Nordic Innovation

Handling of electric car batteries in the island Nordic countries

Towards a safe and efficient system

Summary

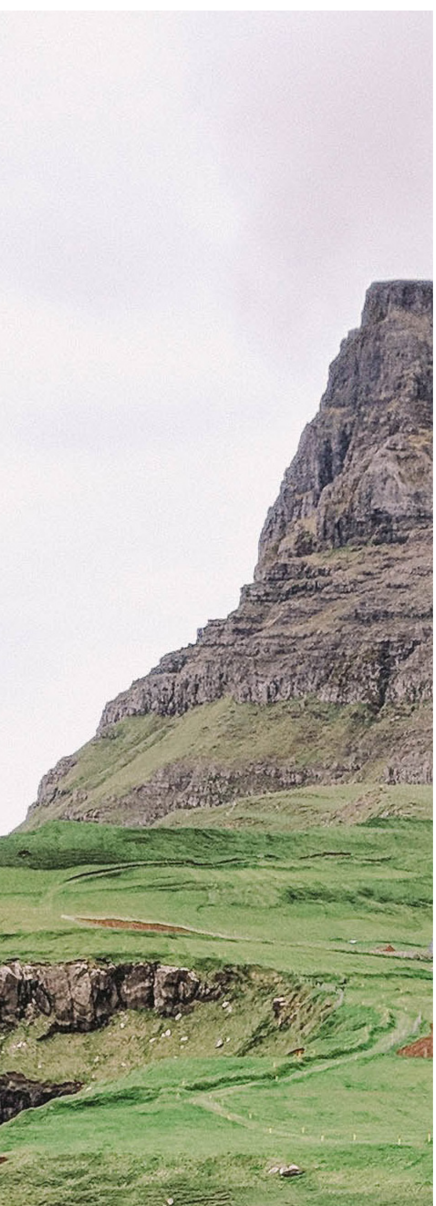
The number of electric vehicles (EVs) sold in the Nordic countries is increasing, therefore there is a need of designing a safe and efficient system to collect, transport and handle the batteries once they have reached end-of-life (EoL). An important step for batteries destined for recycling is the pre-treatment process. During this process the battery is discharged and might be disassembled into its constituent components. The pre-treatment process is mostly done manually today, e.g., in Sweden, Germany, and may comprise considerable ergonomics and safety risks for the operators. The PROACTIVE project aims to set up an efficient and safe process for EoL handling of Li-ion batteries used in EVs in the Faroe Islands, Greenland, and Iceland, including packaging, storage, tools and health and safety aspects related to that work.

In the project we have: **1)** Mapped the current status of stakeholders and processes related to EV battery handling in the Faroe Islands, Greenland, and Iceland; **2)** Defined the needs of the three island countries based on the prerequisites in each one and did benchmark of the end-of-life battery handling process with the leading Nordic countries to fill in the gaps; **3)** Developed a concept of a pre-treatment process from the moment of receiving the batteries, through the required steps to discharge the battery (where applicable), remove all the liquids, handle/store the battery according to the safety and ergonomics principles; **4)** Established safety guidelines and ergonomics guidelines as well as created a simple risk analysis flowchart related to the battery handling based on the best practice/lessons learned from the other Nordic countries; **5)** Established great network and collaboration with the project partners and with the Nordic Innovation organization.

The results from the project show that there are similarities between the studied countries when it comes to challenges of handling EoL batteries. These challenges include lack of regulations and an economical system that ensures that actors are able to receive and handle the batteries, need for more knowledge about the batteries and safe ways to handle and store them, also lack of training and tools as the technology is constantly developing. Our project has contributed to a raised awareness about the end-of-life battery handling in the studied countries, through publications via partners' websites but also spreading information through national magazines.

The most important results and key accomplishments

The first activities in the project **(Work Package 1)** focused on the current state mapping of the end-of-life EV battery market in the three studied countries: the Faroe Islands, Greenland and Iceland. The mapping was mainly performed via interviews with all project partners and other actors along the value chain, as well as desktop research.



The most important learnings and outcome from the first activities:

