Skytanking STR
40k L EV-Refueller
EV RE lessons learned

Skytanking Facts & Figures

110 airports across **16** countries*

40 million cbm refuelled per year (in 2019)

2 million aircrafts refuelled per year

4 fuellings per minute

70 management and operations of tank farm and **16** hydrant systems worldwide*

100+ into-plane operations **~600** into-plane refuelling vehicles *

2,900+ employees worldwide

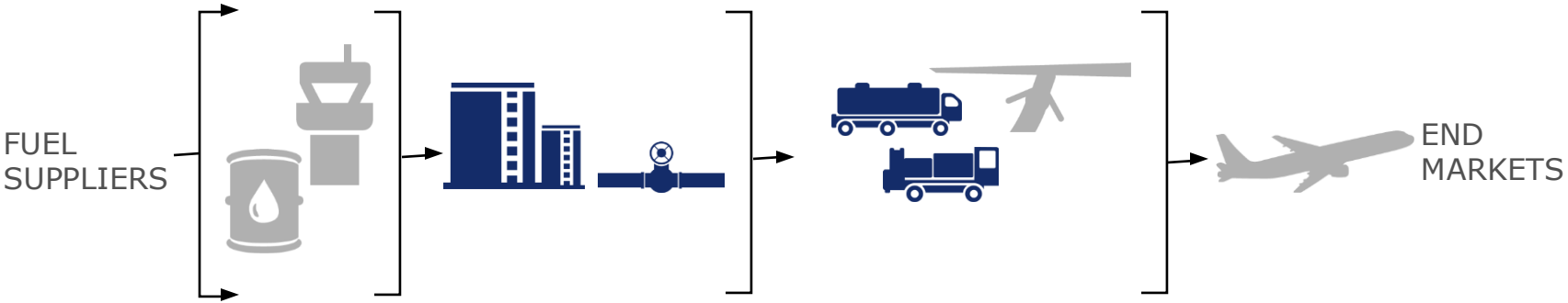
Associate member of **JIG, ACI** and an active member of **IATA Fuel Group**

Founded **1998** in Hamburg

* includes PrimeFlight's 17 US locations

Our Business

We aim to be the preferred partner in aviation fuelling by offering **independent**, **tailor-made**, **innovative** and **cost-efficient** solutions according to the **highest standards** for aviation fuelling services.



Gefördert durch:

Bundesministerium für Wirtschaft und Klimaschutz

aufgrund eines Beschlusses des Deutschen Bundestages

finalize!

Elektrische Flughafenflotte -

Smarte Ladeninfrastruktur

eingereicht im Rahmen der Richtlinie zu einer gemeinsamen Förderinitiative zur Förderung von Forschung und Entwicklung im Bereich der Elektromobilität des BMUB vom 22.02.2021

Übersicht der Projektpartner:

Partner (Kurzbezeichnung)	Ansprechpartner	Adresse
Projektkoordinator Flughafen Stuttgart GmbH (FSG)	Martin Hofmann Tel.: +49 (0)711 948- 3288 hofmann@stuttgart-airport.com	Flughafenstraße 43 70629 Stuttgart
Skytanking GmbH & Co. KG (SKY)	Oscar Sanabria Tel. +49 151 54297503 oscar.sanabria@skytanking.com	Raboisen 6 20095 Hamburg,
ISEA der RWTH Aachen (ISEA)	Jan Figgener Tel: +49 241 80 49312 jan.figgener@isea.rwth-aachen.de & AL-NIS@isea.rwth-aachen.de	Mathieustr. 10 52068 Aachen

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What is the project about? (In General)

Develop an innovative solution for the electrification of a large part of the airport's handling fleet.

The project, called **finalize!** and funded by the German Federal Ministry of Economics and Climate Protection (BMWK), is part of “STR zero”, the airport's climate strategy, and at the same time aims to meet the partners' sustainability goals.

STR airport in a nutshell:

- 13million passengers per year (2019). Considered mid size airport in Germany.
- 250 individual operating companies.
- Total Engine-Powered Fleet of 239 vehicles with 36.8% EV (88 vehicles).
- Pushback-tugs, PRM lifts, Refueling Vehicles, GPUs, 14 ton high-loaders among other N3 vehicles are still fully Diesel operated.
- Installed charging capacity of approx. 5MW.
- Peak charging demand of 7MW.

- Aircraft Handling fleet non-EV responsible for approx. 541,000 L Diesel as of 2019 (Approx.. 1,443 tons of CO_2 equivalent).
- Self-Imposed Goal of operating 100% electric aircraft handling fleet by 2030. (STR airport operated vehicles)

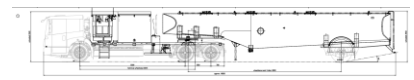
Some Goals of the General project:

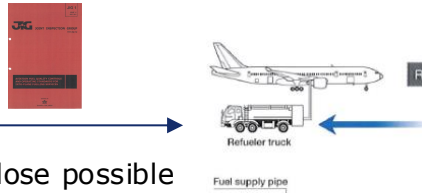
- To **electrify** the currently **largest diesel consumers** at the Stuttgart site and to establish **the necessary measures to put the vehicles into production**.
- To **significantly reduce CO_2 emissions in aircraft handling in vehicle classes N1-3** and thus contribute to the achievement of the goal of "100% electric fleet for aircraft handling by 2030“.
- To carry out **comparative** investigations between **diesel vehicles** and **electric vehicles** in the sense of holistic LCA considerations and profitability calculations, to identify the respective drivers and Identify opportunities for optimization.
- To serve as a comprehensive **live demonstrator** for the **national** and **international** network of airport operators and tank service providers and, through strong stakeholder participation, to ensure the **transferability** of the results to other airports. to **discuss** and **promote**.
- Develop and implement solutions for intelligent charging management, which will serve to **standardize charging systems** based on CCS.
- Ensure the ecologically and economically sensible energy-related integration of electric vehicles into the airport network, including: by integrating a battery storage system as well as researching and testing optimized charging strategies

STR plans to replace 78 equipment into Electric + Charging infrastructure.

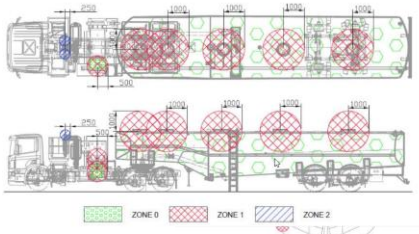
AP1

- Procurement
- Commissioning
- Training
- Normal Operations
- Record Performance



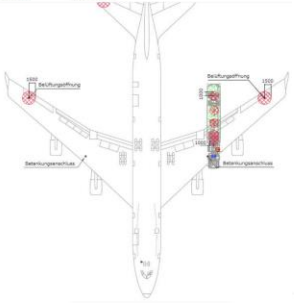


- Identify, define and close possible training Gaps with existing trainings for Diesel vehicles.
- Maintenance Training, servicing training definition.
- HSSE and Hazard Training requirements.

