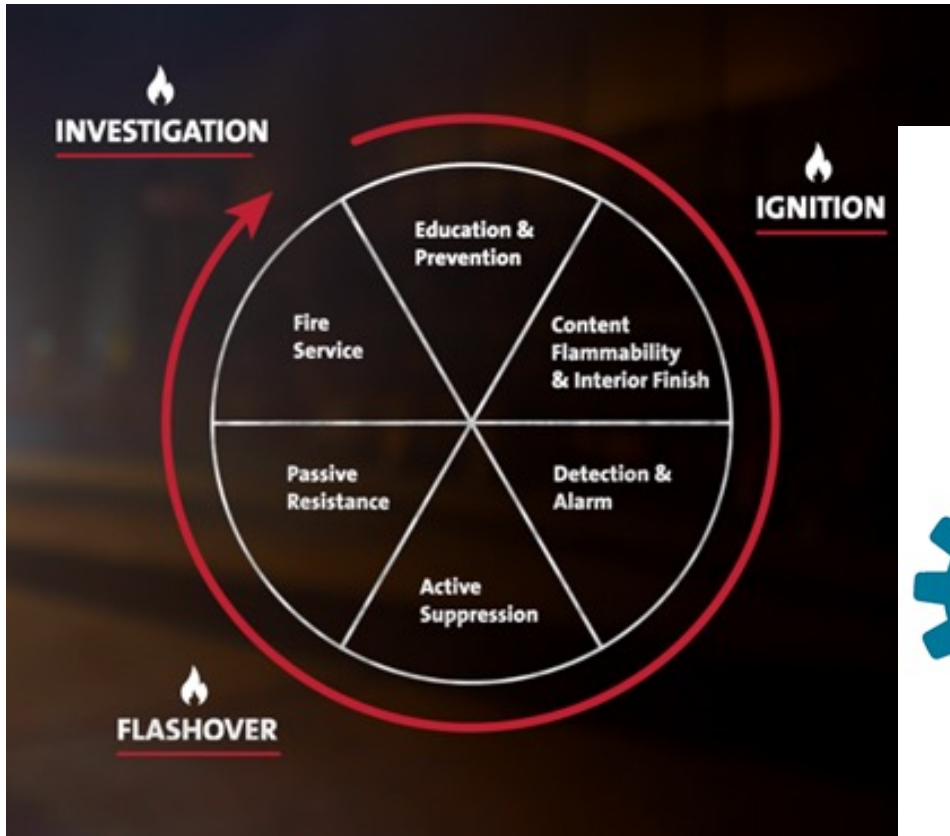


Moving target

- New fuels, new chemistries, new boxes
- Determining which hazards extend outside scope of first response
- Staff development to the new fire environment
- Codes and standards are slow, technology is fast
- Developing best practices for extinguishment and gear cleaning
- Impact on building systems and evolutions
- Community actions to eliminate secondary incidents
- Public messaging and the fire service role goes beyond operations
- DIY impacts



Addressing the challenge today and into the future



• DOW	30,183.78	▼ 522.45 (1.70%)
• NASDAQ	11,220.19	▼ 204.86 (1.79%)
• S&P 500	3,789.93	▼ 66.00 (1.71%)



World Fire Congress

2024 | UNITED STATES

Fire Risk of Emerging Technologies

Steve Kerber, PhD, PE
steve.kerber@ul.org





World Fire Congress

2024 | UNITED STATES

Energy transition in the built environment: Dutch facts and figures for AFV and PV

Dr. Nils Rosmuller

Applied Professor,
Energy and Transportation Safety

1. The built environment

The term "**built environment**" refers to human-made conditions and is often used in architecture, landscape architecture, urban planning ...

These curated spaces provide the setting for human activity and were created to fulfil human desires and needs

Buildings, public infrastructure, industries and agriculture

1. The built environment

High-rise buildings



An artists impression of the completed building. Illustration: AM

Car parks



Infrastructure



A rainbow bike road in Utrecht, Netherlands. Photo Credit: Dutch Cycling Embassy

Warehouses, barns

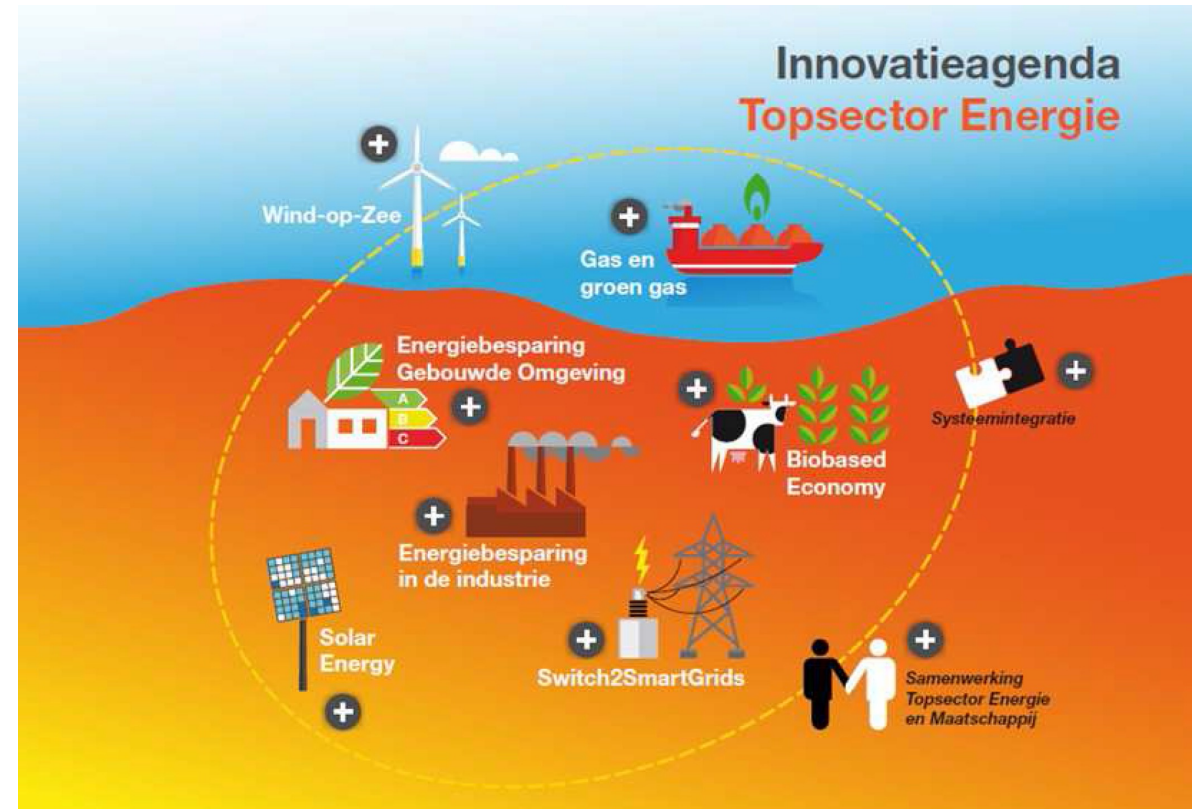


Industries



2. The Energy Transition

- Sustainability
- Clean/'green' fuels
- Electrification
- Hydrogen
- Geo, bio, wind, solar...
- Nuclear