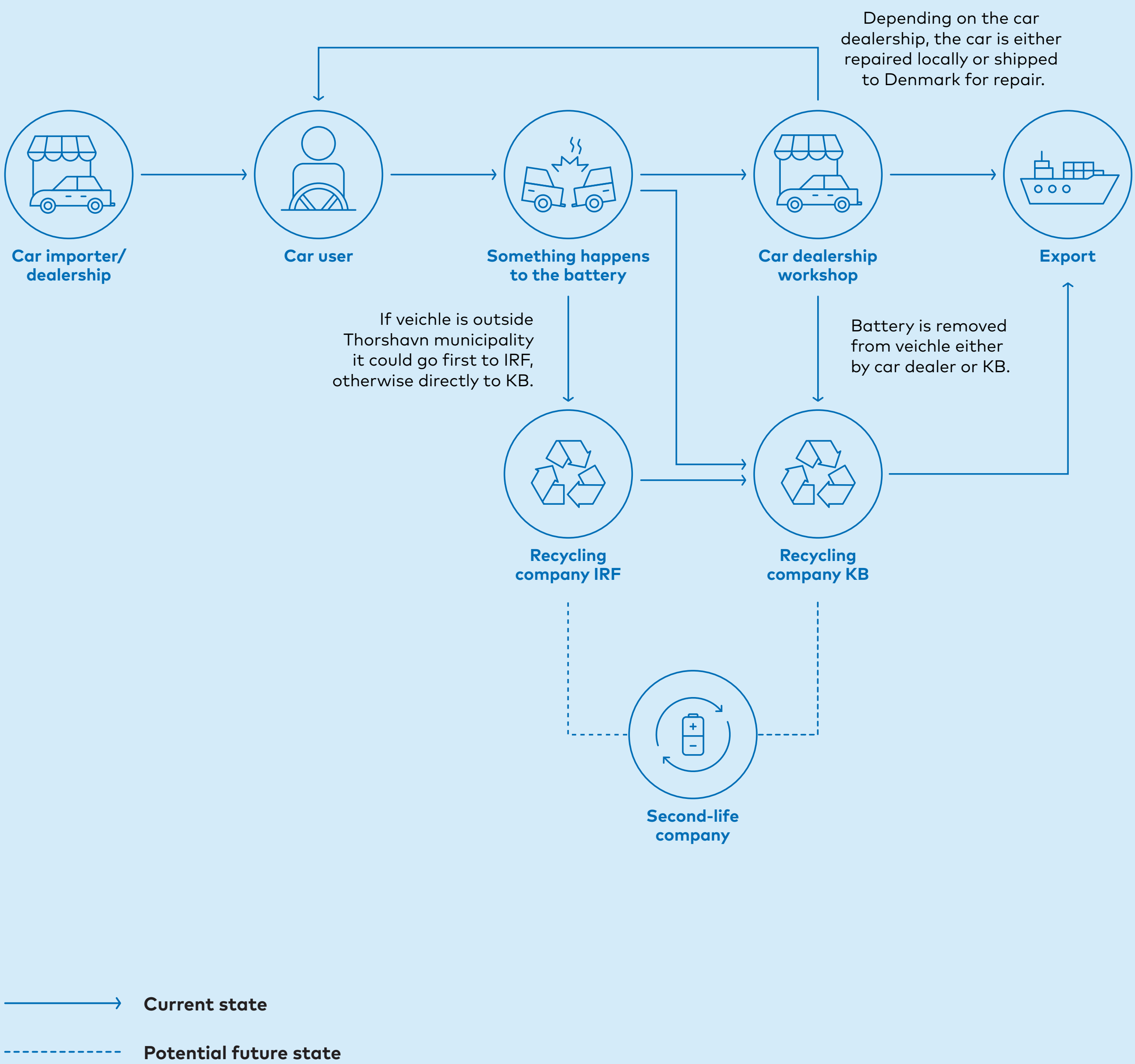
- The mapping enabled to understand how big volumes of EVs there are – which will lead to the number of end-of-life EV batteries that may have to be handled within the nearest years as well as the current preparation status of the actors along the EV battery value-chain in the focus countries.
- When identifying the main actors who handle EV batteries in the Faroes Islands, Greenland, and Iceland, it was noticed that all countries have in common three actors, i.e., car importers, recycling/waste handling companies, and shipping companies. In the Faroe Islands and Iceland, the fire department plays a role as well. In Greenland, the national energy company was identified as a potential actor for battery second-life use. In Iceland, car dismantlers and start-ups currently working with used EV batteries were also identified.
- Knowledge about EV batteries is scarce, however there is a big interest in our project from the political level down to the operating level; all interviewed actors expressed both the interest in the findings from the project as well as potential support to educate (i.e., guidelines how to dismantle EV battery safely, ways to pack and store the batteries, etc.).
- Most of the hands-on experience/training with EV batteries in the studied countries have car mechanics (associated with car importers) however only in Iceland the special trained car mechanics are allowed to do more work on the batteries. For Greenland and the Faroe Islands, changing the batteries in the cars has to be performed in Denmark,

which means the batteries may be potentially leaving these countries instead of being a resource locally. At the time of finalizing this report, the situation in the Faroe Islands has changed – most of the car dealer workshops can repair the car and replace the battery modules when needed.

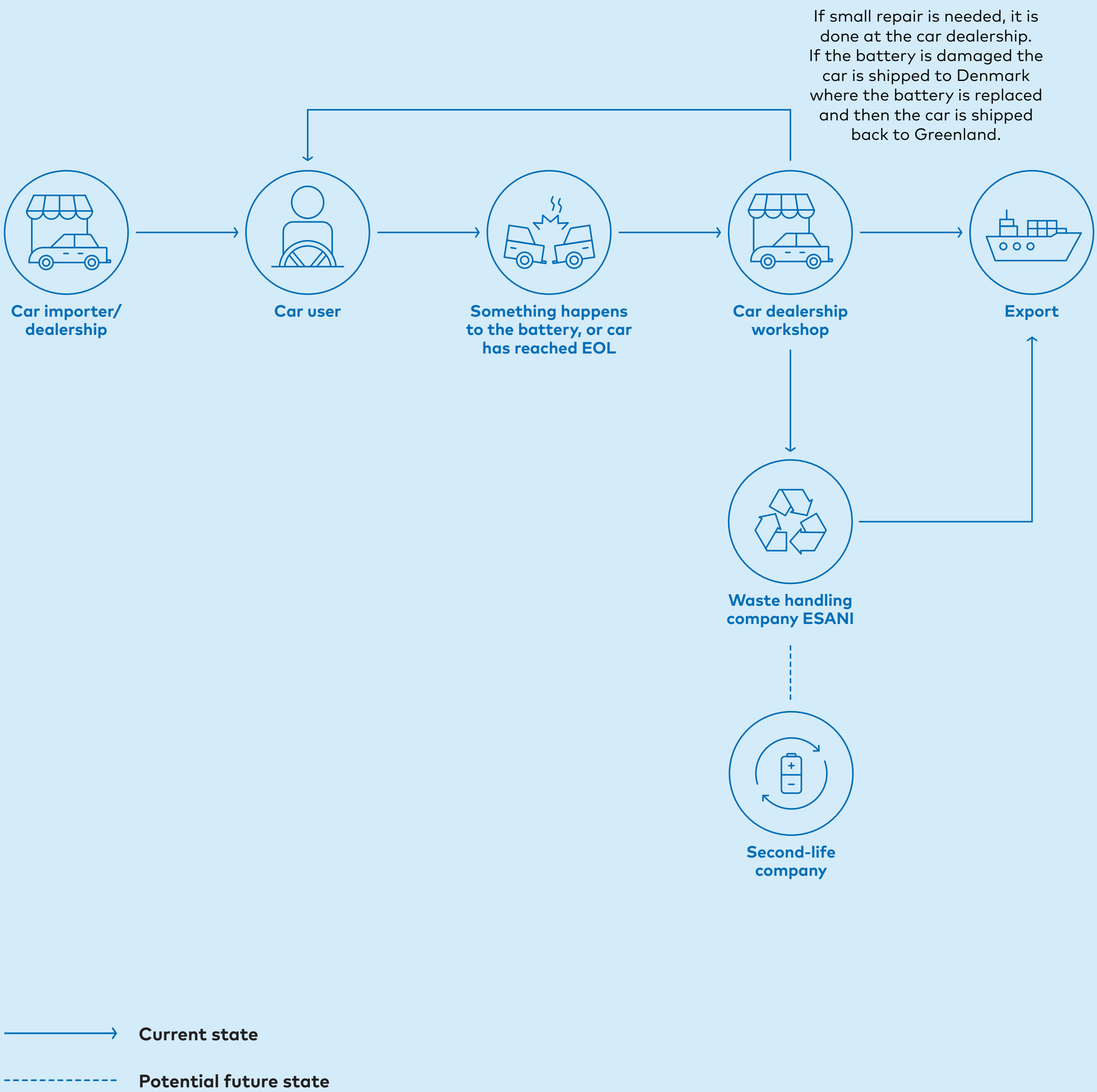
- There are some attempts and initiatives to give a second life to EV batteries, e.g., creating systems for energy storage for private usage (start-up in Iceland), to bigger energy storage systems in small settlements in Greenland.
- There are two common shipping companies in all the focus countries, and they follow the international regulation concerning transportation of dangerous goods (UN3171) which would apply to end-of-life EV batteries; however the experience with transporting EV batteries is very limited.
- Establishing a process to handle end-of-life EV batteries might be highly dependent on the incentives and political decisions on the taxation of EVs in the focus countries, e.g., discussions in Greenland on the same tax levels on EVs as for the combustion engine vehicles. On the other hand, the Faroe Islands have well-established incentives with reduced tax and road fee, also free chargers for EVs to the households (discounts on energy), etc. In Iceland incentives include, e.g., discount of VAT for EVs and EVs can be parked for 90 minutes for free in the capital city.
- The Reference Group for the project was established including Batteriretur (Norway), the Icelandic Recycling Fund (Iceland), the Ministry of Research and Environment (Greenland).