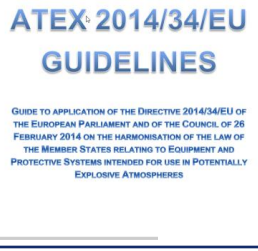


AP0 – Projektkoordination

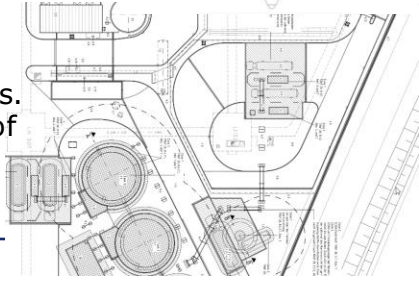
- WP1: Procurement and integration of e-vehicles.
- WP 2: Construction / Expansion of infrastructure
- WP 3: Environmental Impact and Cost Assessment
- WP 4: Energy-efficient integration of vehicles
- WP 5: Standardization
- WP 6: Demonstrator 100% electric aircraft handling

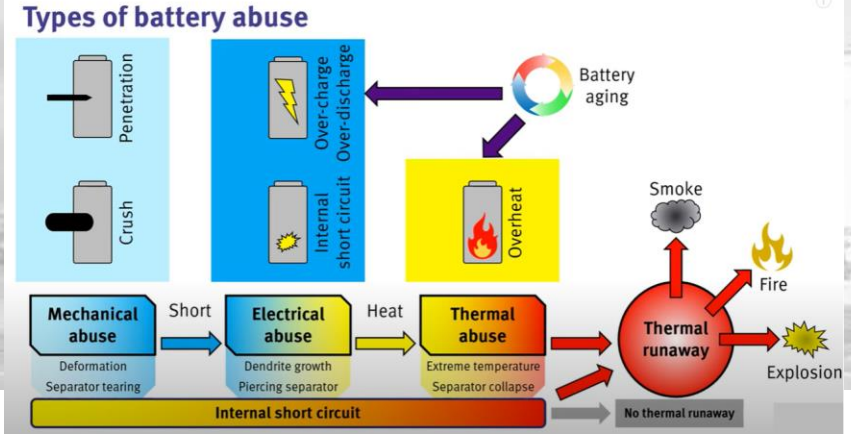


- AP2.1: Contribute to Charging strategies in combination with fuelling data and profiles.
- AP2.2: Planning, construction and expansion of the charging infrastructure.
- AP2.3: Interface with the Airport.



- AP5: Gaps in normative for N3 cat vehicles, EN12312-5.
- AP6.1: Transferability to other airports.
- AP6.2: Transferability to other fields of application.
- AP6.3: live demonstrator.




Types of battery abuse
Penetration
Crush
Over-charge
Over-discharge
Internal short circuit
Battery aging
Overheat
Smoke
Fire
Explosion
Mechanical abuse
Deformation
Separator tearing
Short
Electrical abuse
Dendrite growth
Piercing separator
Heat
Thermal abuse
Extreme temperature
Separator collapse
Thermal runaway
Internal short circuit
No thermal runaway


JET A-1
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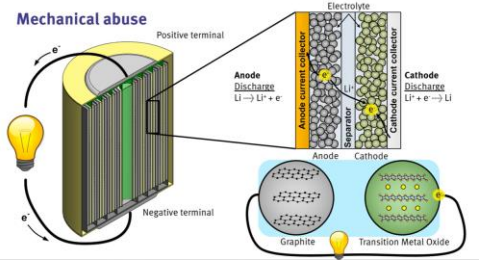
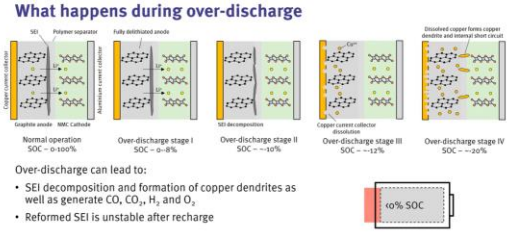
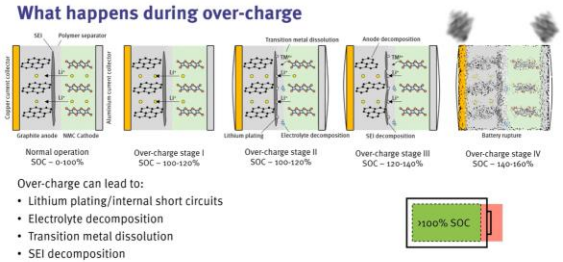
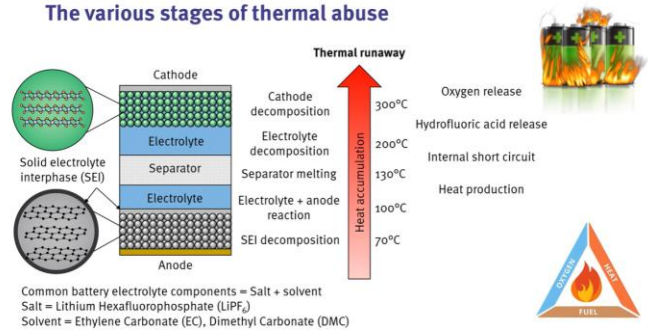
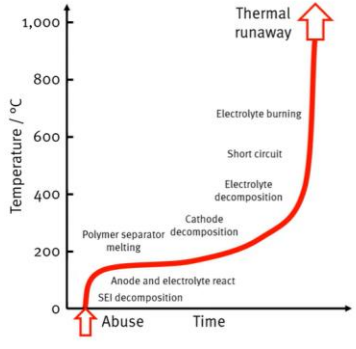
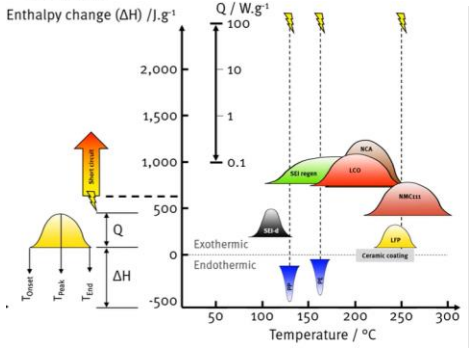

Mechanical abuse
Electrolyte
Positive terminal
Anode current collector
Cathode current collector
Anode
Discharge
Li → Li+ + e-
Cathode
Discharge
Li+ + e- → Li
Separator
Anode
Cathode
Negative terminal
Graphite
Transition Metal Oxide