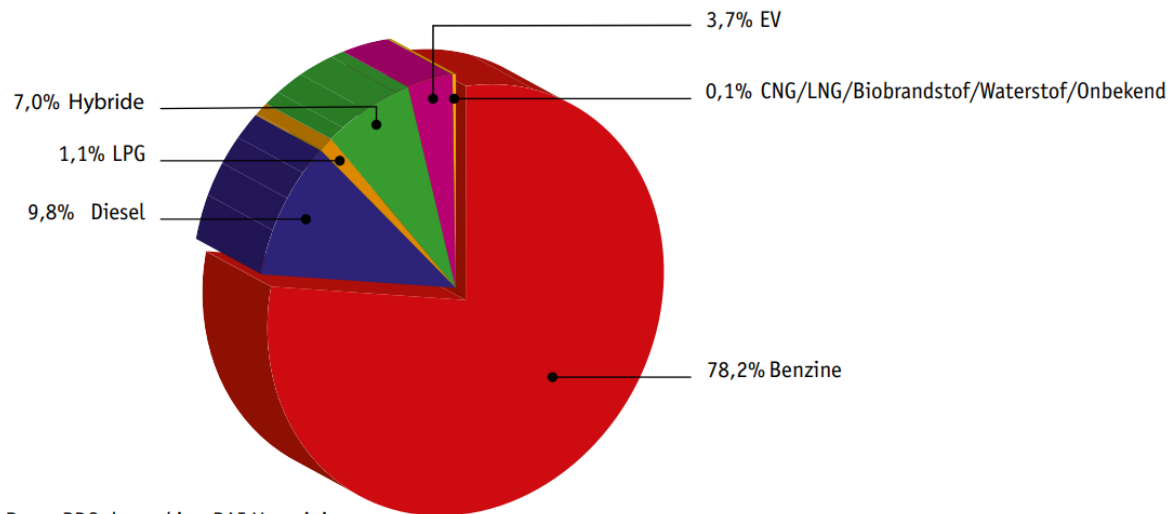


3a) Dutch F&F: Alternative-fueled vehicles (AFV)

- Database (The Netherlands)
- Start: 1 januari 2021
- Alternative (clean(er)) Fuels:
 - **BEV, (P)HEV, FCEV, CNG, LNG**
- Type of vehicles:
 - Everything with 4+ wheels
- **Fire brigade on the incident scene**
- Data collection: Questionnaire

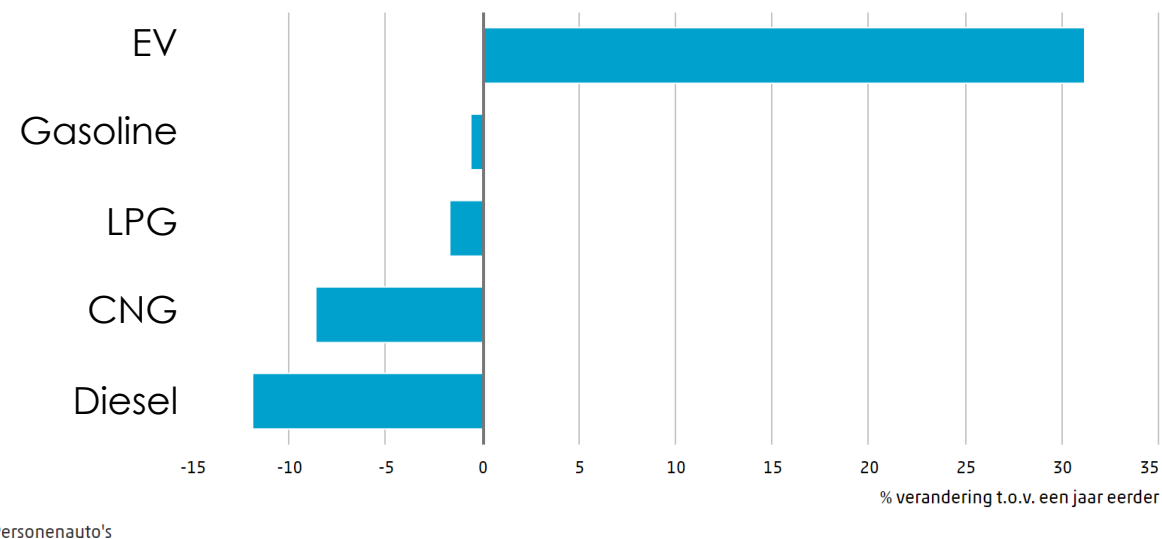


Fuel type passenger cars (% in 2023)