The following figures present an overview of the current and potential future flows of EV batteries in **1)** the Faroe Islands, **2)** Greenland and **3)** Iceland.

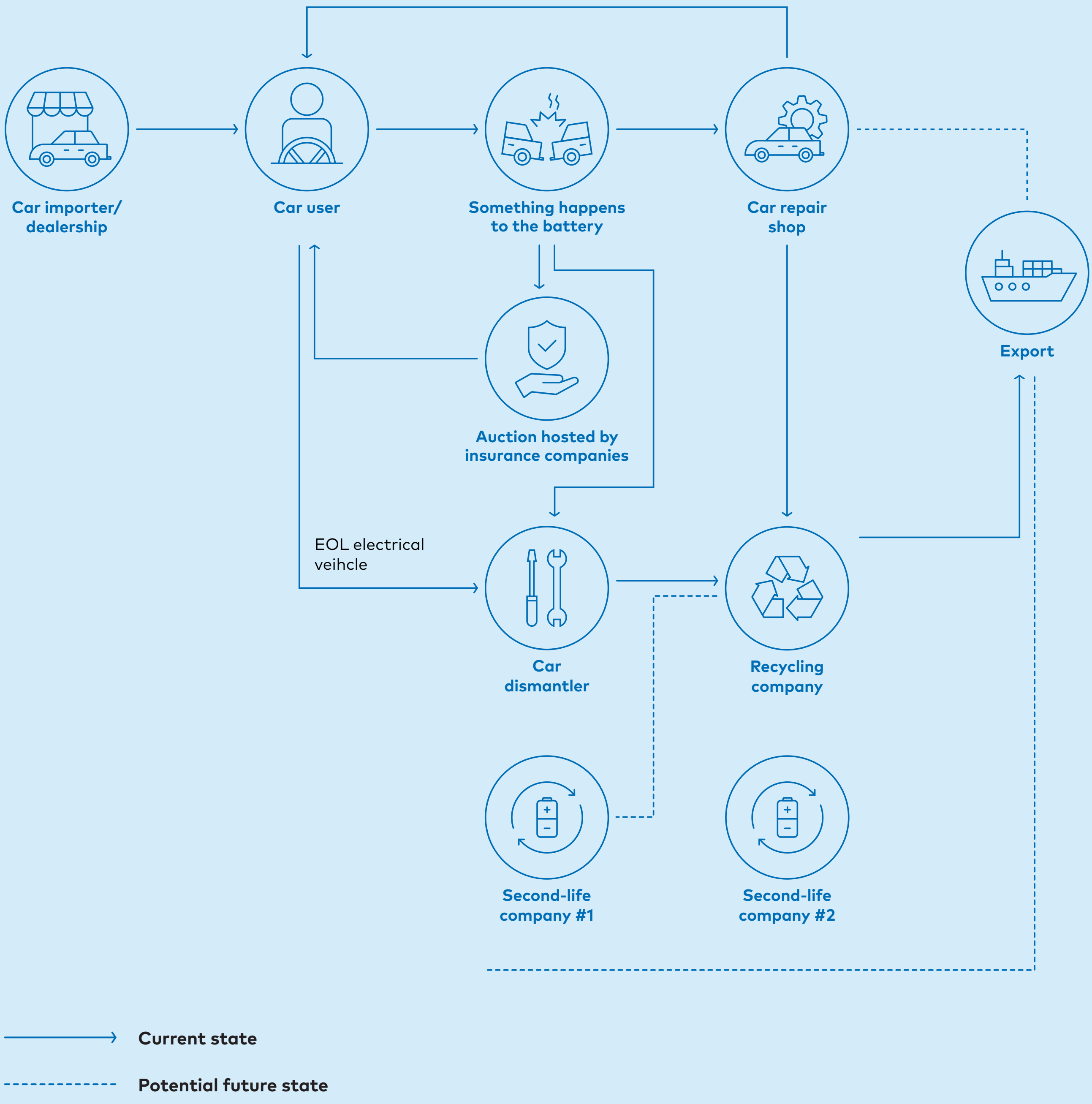
The Faroe Islands:



Greenland:


If small repair is needed, it is done at the car dealership. If the battery is damaged the car is shipped to Denmark where the battery is replaced and then the car is shipped back to Greenland.
Car importer/ dealership
Car user
Something happens to the battery, or car has reached EOL
Car dealership workshop
Export
Waste handling company ESANI
Second-life company
Current state
Potential future state

Iceland:



Car importer/
dealership
Car user
Something happens
to the battery
Car repair
shop
Export
Auction hosted by
insurance companies
EOL electrical
veihcle
Car
dismantler
Recycling
company
Second-life
company #1
Second-life
company #2
Current state
Potential future state

In **Work Package 2** a comparison was done of the current performance of the project and reference group members and the potential or desired performance for Iceland, the Faroe Islands and Greenland. For the need analysis we evaluated the current resources and identified the needs of stakeholders regarding handling of the future volumes of batteries. Interviews with all the partners in the focus countries, as well as benchmark organizations/ companies: Batteriretur (Norway), ARN (the Netherlands), Ecaraccu (the Netherlands), and Autokierratys (Finland) were carried out.

An on-line workshop was carried out with all the partners using MURAL tool to map the most important areas and all the needs based on earlier performed benchmark.