What happens during over-discharge
Normal operation
SOC ~ 0-100%
Over-discharge stage I
SOC ~ 0-8%
Over-discharge stage II
SOC ~ ~10%
Over-discharge stage III
SOC ~ ~12%
Over-discharge stage IV
SOC ~ ~20%
Over-discharge can lead to:
• SEI decomposition and formation of copper dendrites as well as generate CO, CO2, H2 and O2
• Reformed SEI is unstable after recharge
<0% SOC


What happens during over-charge
Normal operation
SOC ~ 0-100%
Over-charge stage I
SOC ~ 100-120%
Over-charge stage II
SOC ~ 300-120%
Over-charge stage III
SOC ~ 120-140%
Over-charge stage IV
SOC ~ 140-160%
Over-charge can lead to:
• Lithium plating/internal short circuits
• Electrolyte decomposition
• Transition metal dissolution
• SEI decomposition
• Battery rupture
>100% SOC


The various stages of thermal abuse
Thermal runaway
Cathode
Electrolyte
Separator
Electrolyte
Anode
Solid electrolyte interphase (SEI)
Cathode decomposition
Electrolyte decomposition
Separator melting
Electrolyte + anode reaction
SEI decomposition
Heat accumulation
300°C
200°C
130°C
100°C
70°C
Oxygen release
Hydrofluoric acid release
Internal short circuit
Heat production
Common battery electrolyte components = Salt + solvent
Salt = Lithium Hexafluorophosphate (LiPF6)
Solvent = Ethylene Carbonate (EC), Dimethyl Carbonate (DMC)


Thermal runaway
Temperature / °C
Time
Abuse
Electrolyte burning
Short circuit
Electrolyte decomposition
Cathode decomposition
Polymer separator melting
Anode and electrolyte react
SEI decomposition


Enthalpy change (ΔH) /J.g-1
Q / W.g-1
Temperature / °C
Exothermic
Endothermic
Short circuit
Q
ΔH
NCA
LCO
NMC111
LFP
Ceramic coating


EN 12312-5:2021 (E)
Table A.1
No
Hazards identi
EN ISO 12100:2010,
Table B.1
General mechanical ha
Collision or being run
machinery mobility
1
Being thrown
Crushing or shearing
Impact
Cutting
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ECE/TRANS/326 (Vol.II)
Econ
In
Economic Commission for Europe
Inland Transport Committee
A
ADR
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AVIATION FUEL QUALITY CONTROLS
AND OPERATING STANDARDS FOR
INTO-PLANE FUELLING SERVICES
ENDORSED BY
IATA
TECHNICAL FUEL GROUP
1
JET A-1
2
JET A-1
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Annex A
(informative)

List of significant hazards

green: keep
red: modify
yellow: questions

Table A.1 — List of hazards in addition to those of EN 1915-1:2013

No	Hazards identified in EN ISO 12100:2010, Annex B and Table B.1	Hazardous situations	Relevant clauses/subclauses in this Part of EN 12312
	Mechanical hazards		
1	General mechanical hazards 5.1.6.- did MB do it? Stability according to EN1915-2: 2007+A1:2009) 5.7.22 Eisterer	Imbalance due to energy of moving elements (dynamic forces)	5.1.1; 5.1.8; 5.1.13
		Structural failure due to insufficient mechanical strength	5.1.1; 5.1.2; 5.1.6; 5.7.2.2; 5.7.2.7
		Liquids under pressure	5.6.1.1
	Collision or being run over due to machinery mobility reduced Noise level	Collision or person run over due to insufficient visibility	5.2.11
		Collision or person run over due to horizontal movements of the vehicle	5.2.9; 5.3.2
		Collision or person run-over due to insufficient brakes	5.1.4; 5.3.2
	Being thrown	Operator thrown or injured due to inadequate restraint	5.1.4
		Operator thrown or injured due to unexpected jerks while driving the vehicle	5.1.4
	5.1.5: Eisterer: g) Crushing or shearing	Crushing or shearing between fixed and moving elements due to inappropriate or missing protective measures	5.1.5; 5.2.3; 5.3.1; 5.3.5; 5.5.4; 5.5.10
		Crushing between equipment and aircraft or other GSE during positioning	5.5.10;
	Impact Acceleration behavior due to EV	Hitting due to unexpected movements of equipment	5.1.5; 5.2.3; 5.2.9; 5.5.8
	Cutting	Cutting or scratches due to sharp corners or edges	5.1.1
	Fluid injection	Hitting by high pressure hydraulic oil jet or fuel caused by inadequate piping system or hoses	5.6.1.3; 5.6.1.9
		Eyes sprinkle with any liquid	5.1.15

B. *APPENDIX B*

FIGURES IN DETAIL

The following figures are shown in a larger format for clarity.

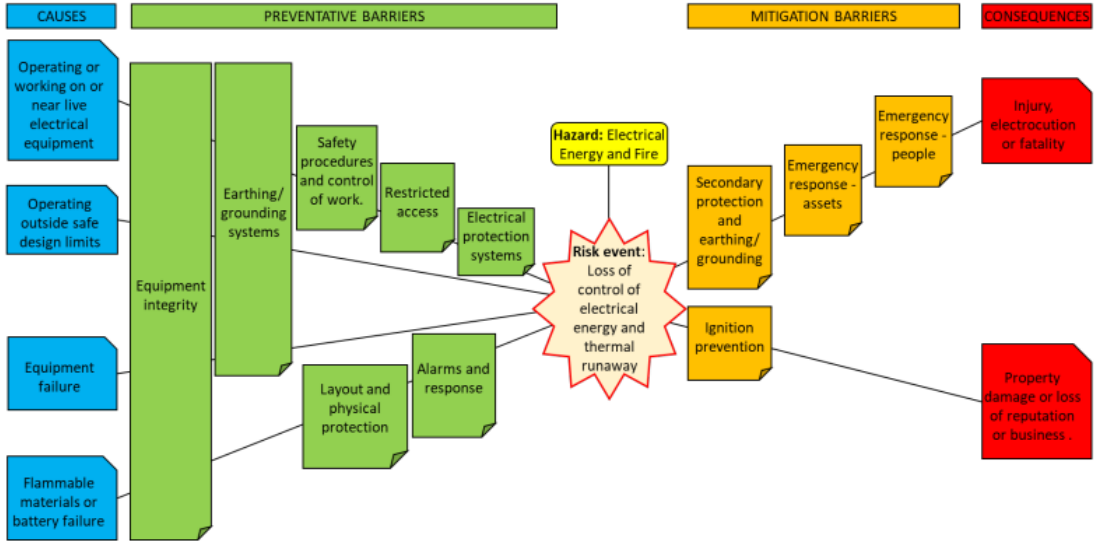

Figure 6. Barriers added to the bow tie model

Hydrocarbon refuelling rates: ca. 300kWh/min)

model causal relatior

and specify the correct type and number of barriers to control these risks. The CPO has better control over the risks of BESS.

b) Mechanical protection

from a fire or as a result of a fire within an enclosed car park.