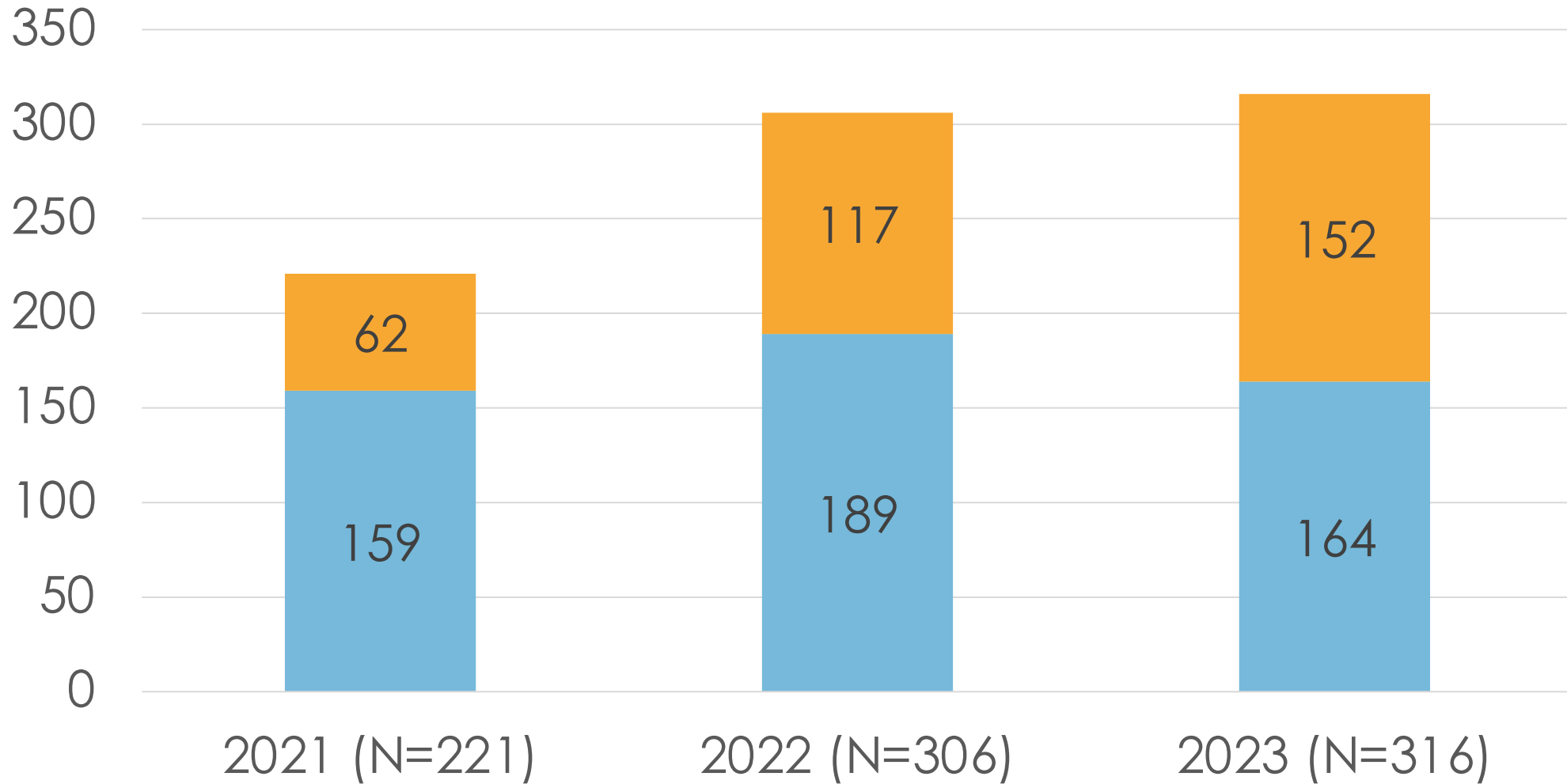


Bron: RDC, bewerking RAI Vereniging

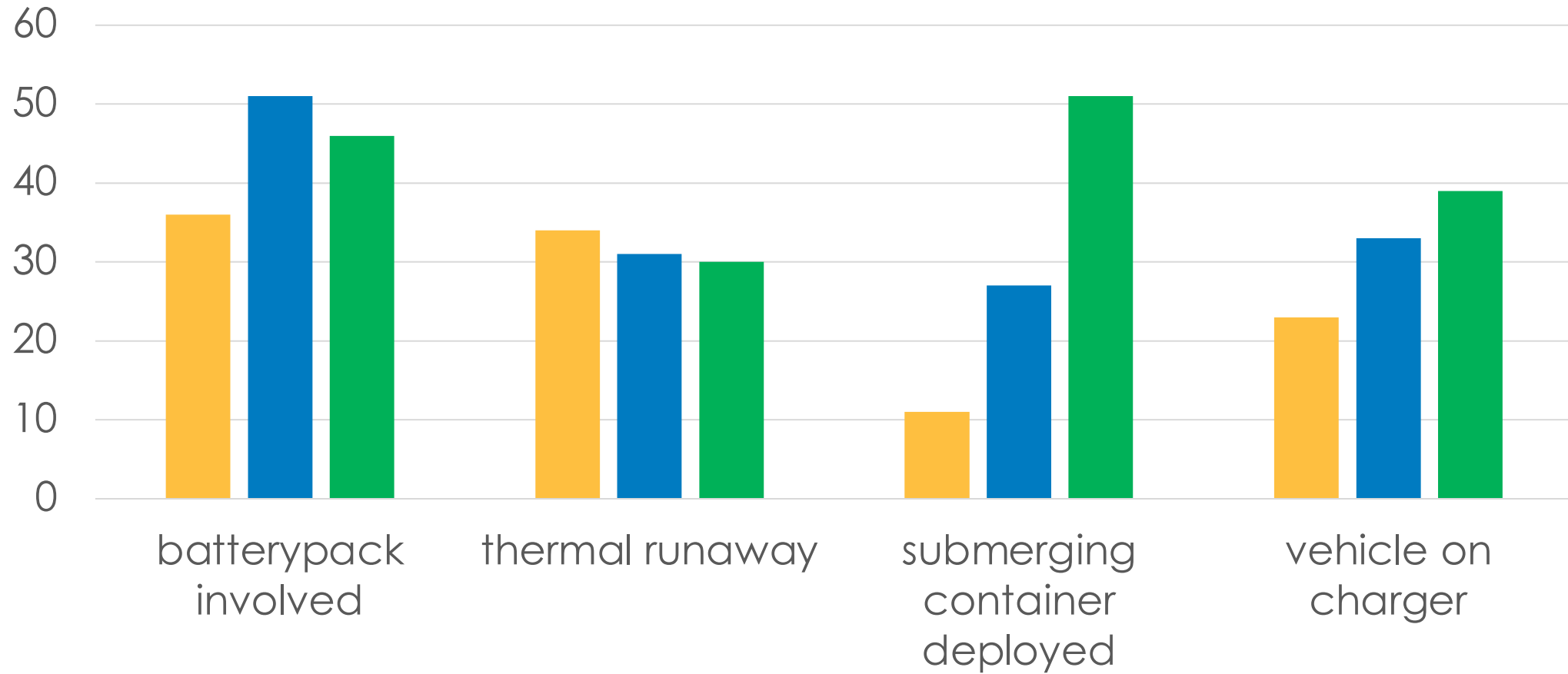
Development passenger cars per fuel type (% in 2023)



Number of AFV-Incidents



Incident Characteristics (in absolute numbers)



3a) Key lessons: AFVs

- **Incidents** (fire and accidents): Despite the +30% EV, the absolute incident number (fire and accident) remains the same (2021-2023)
- **Fires**
 - In case of fire → EV at charger in about 25%-35%
 - Battery in about 35% in thermal runaway
- **Accidents**
 - Substantial increase in deploying the submerging container
 - Battery hardly in thermal runaway
- **Serious fire fighter issues**
 - TR, copious amounts of water, contaminated cooling water, explosions, HF



3b) Solar energy



3b) F&F Solar system fires in NI (TNO and ECN , 2019)

Plaats	datum	Etmaal-gemiddelde windsnelheid de Bilt [m/s]	Maximum temperatuur de Bilt [C]	Globale straling de Bilt [J/cm2]	pand	type	markt
Aalten	29-6-2018	3.8	26.1	2,953	schuur		residieel
Apeldoorn	1-6-2018	3.8	22.2	4,788	uis	indak	residieel
Appelscha					uis	indak	residieel
Denekamp					pand	platdak	zakelijk
Drachten					je	indak	residieel
Enschede					pand	platdak	zakelijk
Haarlemmermeer					uis	?	residieel
Heiloo					uis	indak	residieel
Horst					uis	indak	residieel
Hulst					uis	indak	residieel
Ijsselstein					pand	schuin dak	zakelijk
Lemelerveld					uis	indak	residieel
Leidsche Rijn					pand	platdak	residieel
Lytsewierum							
Meijel							
Melick					uis	indak	residieel
Onbekend					uis	opdak	residieel
Opmeer					uis	platdak	residieel
Rotterdam					uis	opdak	residieel
Stein					uis	platdak	residieel
Twello						?	residieel
Utererp					pand	opdak	zakelijk
Vinkeveen					uis	indak	residieel
Ijsselstein					pand	?	zakelijk
Zutphen					uis	platdak	residieel
Zwaanshoek2016					uis	indak	residieel
Zwaanshoek2018					uis	indak	residieel
Wilaarderaburen					pand	?	zakelijk



TNO-rapport

TNO 2019 P10287
Brandincidenten met fotovoltaïsche (PV) systemen in Nederland.