The deliverable was a detailed gap analysis between the current states and benchmark with best practice from Stena Recycling Sweden and Batteriretur in Norway and partners' need analysis based on the local/national prerequisites.

The most important learnings and outcome from WP2 and partially WP3 were:

- Based on the benchmark the following areas were identified as the crucial ones to have in place for the end-of-life EV battery handling: tools and Personal Protective Equipment (PPE), storage, packaging, transport, training and certification, manual work and ergonomics.
- Based on the gap/need analysis, specific priorities for each focus country were set up and are as follows: basic training material on safety of end-of-life EV battery handling including tools and storage area and PPE, guidelines how to transport safely the batteries after car accident, guidelines for and samples of packaging depending on the status of the batteries (damaged, good), a training material on safe dismantling of the battery from a car and ergonomics/work guidelines.
- Pictures from all sites – with the inbound area, potential storage area for EVs and batteries, production halls and outbound area were collected (material for the concept creation).

Work Package 3 and WP4 were about conceptualization and implementation of the processes.

The most important accomplishments and outcome in these work packages are as following:

- Developed safety guidelines to handle end-of-life EV batteries (training material) including tools and storage area and PPE, guidelines how to transport safely the batteries after car accident, guidelines for and samples of packaging depending on the status of the batteries (damaged, good), safe dismantling of batteries from the cars. The main material was created in English, however partners from the focus countries have made translations to the local languages. Trainings of the personnel at the companies in the focus countries will be performed after our project is finished, however.
- Created a flow chart with risk analysis based on different scenarios: receiving a car with battery, receiving only the battery pack, only battery modules and a scenario in case of a fire.
- Developed good and safe ergonomics/ manual work guidelines – including recommended work postures and body motions for safe work.

- 3D sketches of different set-ups/scenarios of workplaces with batteries based on the maturity level of the company and depending on the level of work to be performed with batteries.

All the above mentioned key deliverables are included in the following annexes.

A big accomplishment and highlight were two face-to-face project meetings that took place in June and October 2022. The project started when the Covid 19 pandemic started so we had to do our best to carry out the project via on-line collaboration only. The first physical meeting took place in Denmark in June 2022 and was combined with a visit to a brand new Stena Recycling's battery centre in Farum. Based on this "state of the art" process, the discussions continued on the future settings and possibilities of similar processes in the studied countries. The second physical meeting was in Iceland in October 2022 and included many visits to stakeholders who have more experience with EV batteries: car importers, a start-up building energy storage solutions, as well as we visited two of our partners' companies: Netpartar and Hringras.

The physical meetings contributed to having a great momentum in the project, provided further ideas to the training material we developed in the project, strengthened our relations and collaboration and even brainstorm around potential ideas of future projects.

Annexes

01	An example from the project
02	Safety guidelines
03	Flow chart with risk analysis
04	Ergonomics/work environment guidelines
05	Work scenarios

An example from the project

One important aspect in project PROACTIVE raised by the partners in the studied countries: the Faroe Islands, Greenland and Iceland concerned a risk assessment – what/how should be done when receiving an electric vehicle with good or damaged battery at their sites. The partners might be performing different activities when handling batteries, however in all cases most likely the first step will be to make an assessment/evaluation of the overall condition of the battery (when not known).

Therefore, we created a simplified risk assessment for different scenarios: 1) in case the activities would be from the electrical vehicle level to dismantle to battery cell level; 2) from battery pack level to cell level; and 3) from a battery module level to cell level. The risk assessment is based on the following references: Wörhl et al., (2021) and Skoda training on high voltage cars.

To the right are figures showing an example of Figure 4. Battery pack and Figure 5. Battery modules.

The risk assessment focuses on all activities based on "green" batteries, i.e., batteries that are in a good condition and not damaged, and based on "red" batteries, i.e., critical, damaged batteries. We have also included steps and needed actions in case a vehicle/battery catches fire.

The risk analysis flow chart is included in Annex 3.

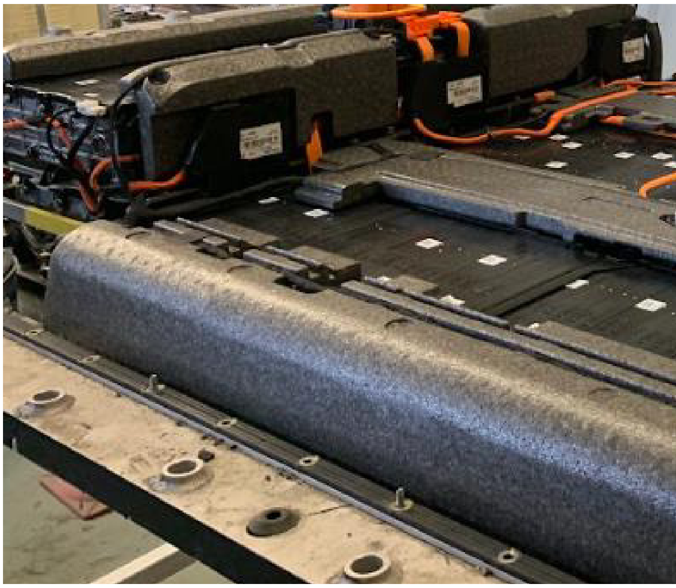


Figure 4 An example of a battery pack

Figure 5 An example of battery modules

Basic safety guidelines for end-of-life EV battery handling

Content:

Abbreviations:

EV – Electrical Vehicle
ICE – Internal combustion engines
LiB – Lithium-ion Battery
PPE – Personal Protective Equipment

Definitions:

A battery cell – a single unit device that converts chemical energy into electrical energy.

A battery module – a collection of cells connected in series or in parallel.

A battery pack – a series of individual modules and protection systems organized in a shape that will be installed in a vehicle (weight 500-600kg).

1 At the crash site (battery in the car)

On their way to and at arrival to the accident location:

- As soon as possible obtain information about the vehicle
- At scene, assess and identify the vehicle to get an overview of the situation
- Use thermal camera to check thermal runway
- Stabilize the vehicle, secure it against rolling away

Assesment of fire – Observe the vehicle and its behavior:

If there is an ongoing fire, the origin of the fire needs to be determined. If the high voltage battery is not yet involved in this active fire, conventional extinguishing methods can be used.

If the battery is damaged and there is a fire it can lead to a full battery fire. If this event has started, cooling the system is an effective way to stop the heat propagation between the cells and reduce the number of affected cells. To cool down the system, use as much plain water in order to drown it.