b) Property or reputational damage and/or loss of

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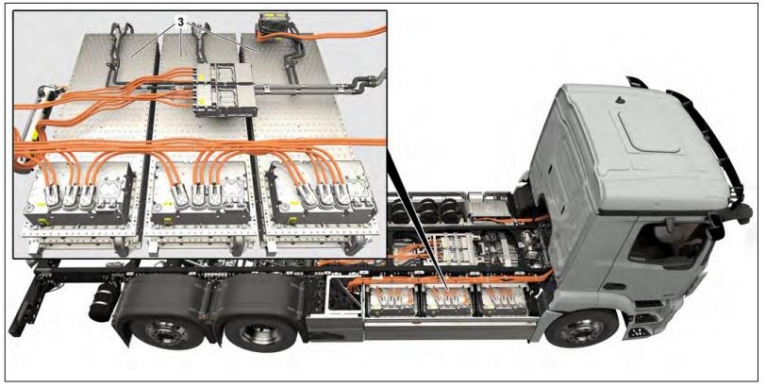

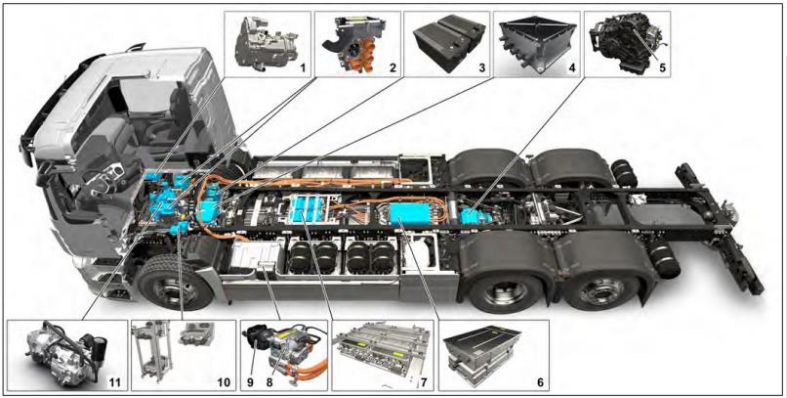

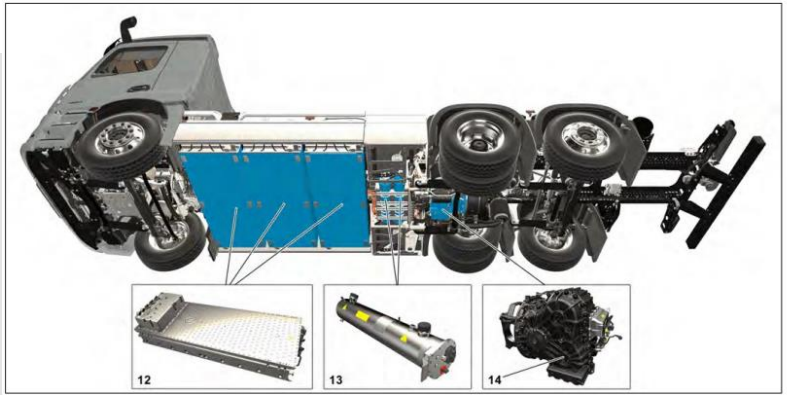

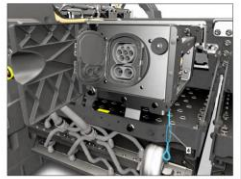

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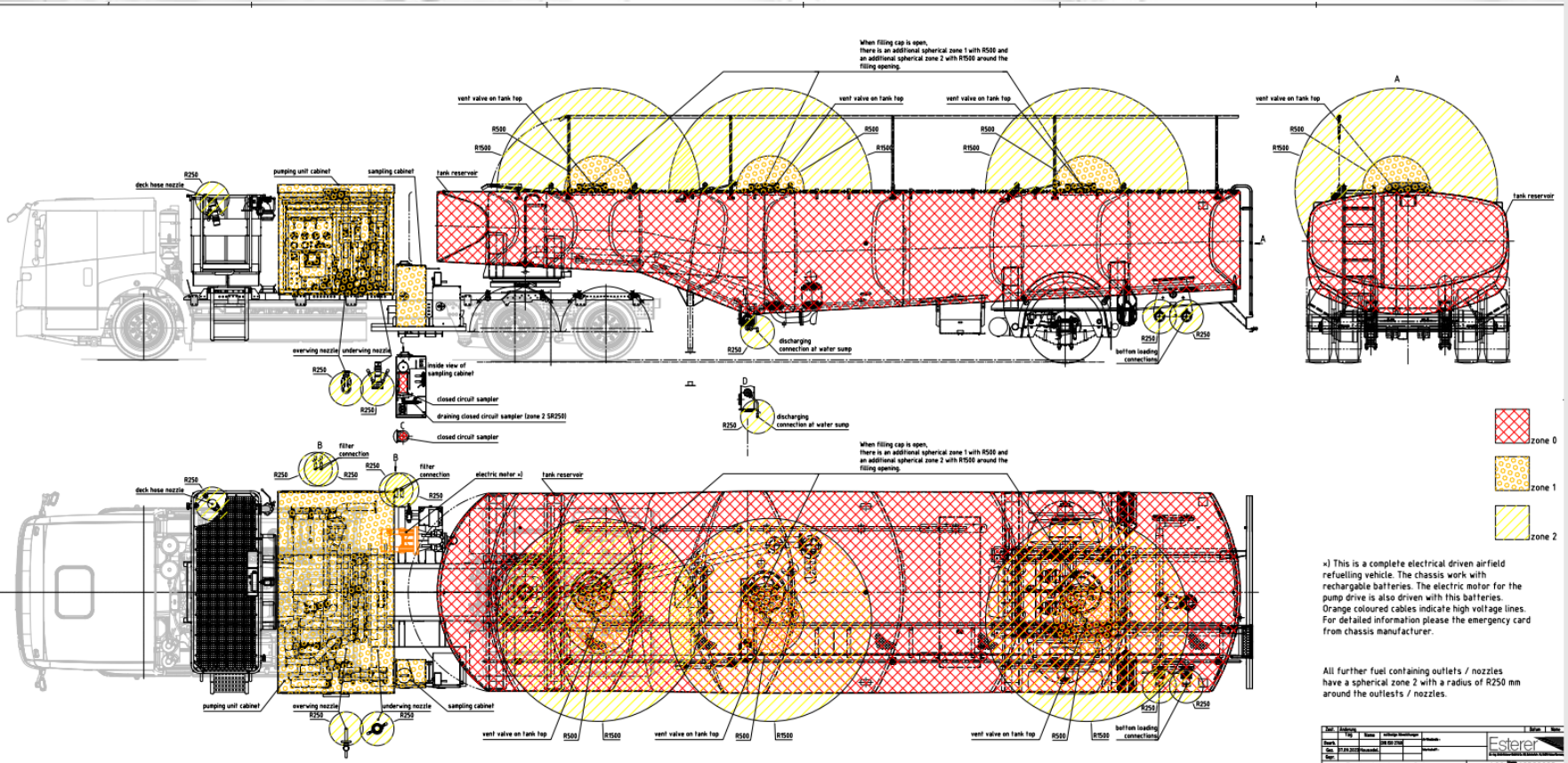