Een inventarisatie

Datum: 13 maart 2019
Auteur(s): E.E. Bende, N.J.J. Dekker

Exemplaarnummer: 1
Oplage: 10
Aantal pagina's: 65 (incl. bijlagen)
Aantal bijlagen: 20
Opdrachtgever: Rijksdienst voor Ondernemend Nederland (RVO)
Projectnaam: PV-branden
Projectnummer: 060.37017

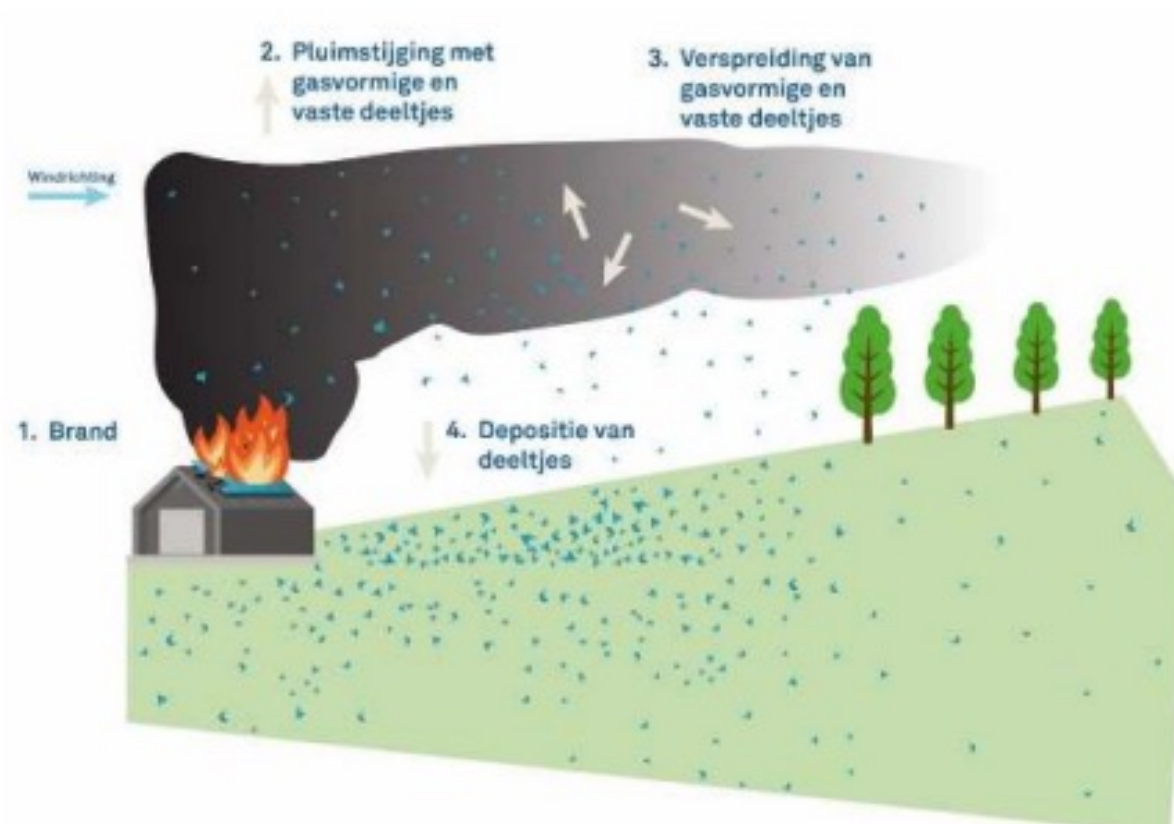
Alle rechten voorbehouden.
Niets uit deze uitgave mag worden vermenigvuldigd en/of openbaar gemaakt door middel van druk, fotokopie, microfilm of op welke andere wijze dan ook, zonder voorafgaande toestemming van TNO.

Indien dit rapport in opdracht werd uitgebracht, wordt voor de rechten en verplichtingen van opdrachtgever en opdrachtnemer verwezen naar de Algemene Voorwaarden voor opdrachten aan TNO, dan wel de betreffende terzake tussen de partijen gesloten overeenkomst.
Het ter inzage geven van het TNO-rapport aan direct belanghebbenden is toegestaan.

© 2019 TNO

- **24 fires in 2018**
- 20 private houses
- 4 others
- **80-90% in-roof systems**
- **Causes:**
 - 70% installation error
 - 10% junction box
 - 20% heat development

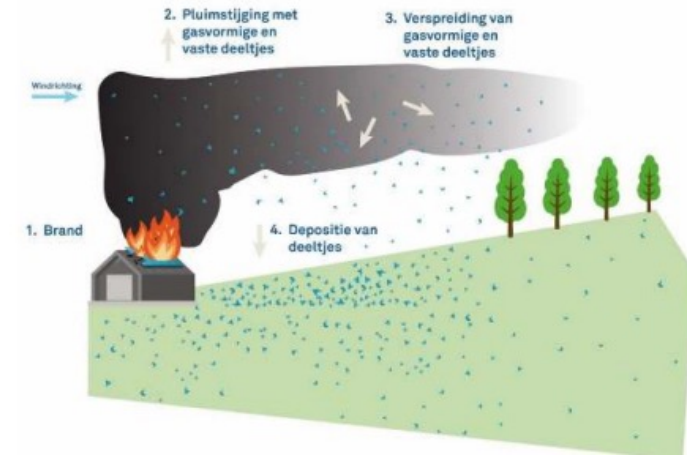
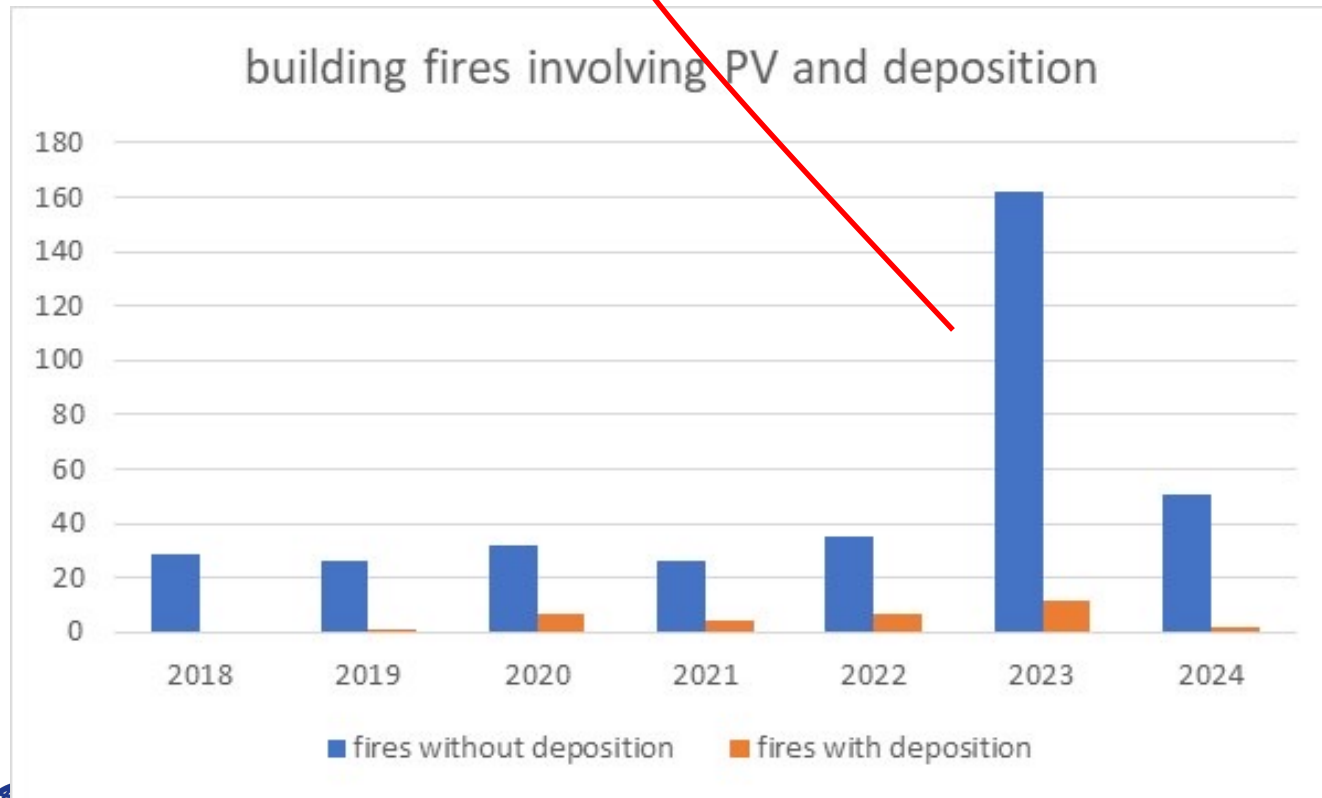
3b) Building fires involving solar panels



Deposition of sharp-edged, (non-toxic) solar cell fragments
→ danger to human, animals, and crop
(NIPV (2020, 2021) and RIVM (2022))

3b) Building fires involving solar panels

More advanced data collection method since the end of 2022.