If there is no fire, determine the condition of the high voltage battery. If there is no fire yet but it is expected due to the battery being damaged, it is advised to cool the battery prophylactically from the outside. **Note the battery can take up fire to several weeks after the accident (often 3 weeks are typical as mentioned in the reference below).**

At scene:

The LiB cells can produce a large amount of toxic gas when they experience thermal runaway and can also vent gases without undergoing thermal runaway, so it might be important to use a breathing apparatus (especially in a confined space).

In case of possible danger, ensure a safety zone. Crew should use fire gear and gloves for 1000 volts and never touch orange cables. When possible, follow the car until it arrives to the car dismantler/recycling and brief them.

Key parameteres for a successful verification of battery status:

- **Optical analysis:** pay attention to the deformation of the battery case, leakage of liquids, rupture, and smoke generation.
- **Acoustic analysis:** due to the pressure build up inside the cell housing the gas will be released at designated vent openings if the pressure exceeds a certain limit. The audible consequences are hissing and crackling.
- **Gas analysis/smell:** the first impression of a ruptured traction system would be a sweet solvent-like odor, typical for leaking electrolyte.
- **Thermal analysis:** the temperature of a lithium-ion cell is a good indicator for its state in regard of safety. The temperature can be measured by directly attached thermocouples or an infrared (IR) camera.

Assessment criteria for evaluation good/damaged batteries:

ASSESMENT CRITERIA			Classification
Visual, sensory	**Functional, electrical**	**Thermal**	
• No smell of solvent • No relevant mechanical damage • No fluid leakage	• High-voltage battery can be diagnosed • No relevant entries in the event memory	• Temperature within the tolerance	**NORMAL** Not critical: No action required
Fulfilment of **ALL** criteria gives a classification of "Normal" →			
• Relevant mechanical damage, e.g.: dent, crack or split, faulty seal • Corrosion damage • Burn smell • Smell of solvent	• High-voltage battery cannot be diagnosed • Relevant entries in the event memory	• Temperature above the tolerance and in-creasing temperature	**WARNING** Critical: Failure to comply with recommended actions (from manufacturer) can result in a serious injury
Fulfilment of **ONE** criteria gives a classification of "Warning" →			
• Fluid leakage and/or suspected fluids in the high-voltage battery system • Smoke/steam • Fire, sparks • Noises (hiss, crackle) • Mechanical damage with open, accessible contacts/conductors • Smell of solvent		• Rising temperature and temperature > 80°C	**DANGER** Dangerous: Failure to comply with recommended actions results in a serious injury or death
Fulfilment of **ONE** criteria gives a classification of "Danger" →			

Source: Skoda training on high voltage cars

At the crash site:

After the fire is extinguished, the burnt-out vehicle still shall be monitored. Even if the battery seems undamaged, there is still a possibility that the chemical reaction inside the battery cells can lead to a new fire.

It is very important to use as much water as possible for cooling the battery in order to lower the temperature and also the risk for thermal propagation to other cells. The amount of water required for extinguishing an EV fire differs greatly in comparison with an ICE vehicle fire. EV fire requires more water to be put out than ICE vehicle fires. Tap water is primarily used for this purpose, as it is easily accessible. Water and water mist have good properties for fighting LiB fires.

2 Towing from the accident site

For the towing company:

- The towing company sends out a qualified person who is trained to handle damaged electric vehicles.
- At the handover, the towing company shall be informed about the following:
  - Electric (or hybrid) powertrain
  - Firefighting measure that took place
  - State of the high voltage system
  - Potential danger from the damaged high voltage components
  - Battery in contact with water
  - Risk of electric shock
  - Possibility of a delayed re-ignition of the traction battery

Generally, for road transportation of dangerous goods, the regulations of the ADR have to be fulfilled. However, this does not apply to the removal of a wrecked vehicle from the accident location, because this clearing procedure is defined as an emergency procedure.

3 At the car dismantling/recycling

The vehicle can be delivered from a crash accident and/or due to the vehicle reaching its end-of-life. The transportation of the damaged vehicle (including high voltage battery) from the towing company site to the car dismantling company is not classified as an emergency and therefore subject to special regulation of the ADR.

Quarantine area:

A quarantine area is an isolated outdoor space where a vehicle can be stored and monitored. A place qualifies as a quarantine area, if there are no flammable objects, other vehicles, or buildings close-by, as EVs may re-ignite and the fire could spread.

The quarantine space must have warning signs and be secured against direct access of unauthorized persons. The safe distance from buildings and other vehicles is often recommended 15 meters. Keep the safe distance from combustible materials and complex scrap.

Temperature measurements must be taken on the high- voltage battery in the quarantine at regular intervals, e.g. daily. It is good to add sensors to help to measure temperature.

Storage of batteries:

There shall be different containers for different type of batteries:

- Good ones - to be reused in 2nd applications
- Damaged ones

To consider in the storage solutions:

- Amount of roller/conveyor racks
- Temperature control/humidity aspects - for the good batteries
- Ventilation, filter
- Alarms
- Water "bath" under the racks

Assesment of fire – Observe the vehicle and its behavior:
If there is an ongoing fire, the origin of the fire needs to be determined. If the high voltage battery is not yet involved in this active fire, conventional extinguishing methods can be used.

If the battery is damaged and there is a fire it can lead to a full battery fire. If this event has started, cooling the system is an effective way to stop the heat propagation between the cells and reduce the number of affected cells. To cool down the system, use as much plain water in order to drown it.

If there is no fire, determine the condition of the high voltage battery. If there is no fire yet but it is expected due to the battery being damaged, it is advised to cool the battery prophylactically from the outside. **Note the battery can take up fire to several weeks after the accident (often 3 weeks are typical as mentioned in the reference below).**

If vehicle has been on fire, the burnt-out vehicle still shall be monitored. Even if the battery seems undamaged, there is still a possibility that the chemical reaction inside the battery cells can lead to a new fire.

It is very important to use as much water as possible for cooling the battery in order to lower the temperature and also the risk for thermal propagation to other cells. Tap water is primarily used for this purpose, as it is easily accessible. Water and water mist have good properties for fighting LiB fires.

LiB fires can result in a relatively large amount of contaminated water or other foam/liquid run-off material that should be collected and disposed of in a responsible manner.