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Root Causes

Preventive Barriers

Mechanical Abuse: vibration, penetration, shock, water ingress into Battery

Internal short: Internal cell failure, cell aging

Thermal abuse: cooling failure, too high/low ambient temperature

Electrical abuse: Overvoltage, (discharge rates, lightning strikes)

Software Malfunction of HV components

Neglecting standard procedures

Vehicle integrity by manufacturer (HV component design): Certified under ECE100 - PKW tests level

BMS

Electrical protection (Manufacturer Insulation & fuses of HV-Equipment)

Mechanical protection (HV Enclosure):

Certified under ECE100 - PKW tests level

Quarterly capacity

Authorized Training on defined HV and support components: Focus when maintenance is needed.

Continuous monitoring + daily check of Battery pack conditions (live interface to Dispatch/shift supervisor + fire department)

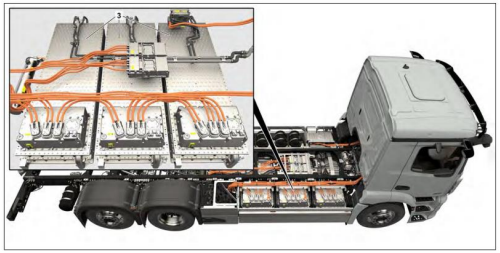
Safety procedures and control of work

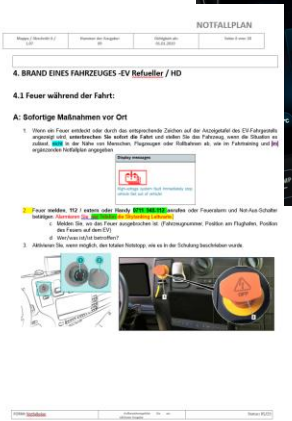
Recurring Training on Vehicle

Explosion is not possible due to Battery construction.

Hazard: Fire hazards

Top Event: Li-ion battery cell failure leading to fire, thermal runaway

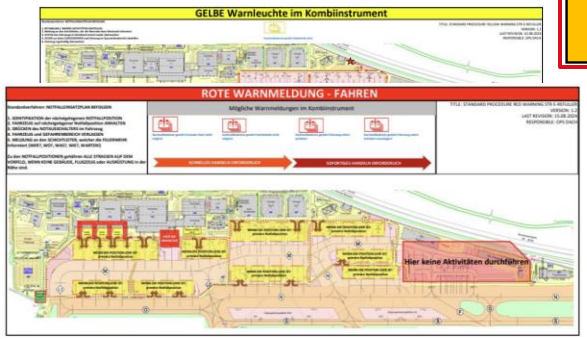


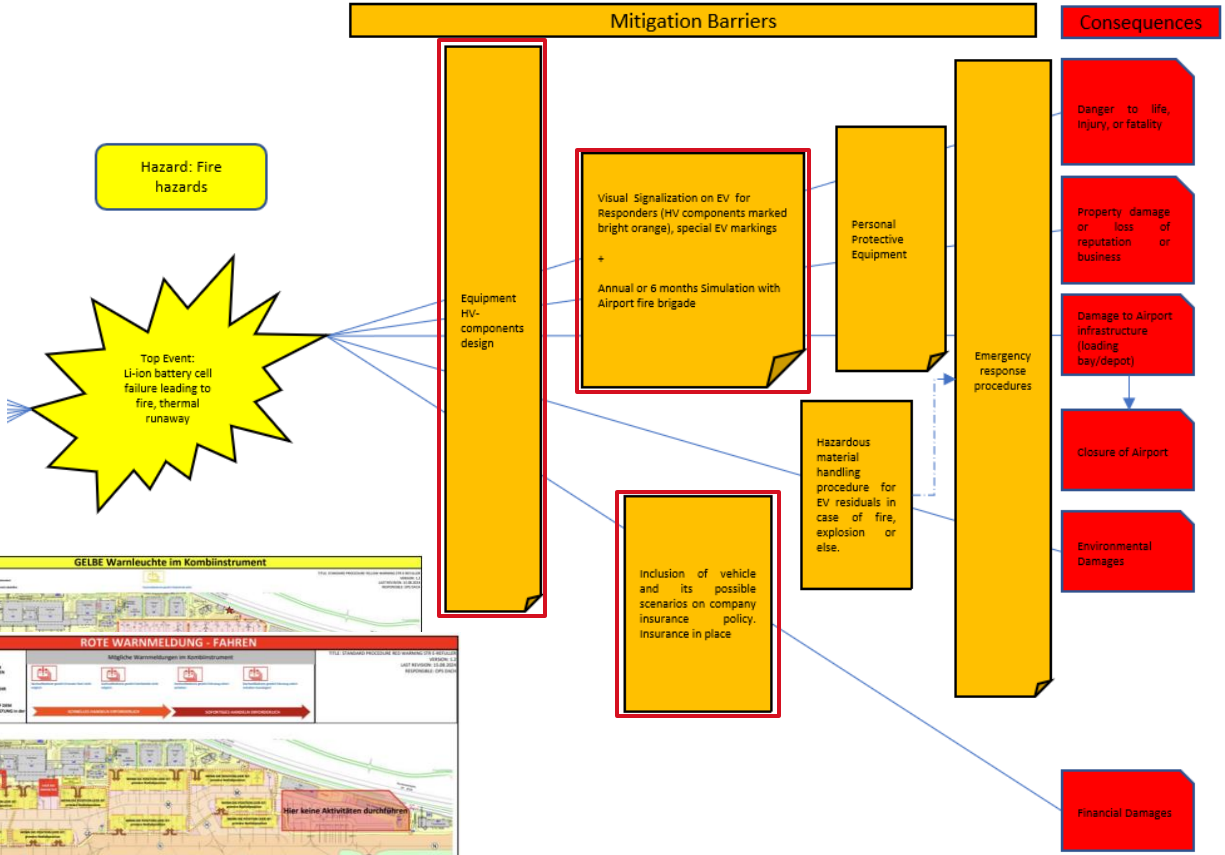


- Definition of scenarios and its adapted response plans.
- GSE personnel evacuation procedures
- Aircraft isolation + RE repositioning

Thermal runaway:

1. Temperature increase above permitted levels
2. Report to Driver by BMS
3. 5 min time to react until there is an imminent danger to the driver (fire +Gas). Driving is not ensured.
4. Battery starts to release Gas thru the enclosing as per design.
5. Exponential failure extends to the other batteries.
6. Battery temperature reaches an ignition temperature and ignites (gas ignition + battery)





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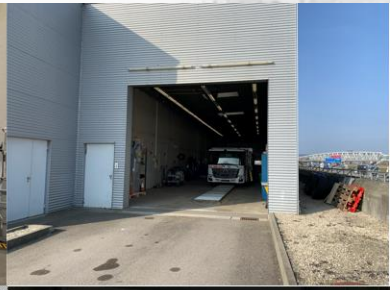

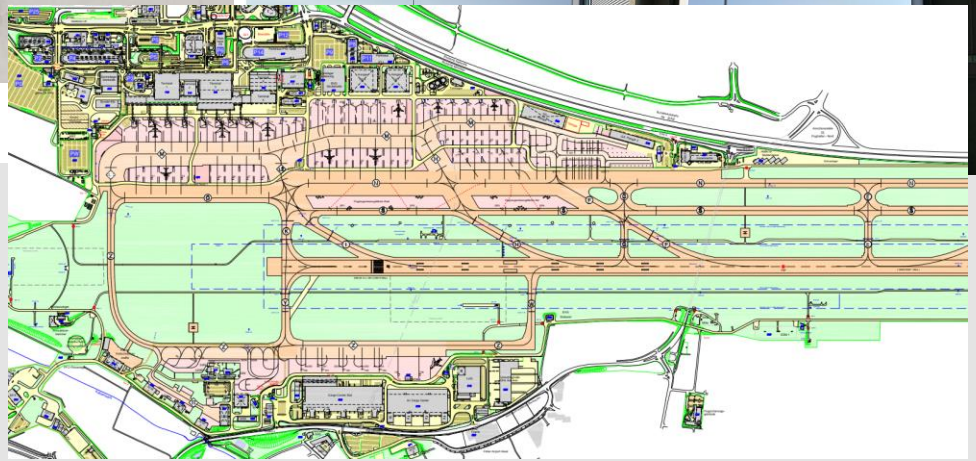

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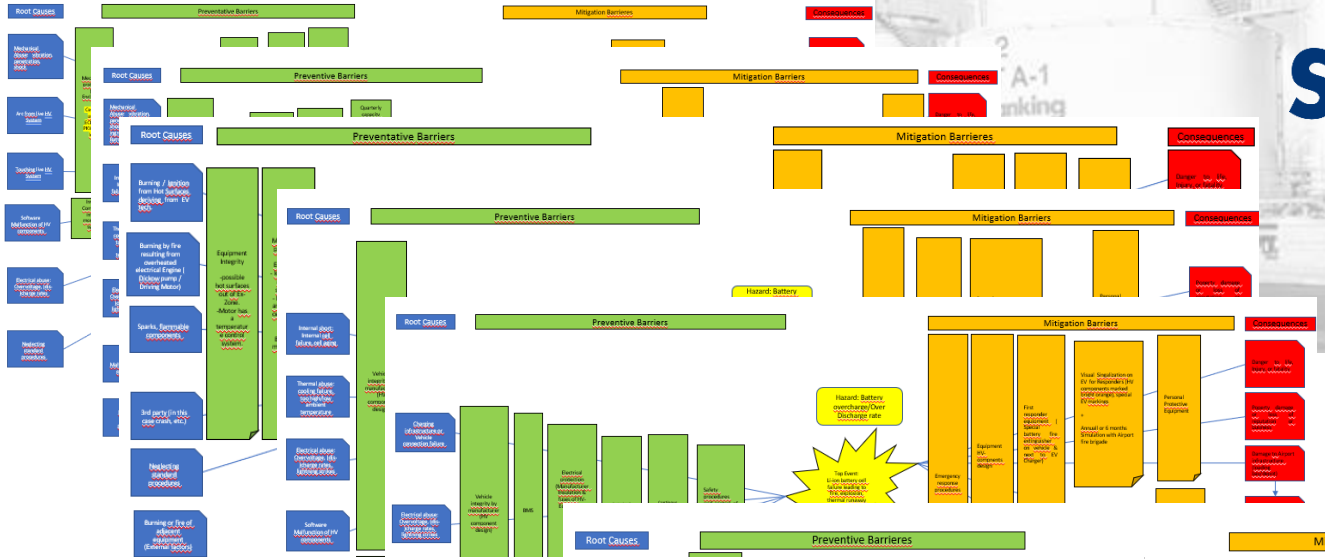
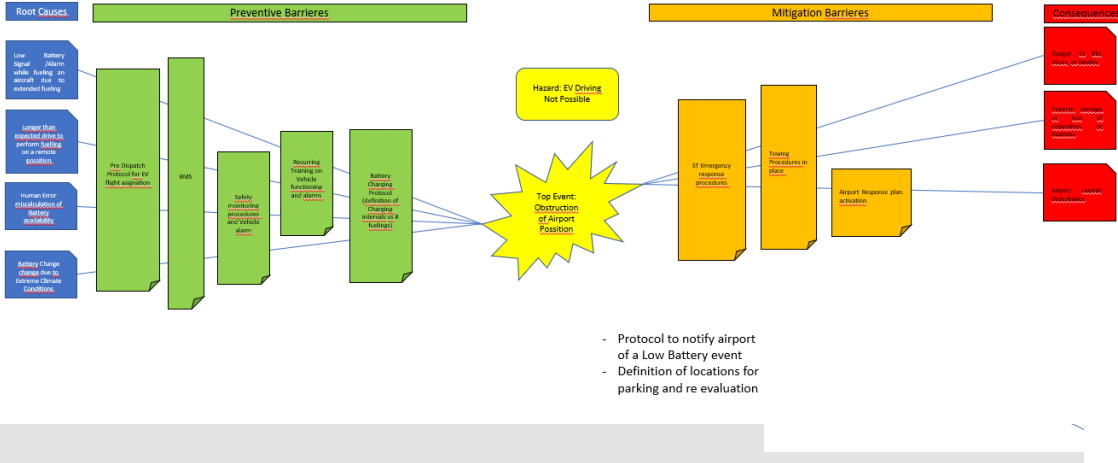
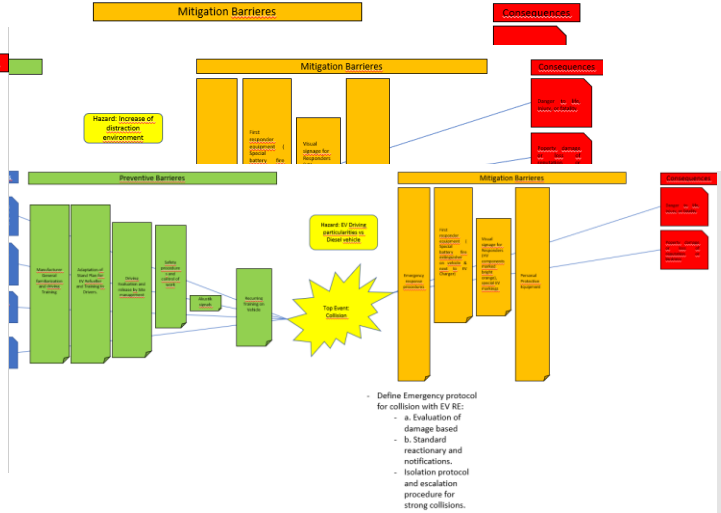




- Protocol to notify airport of a Low Battery event
- Definition of locations for parking and re evaluation



- Define Emergency protocol for collision with EV RE:
  - a. Evaluation of damage based
  - b. Standard reactionary and notifications.
  - Isolation protocol and escalation procedure for strong collisions.