- 349 building fires involving PV
 - 361: no deposition
 - 33: deposition
- Deposition characteristics:
 - buildings with fire load and 100s of PV panels
 - solar cell fragments
 - distance: several kilometers

3b) Key lessons PV-panels

- Solar panels complicate firefighting:
 - Deposition of sharp-edged pieces
 - ‘Umbrella effect’ in case of fire suppression
 - Electrocution risks



4) Key message ET in built environment

- Energy transition (ET) affects life safety of citizens and firefighters due to 'new' fire risks in the built environment, complicating fire suppression
- Designers, OEM's, spatial planners have to take their responsibility for safety,
- Communicate with the FRS, rather than passing the responsibility for safety to them (suppressing the accident consequences)
- **Maximum effort on prevention and legislation to better 'guarantee' safety**



World Fire Congress

2024 | UNITED STATES

Energy transition in the built environment: Dutch facts and figures for AFV and PV

Dr. Nils Rosmuller

Applied Professor,
Energy and Transportation Safety



World Fire Congress

2024 | UNITED STATES

Lithium-Ion Battery/ Electric Vehicle Fire Incidents Around the United States

Michael G. Abraham, PE

Bureau of Alcohol, Tobacco, Firearms,
and Explosives

Fire Research Laboratory

ATF -Certified Fire Investigators (CFI)

- ATF is the primary agency investigating fires affecting interstate or foreign commerce.
- ATF has approximately 110 Certified Fire Investigators nationwide.
- Two-year, full-time training program involving fire scene examinations, in-person training, and a research project.
- IAAI CFI certification



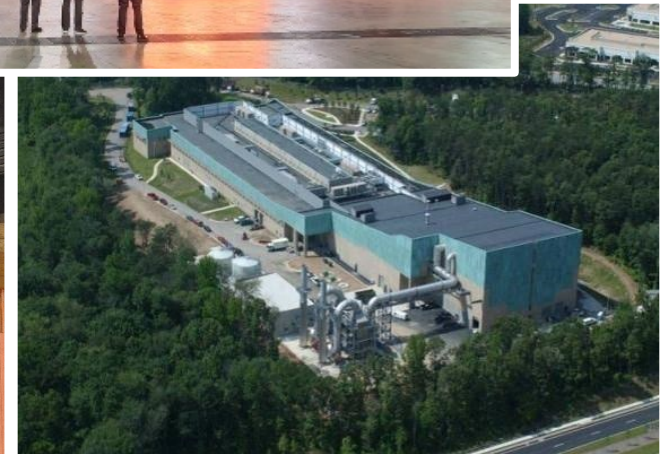
ATF National Response Team (NRT) & International Response Team (IRT)

- Mission to investigate large fire and explosion incidents anywhere in the U.S.
- 15 full-time Special Agents, 115 part-time Special Agents, Fire Protection and Electrical Engineers, Chemists, Accelerant Detection Canines, etc.
- Over 900 callouts nationwide since 1978.
- 43 International callouts to countries in Europe, Africa, Asia, and South America.

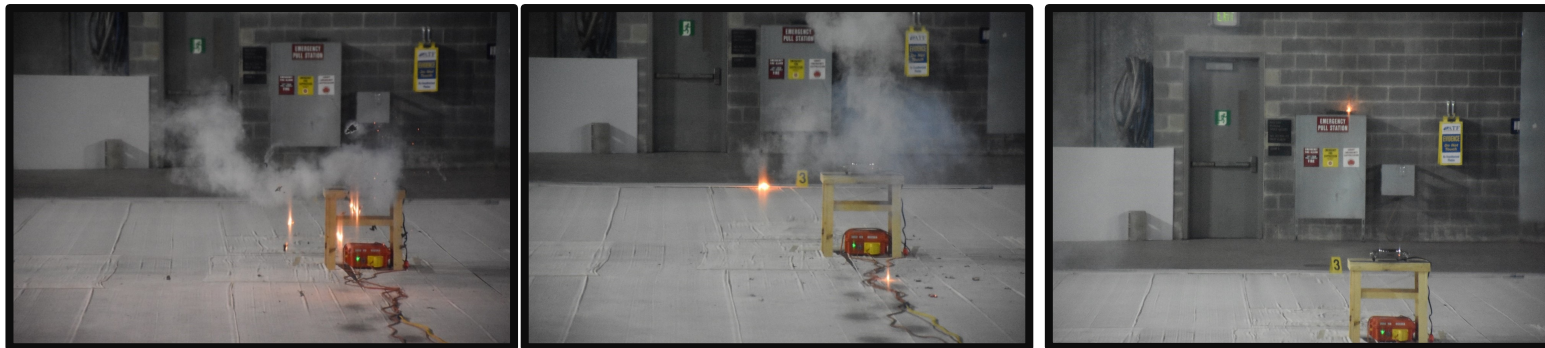


ATF Fire Research Laboratory (FRL)

- Support fire investigations and the resolution of fire-related crimes for Federal, State, Local, and International Authorities
- On-scene Support and Evidence Examinations
- Full-Scale Testing
- Research, Training, and Education