Key parameteres for a successful verification of battery status:

- **Optical analysis:** pay attention to the deformation of the battery case, leakage of liquids, rupture, and smoke generation
- **Acoustic analysis:** due to the pressure build up inside the cell housing the gas will be released at designated vent openings if the pressure exceeds a certain limit. The audible consequences are hissing and crackling
- **Gas analysis/smell:** the first impression of a ruptured traction system would be a sweet solvent-like odor, typical for leaking electrolyte.
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Fulfilment of **ONE** criteria gives a classification of "Danger" →			

Source: Skoda training on high voltage cars

Important to think of – the batteries may recharge after being fully discharged! Working with a traction battery requires high voltage qualification and special equipment.

Because of the different designs of the traction systems, the complete disassembly requires qualified specialists; some car manufacturers require at least 2 people working with the battery pack dismantling due to the risks.

Once the modules are removed from the battery pack, depending on their status, they can be reused in different projects and get a second life. If a second life is not possible/economically viable, the cells and modules will be recycled.

4 Battery packaging

Battery packaging has to follow ADR packing instructions for road transport and IMDG for maritime transport. For ADR packing instructions please check: ADR Book. For IMDG maritime transport please check: IMDG code.

There is a need to select packaging based on battery status/condition.
Good batteries: Wooden cage as well as cages made of plastics are ok to use.
Damaged and severely damaged batteries: Steel casing with non-conductive material inside. Enclosure and heat insulation is needed.

Example of packaging for "green"/non-critical batteries.

Example of packaging for "yellow"/damaged batteries.

5 Personal Protective Equipment (PPE) and tools

Personal and collective protection and safety equipment required when working on EVs according to EDUCAM:

Personal protection

- Electrical insulating gloves
- Gloves that provide protection against mechanical hazards
- Gloves that are resistant against chemicals
- Safety shoes
- Electrical insulating shoes
- Electrical insulating clothes
- Eye and facial protection

Collective protection

- Locks, signs and warnings
- Barriers, warning tape, flags

Equipment

- Two-pole voltage detectors
- Electrical insulating tools
- Electrical insulating blankets
- Electrical safety matting

Tools/equipment:

Verify the functionality of the voltage testing device with a 12V power source before using it. During the test, it is necessary to press both buttons to secure that both hands are out of the reach of the electric voltage source.

Need for tools & PPE depending on type of work/involvement with EV batteries:

- **Limited involvement:** Receive battery modules, store them, and transport them onwards. Tools needed: Forklift and PPE.
- **Medium involvement:** Diagnose batteries, package, store and transport them. Tools needed: Diagnostic tool, PPE and forklift.
- **High involvement:** Diagnose batteries, dismantle, package, and store them. Tools needed: Diagnostic tool, thermo-camera, forklift, PPE and insulated tools.

Special training and certification:

Training levels for workshops:

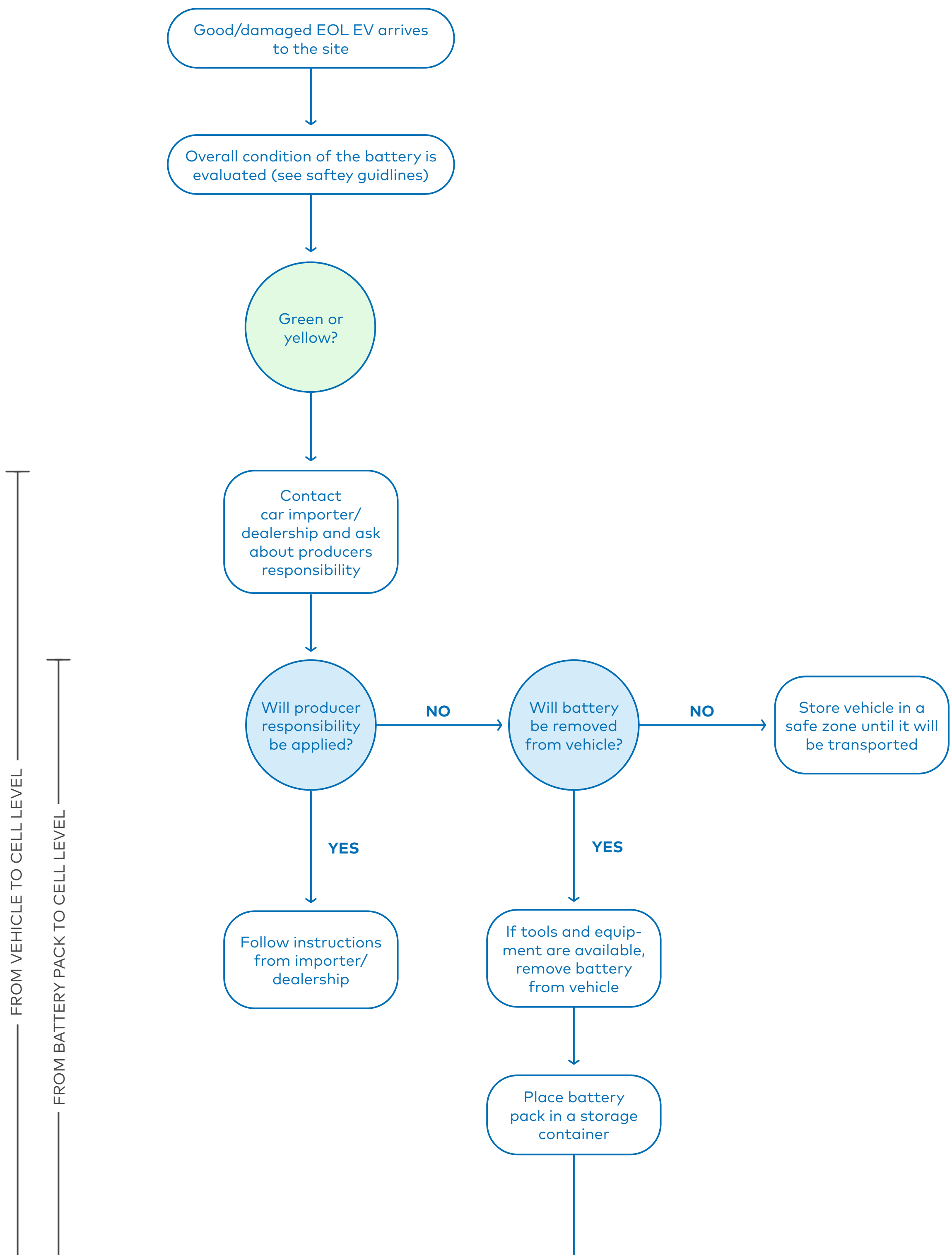
- Normal mechanics - not allowed to work on high voltage systems
- High voltage technicians - allowed to work on an EV but not on a live circuit
- High voltage experts - allowed to go inside the battery