AVIATION - ORGANIZATIONAL APPROVAL LEVELS

The aim of this form is to determine the minimum control requirements for CHANGES AND MODIFICATIONS of equipment, processes, parts, materials, operation and organization procedures, as well as to determine the necessary APPROVAL LEVELS.

NOTE: Level of Change = 0 does not request this approval documentation, except if the unit states that it is necessary for process control.

Levels of Change from 3 to 5 will request the Determination of Control Requirements (Annex 1).

	LEVEL OF CHANGE					
POSITION	0	1	2	3	4	5
Site Manager / Chief of Operations /Project Leader	X					
Area Manager	X	X	X			
Aviation Operations Manager	X	X	X	X		
Operations Director / HSSE Manager / Regional Ops Manager / Country Manager / CTO / CEO	X	X	X	X	X*	X*

* GM/ Country manager needs to be informed.

HSSE Impacts

Potential HSSE impacts:

- [x] Health and safety impact (possible injuries or health effects)
- [x] Environmental impact (e.g. due to possible spills, contaminations, air pollution)
- [ ] Security impact (e.g. additional security threads due to unauthorized access)
- [ ] Financial impact due to potential damage to assets or environmental damage

Description/further details:

The introduction of the EV Refueller does not change the HSSE impacts in it usage and emergency situations when compared to a Diesel vehicle but in the HV handling. There is however a change on HSSE impact in the case of fire as a new material is introduced as energy source that in this cases needs to be handled properly.

Identification of potential hazards arising from the change:

- [ ] Chemical hazards
- [x] Fire/explosion hazards
- [ ] Mechanical hazards
- [ ] Physical hazards
- [x] Hazardous weather conditions
- [ ] Working environment
- [ ] Work organization
- [x] Other hazard factors concerned

(Hazard Identification based on Hazard Classification according to Risk Assessment Standard.)

Description/further details:

- Uncontrolled electrical current HV system.
- Fire Hazards related to EV technology NMC HV systems

- [x] **Additional technical, organizational or personal (T-O-P) risk reduction measures** are required. The measures have to be defined in the section "Agreed Action" of this form and included in the local Risk Assessment.
- [x] **The local Risk Assessment has to be updated accordingly.**

Further comments from the MOC Team regarding the HSSE impacts:

- **EN 12312-5 Gap Assessment revision performed to identify risks due to the change of operating chassis from Diesel to Electric**
- **Bow-Tie Risk assessment performed on the basis of EN 12312-5 Gap Assessment**
- **Additional procedures in the preventive and mitigation identified and adapted/created.**

Operational Impacts

Operational area(s) concerned:

- [x] ITP fuelling service (JIG 1)
- [x] Airport depot (JIG 2)
- [ ] Hydrant system (JIG 2)
- [ ] Ground Handling Operations
- [ ] Head Office
- [ ] Non-operational area (brief description):

Operating Procedures: The change affects the following local Operating Procedures (enter titles and document reference numbers):

- [x] Operating Procedure(s) to be reviewed and updated, where appropriate:
  - FIRE DURING REFUELLING
  - ACCIDENT
  - ACCIDENT WITH INJURIES
  - LEAKAGE/OVERFLOW
  - EXTREME WEATHER
  - RECOVERY PLAN FOR VEHICLES
  - FUELING
  - DRIVING
  - TANK LOADING

- [x] Additional/new Operating Procedure(s) to be prepared:
  - FIRE OF A VEHICLE
  - FIRE DURING DRIVING
  - FIRE ON WORKSHOP
  - FIRE DURING TESTING OF VEHICLE AND/OR COMPONENTS
  - FIRE DURING CHARGING
  - FIRE DURING PARKING
  - CHARGING OF EV RE IN POSS 36
  - EV CHARGING PROCEDURE

Variance Approval Process: The change requires a deviation from the following JIG standards (enter all affected JIG 1/JIG 2 standard references respectively chapters/sections):

- **JIG 1-4.4.3 Engine Emergency Stops.**
- **JIG 1-3.1.13 Emergency Engine Stop controls.**
- **JIG 1-4.21.2 Battery disconnect switch.**

An additional **Variance Approval Certificate** is required: ☐ **Yes** ☐ **No**

(Please refer to JIG 1 / JIG 2, section 1.4.3, respectively the Skytanking Operations and Fuels Quality Control Manual, Appendix 5).

Estimated Financial Impact

The following financial impacts of the change must be anticipated (enter the relevant cost factors, costs (€) and paying parties):

Cost factor (description):	Costs (€):	Paying party:
Training on EV HV maintenance	5K EUR	ST
Training on EV Driving	TBD	MB
Training on EV HV Functioning and risks	TBD	MB

Legal or Contractual Impact

The following legal implications of the change have been identified:

- Insurance liability inclusion. ST Fleet DACH

The change has potential impacts on contracts or agreements with the following stakeholders:

- [ ] Customers:
- [ ] Contractors:
- [x] Suppliers: **MB**
- [x] Airport: **Airport Fire Brigade, Airport Apron Traffic department,**
- [ ] Other Stakeholders:

Further Impacts

2024

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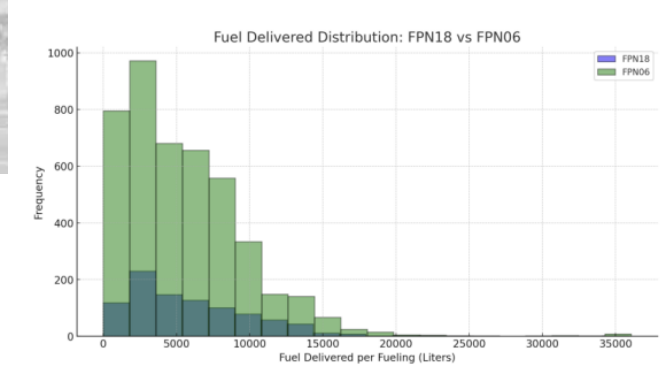