SSA/CFI Silva Research Project



Spokane, WA - 2018 Tesla Model 3 Battery



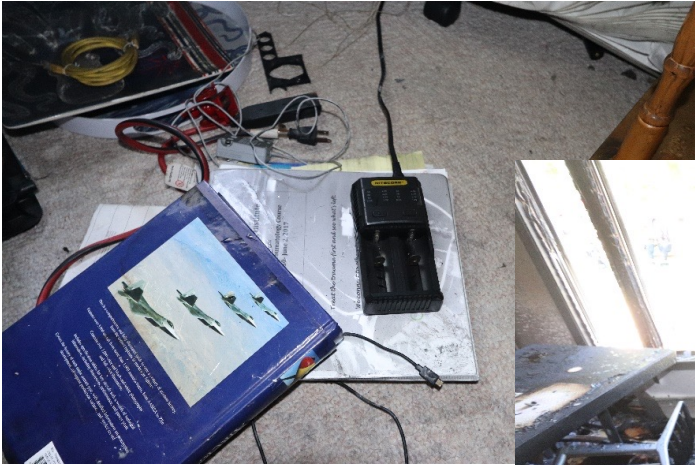
Neptune, New Jersey



Neptune, New Jersey



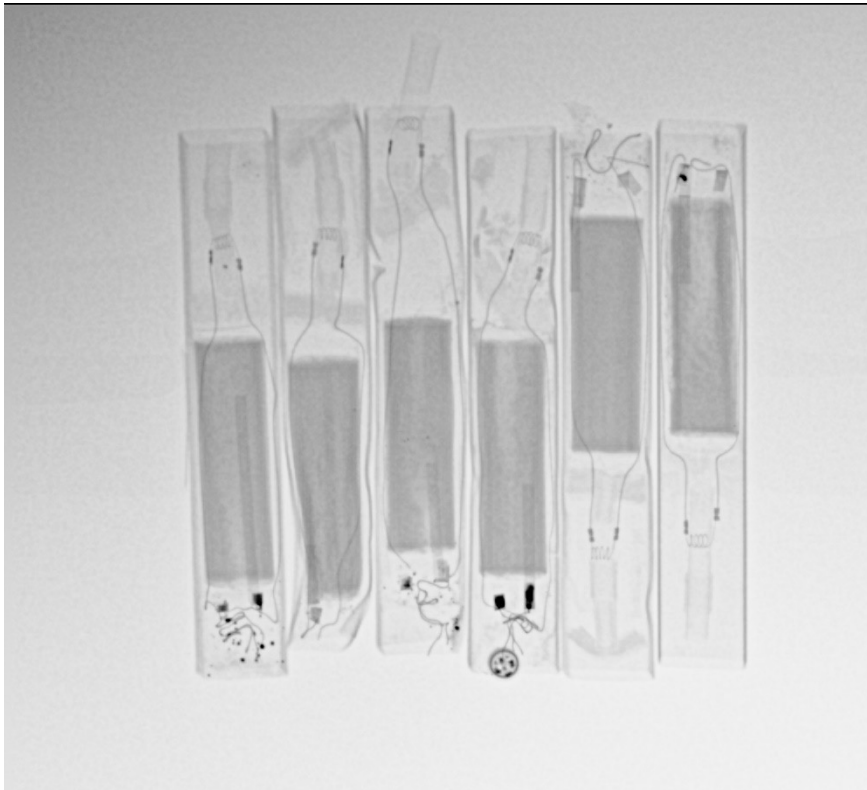
Neptune, New Jersey



Los Angeles, CA



Los Angeles, CA



Hoboken, NJ



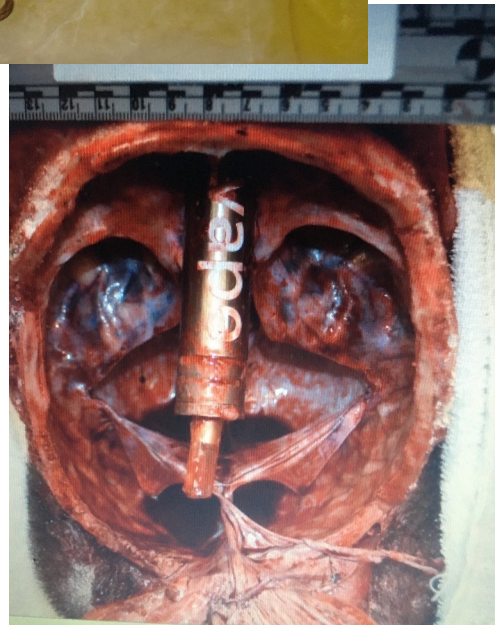
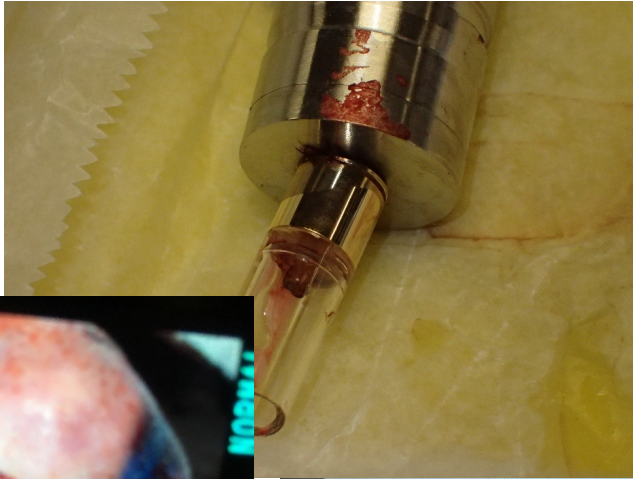
Hoboken, NJ



Vape Failure Fatalities

St. Petersburg, FL

Chewalah, WA



New Orleans, LA - Oil Tanker Bridge Fire



Franklin Township, NJ



Boston Metro Area, MA



Palo Alto, CA



Washington



New York City – Ford Fusion Hybrid



Pittsburgh, PA - Tesla Model X

- Fire occurred in February
- Joint Scene Exam in April
 - Vehicle Removed & Transported
 - Three hours later...





World Fire Congress

2024 | UNITED STATES

Michael G. Abraham, PE
Forensic Engineer
ATF Fire Research Laboratory
Bureau of Alcohol, Tobacco,
Firearms, and Explosives
U.S. Department of Justice

michael.abraham@atf.gov





**World Fire
Congress**

2024 | UNITED STATES

Fire Risk of Emerging Technologies

Adam Barowy

UL FSRI





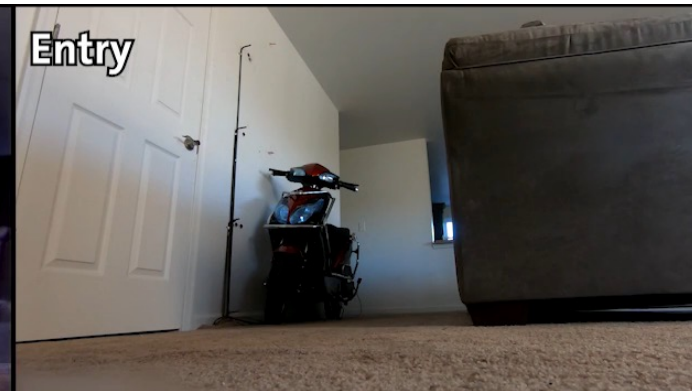
Intentional E-Scooter Overcharge: Living Room

Overcharge Time: 01:39:23

Living Room Low



Entry



Living Room High



Hallway



Living Room Infrared



Living Room Windows



Living Room



World Fire Congress

2024 | UNITED STATES

Impact of Residential Automatic Fire Sprinklers



TAKE CHARGE OF BATTERY SAFETY



What can you do to
“Take C.H.A.R.G.E.
of Battery Safety”?

www.batteryfiresafety.org



Choose certified products.

Handle with care.

**Always stay alert for
warning signs.**

**Recycle devices and
batteries properly.**

Get out quickly if there's a fire.

Educate others on safe practices.

EV Research at FSRI

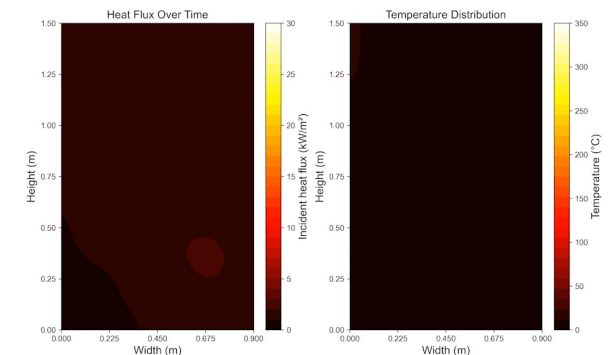
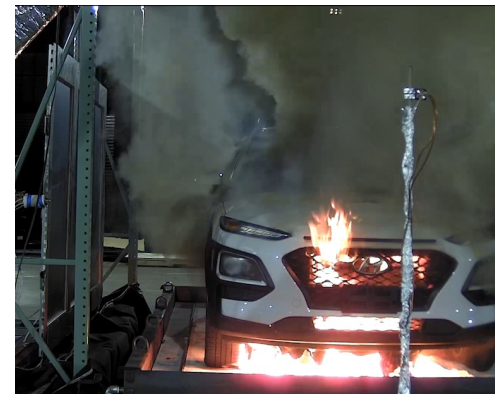
1. Are hazards changing with a transition to electric vehicles (EVs)? If so, how?
2. What fire control strategies can fire fighters use to mitigate demonstrated hazards?