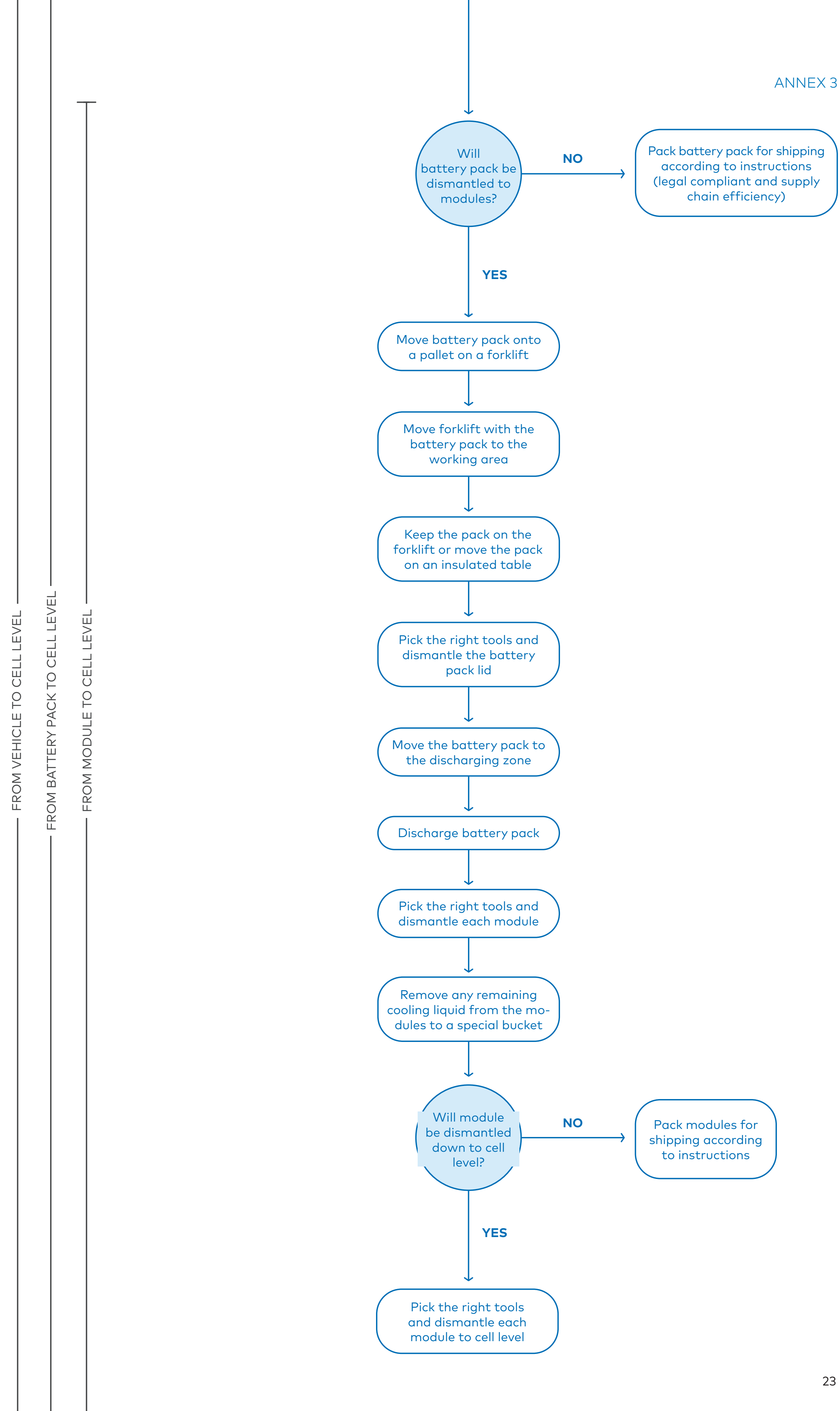
Training for waste handlers/recyclers:

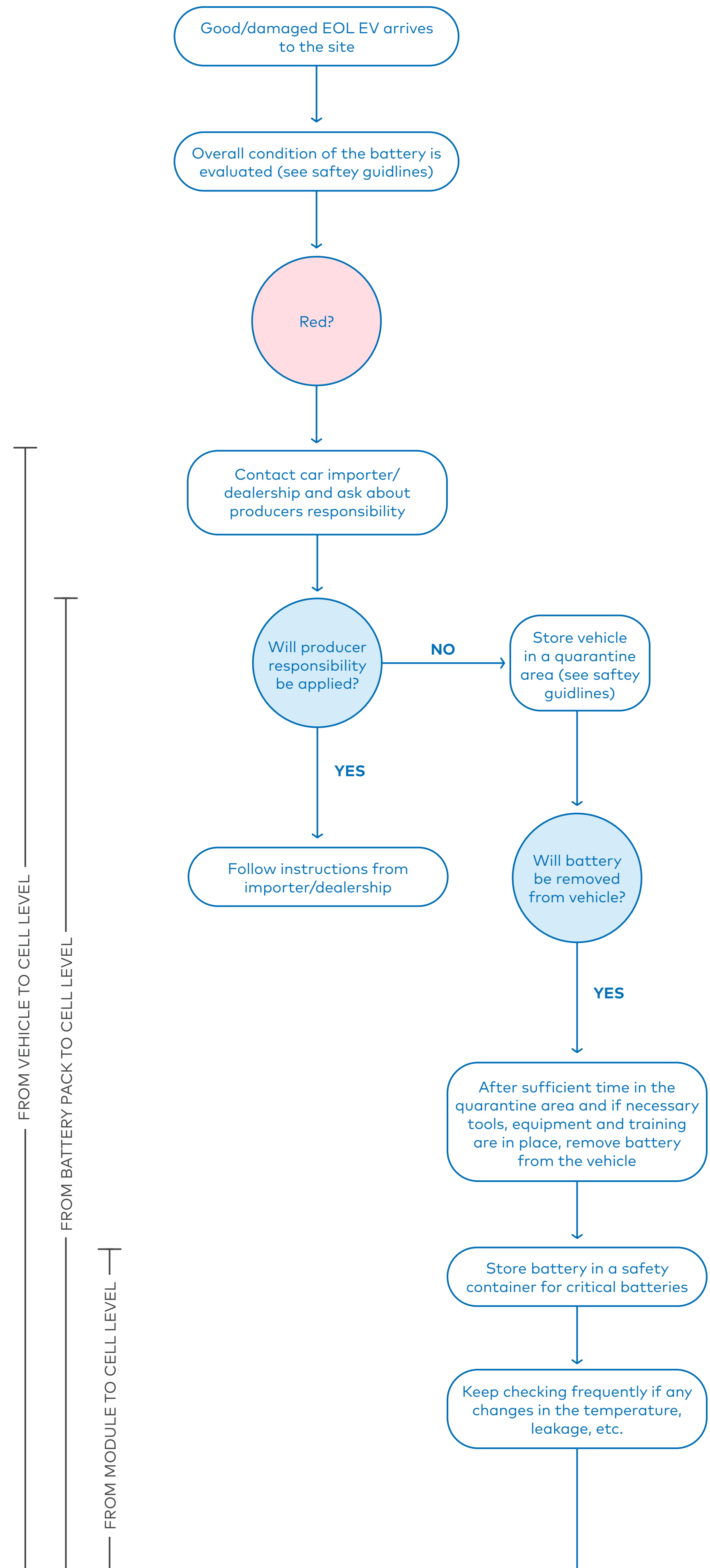
- Knowledge and insights into electricity, voltage & current