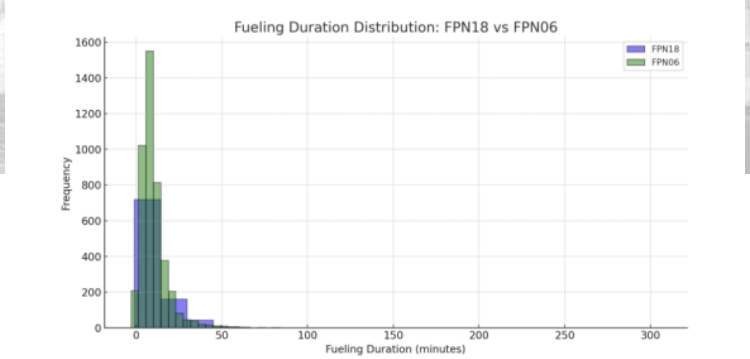

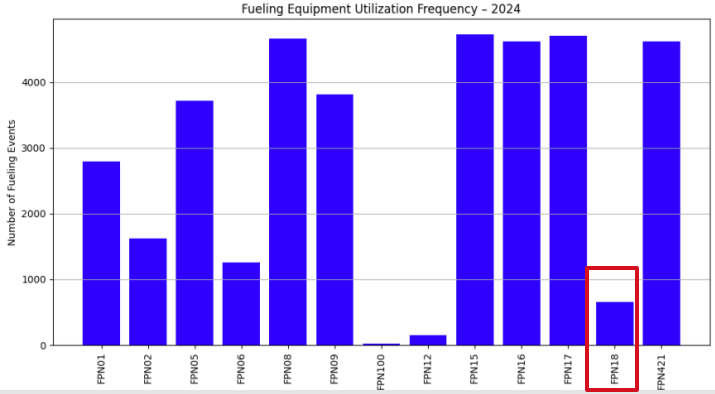

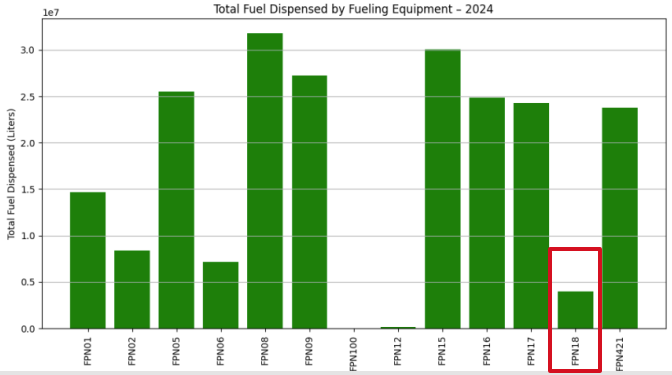

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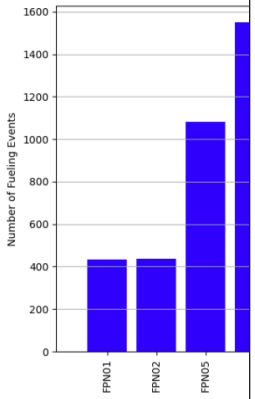
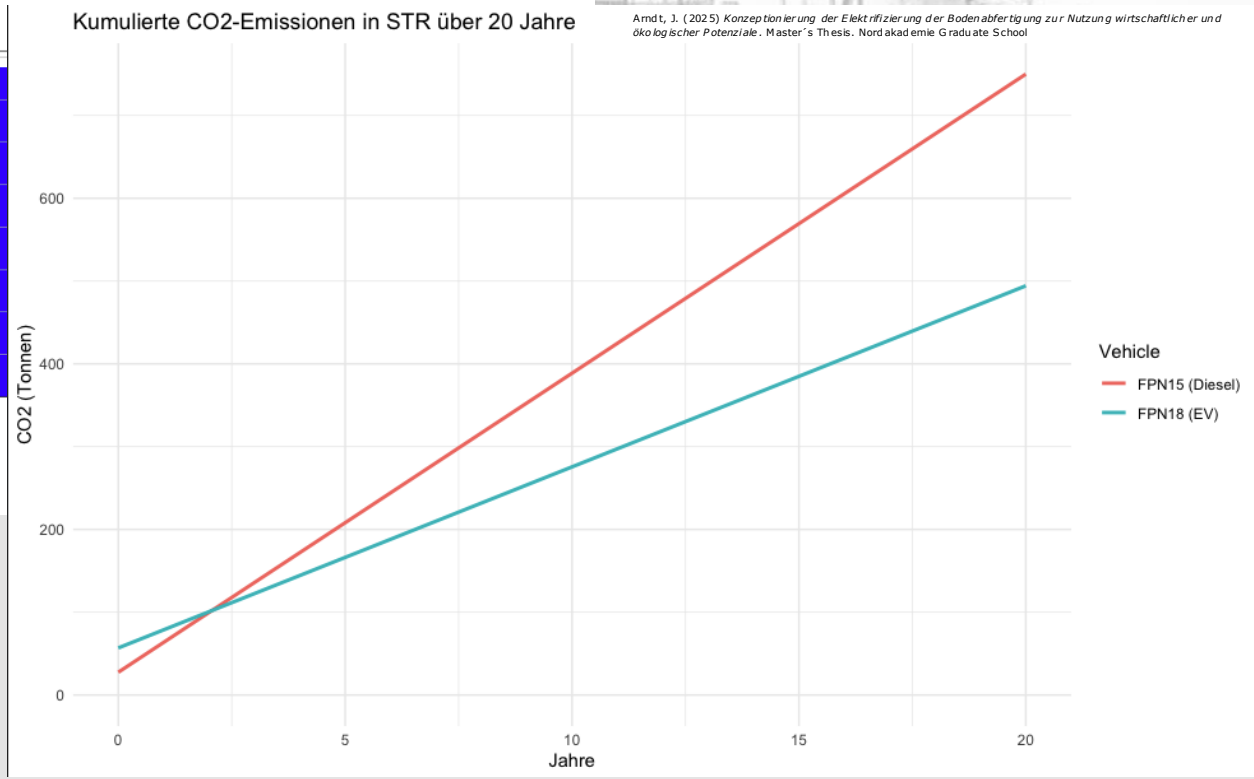
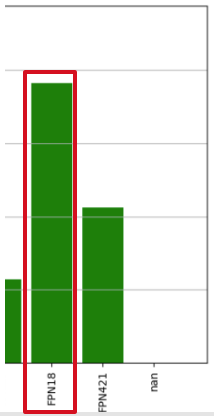




Arndt, J. (2025) *Konzeptionierung der Elektrifizierung der Bodenabfertigung zur Nutzung wirtschaftlicher und ökologischer Potenziale*. Master´s Thesis. Nordakademie Graduate School



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Danke für Ihre Aufmerksamkeit

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