Courtesy: Boston Fire Department (MA)

EV Fire Measurements & Methodologies

1. Heat Release Rate
2. Water contamination
3. Heat Flux
4. Occupational Exposures
 1. Gases, Vapors, and Particulates
 2. PPE Contamination
 3. PPE Decontamination





World Fire Congress

2024 | UNITED STATES

Fire Risk of Emerging Technologies

Adam Barowy

UL FSR

adam.barowy@ul.org



World Fire Congress

2024 | UNITED STATES

EV Battery Fires

SCDF's Current Response, Challenges, and Areas for Further Work

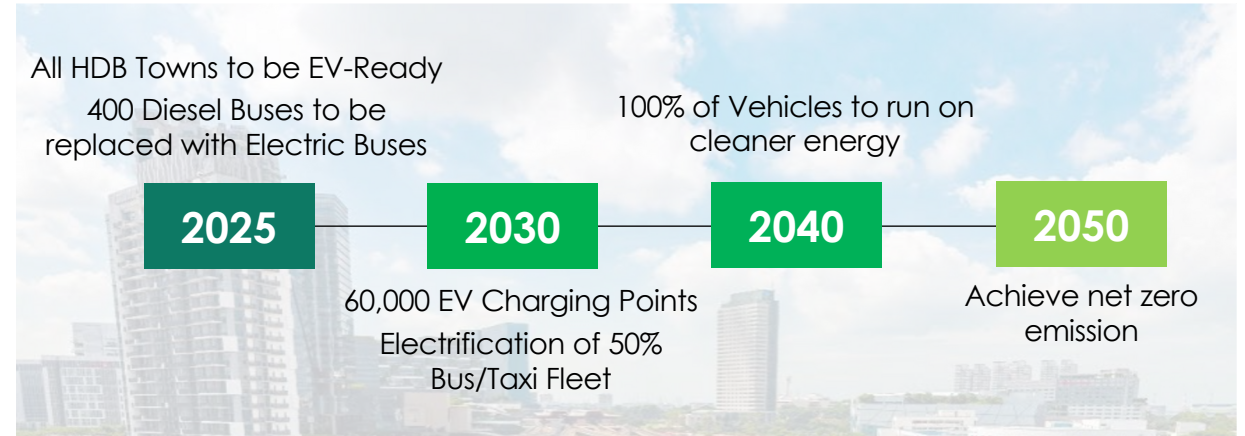
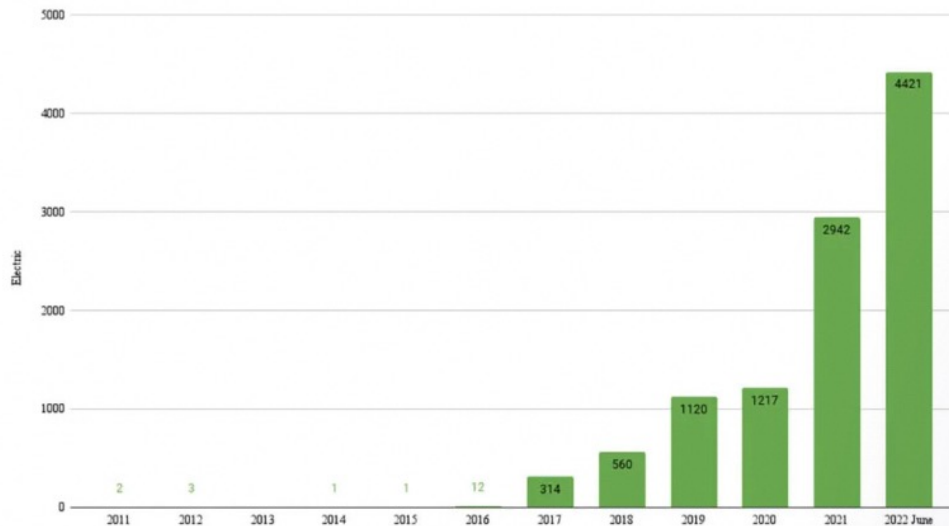
DC Ling Young Ern
Deputy Commissioner
(Operations & Resilience)
Singapore Civil Defence Force



SG EV Landscape

Singapore aims to **achieve net zero emissions** by 2050

Singapore Electric Passenger Car Population 2011 to 2022 1H



SG Green Plan

Energy Reset

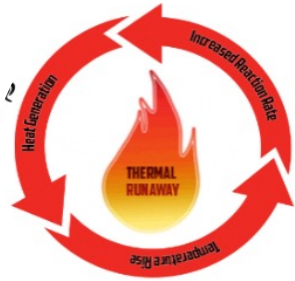


2025 – New Registration of Diesel Cars to cease, HDB towns to be charger equipped

2030 – Car/Taxi Registration to be cleaner energy models, 60,000 island chargers

2040 – All vehicles to run on clean energy

Risks Identified



Thermal Runaway

Phenomenon in which the Lithium-ion cell enters an uncontrolled, self-heating state of propagation.



Off Gassing

Occurs during thermal runaway and involves production of smoke, usually grey or white in color, that issues from the battery.



Vapour Cloud Explosion

EV batteries undergoing thermal runaway will release toxic/flammable gases due to the combustion of electrolytes

EV Fires – Recent Cases in Singapore



Case 1: Sembawang Wharves (Jul 23)

Fire involved a battery module stored in the storage compartment of a Porsche Taycan. Fire was extinguished with a water jet.



Case 2: Kaki Bukit (Jan 24)

Premises was a workshop housing three vehicles: a Porsche Taycan (fire involved the battery pack) and 2 hybrids. Fire was extinguished within 15 mins with a water jet.

Government's Response to EV Incidents

LTA and SCDF established the EV Battery Safety Taskforce (EBST) in August 2023 to develop matters related to strengthening Singapore's response to EV incidents.

The EBST specifically looks at:

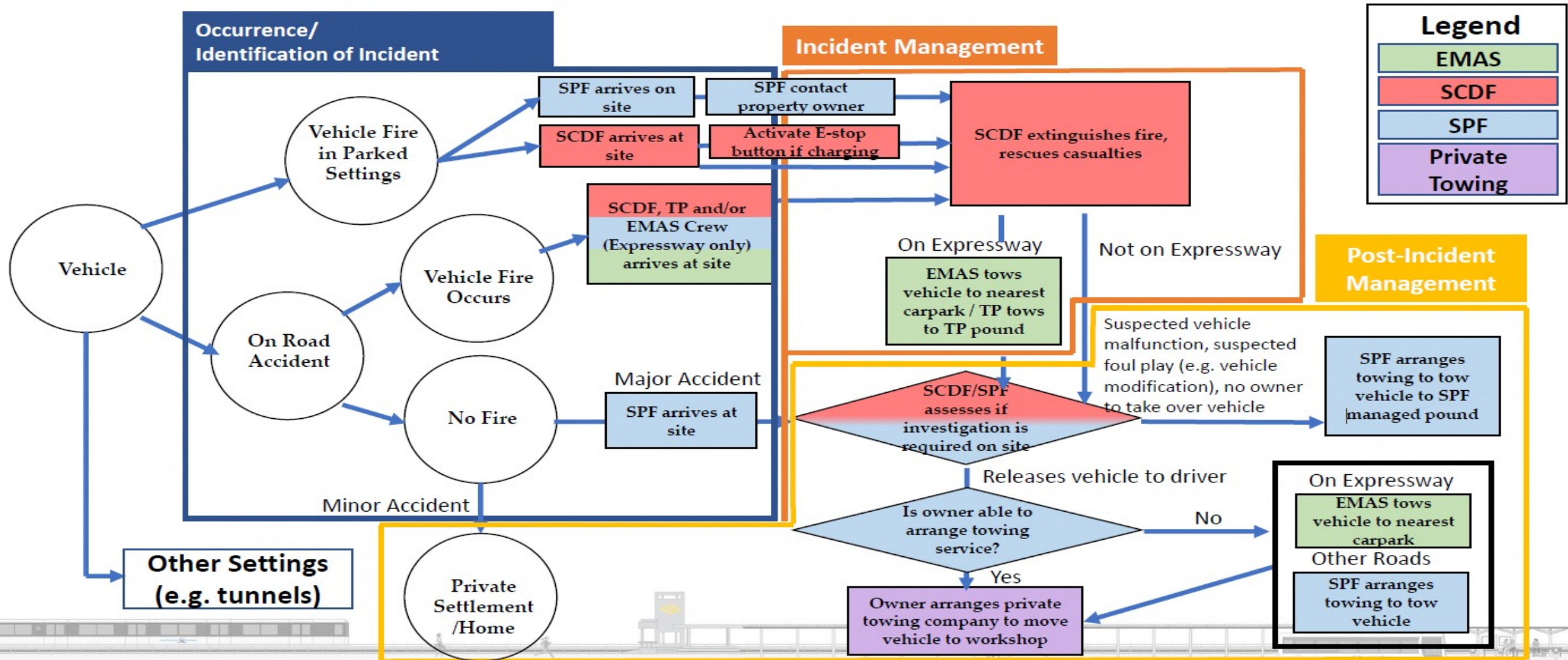
- *Enhancing incident response framework to support Singapore's transition to EVs*
- *Building good public understanding on EV batteries and associated risks*
- *Promoting knowledge sharing among agencies in area of EV batteries*
- *Reviewing sufficiency of existing capabilities, infrastructure, and regulations to manage EV incidents*



63



Government's Response to EV Incidents



Fire Safety Provisions for EV Charging

Indoor & Outdoor Chargers

– 60,000 by 2030

- Each EV charging station shall have an e-stop button within 15m.
- Regulated under the Fire Code (Clause 10.4.2) and national EV charging standard (Technical Reference 25).



SCDF's EV Firefighting Tools



Vehicle Fire Blanket

SCDF recently introduced vehicle fire blankets to **slow fire spread and any release of toxic gases**, to buy time while a water jet is prepared.



Water Injection

Piercing: Recently operationalised tool with a hardened lance that **pneumatically pierces the EV battery compartment** to flood it with water.

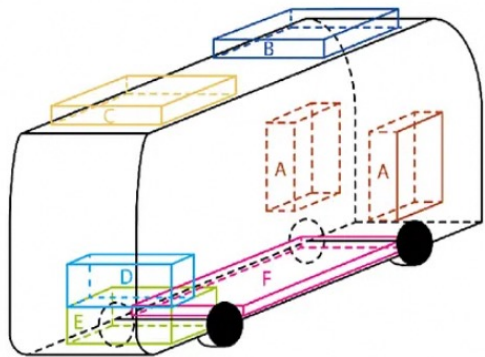
Ultra High Pressure (UHPS) cutting: Latest generation of fire engine will be equipped with **UHPS extinguishing tools to inject water into EV battery compartment**; further trials will be conducted upon delivery in end 24.

EV Fire Test

- **An EV fire test was conducted on 11 April 2024**
 - Validated SCDF's EV firefighting response plan
 - Deployment of vehicle fire blanket in tandem with water jet and battery fire extinguishing system



EV Firefighting Challenge – Large Vehicles

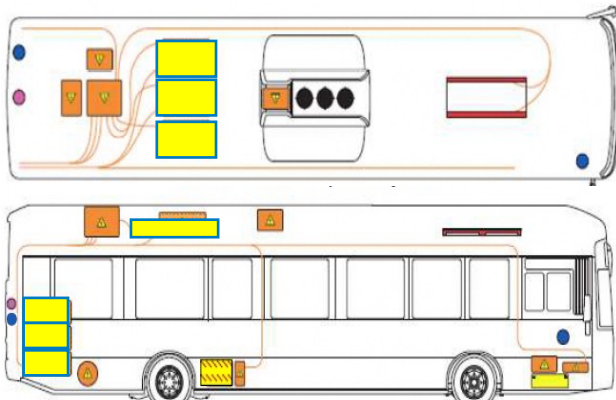


BYD K9	A+C+E [14]
Volvo 7900	C[15]
VDL Citea	B [16]
Solaris Urbino	B [17]
Optare Versa	D+E [18]
Proterra Catalyst	F [19, 20]

Vehicle batteries for electric buses and heavy goods vehicles are mounted in areas other than the vehicle floor.

Accessing the batteries and applying water effectively will be a challenge.

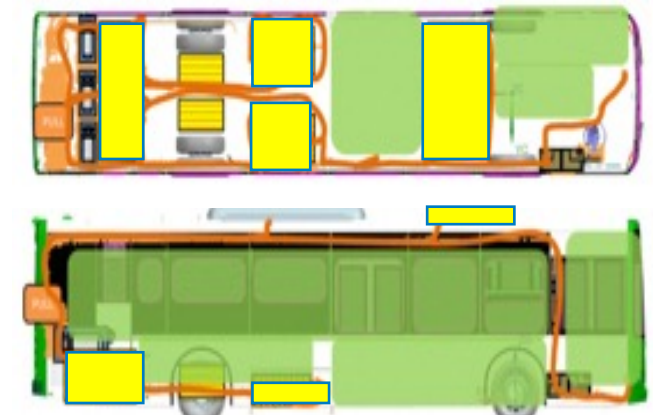
Linkker ST12MSD (single decker)



Yutong E12 (single decker)



BYD K9 (single decker)



More Research Needed on Reignition Risk and Quarantine Methods

01. State-of-Charge is a good means of estimating reignition risk

However, EV instruments display battery related information, but this is often damaged during the incident. Better tools needed to help responders quantify reignition risk.

02. Quarantine of damaged EVs

More research needed on cost effective means of quarantining EVs, if required. For example, to enable safe containment within the vehicle workshop. **Difficult in Singapore due to limited space!**



Conclusion

1. Science & Technology Advancements:

- Safer, superior EV battery & car designs
- Lower incidence of EV fires worldwide compared to ICE vehicles



2. Unique Challenges for Emergency Services:

- EV fires present distinct challenges
- Rare occurrences can skew public perception



3. Confidence Building for a Greener Future:

- SCDF and partner agencies building robust capabilities
- Establishing an ecosystem for comprehensive preparedness

4. Research Opportunities:

- Focus on EV battery fire mitigation approaches
- Aim to enhance global response effectiveness



**World Fire
Congress**

2024 | UNITED STATES

EV Battery Fires

SCDF's Current Response, Challenges, and Areas for Further Work

Ling Young Ern

Deputy Commissioner (Future Technology
& Public Safety)

Singapore Civil Defence Force