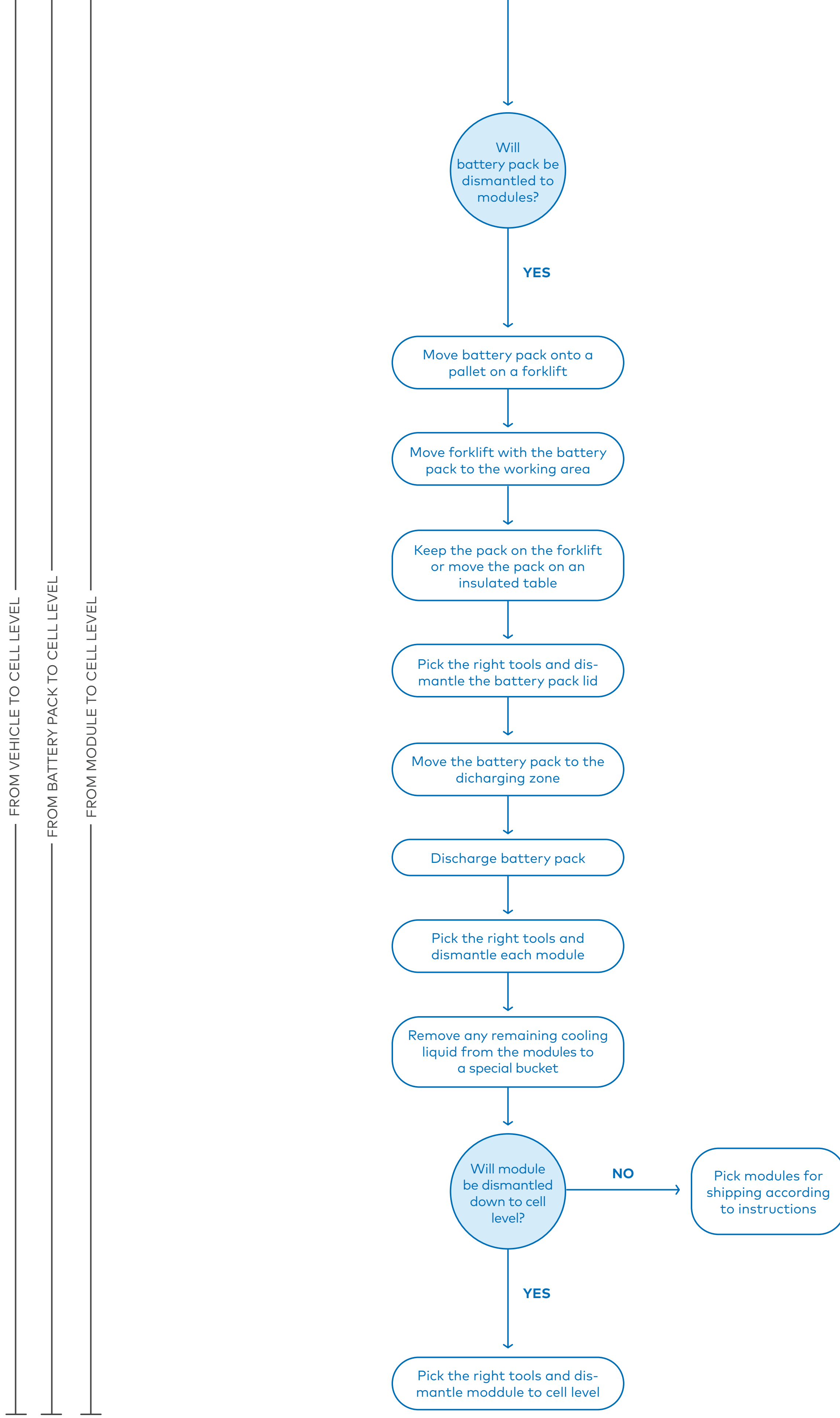
- [ ] Safety manual
- [ ] Packaging manual
- [ ] Training for manual work
- [ ] Certification to take battery out of vehicle
- [ ] License or special training ordered by the government

Flow chart with risk analysis




Will battery pack be dismantled to modules?
NO
Pack battery pack for shipping according to instructions (legal compliant and supply chain efficiency)
YES
Move battery pack onto a pallet on a forklift
Move forklift with the battery pack to the working area
Keep the pack on the forklift or move the pack on an insulated table
Pick the right tools and dismantle the battery pack lid
Move the battery pack to the discharging zone
Discharge battery pack
Pick the right tools and dismantle each module
Remove any remaining cooling liquid from the mo-dules to a special bucket
Will module be dismantled down to cell level?
NO
Pack modules for shipping according to instructions
YES
Pick the right tools and dismantle each module to cell level
FROM VEHICLE TO CELL LEVEL
FROM BATTERY PACK TO CELL LEVEL
FROM MODULE TO CELL LEVEL


Good/damaged EOL EV arrives to the site
Overall condition of the battery is evaluated (see saftey guidlines)
Red?
Contact car importer/ dealership and ask about producers responsibility
Will producer responsibility be applied?
NO
Store vehicle in a quarantine area (see saftey guidlines)
YES
Follow instructions from importer/dealership
Will battery be removed from vehicle?
YES
After sufficient time in the quarantine area and if necessary tools, equipment and training are in place, remove battery from the vehicle
Store battery in a safety container for critical batteries
Keep checking frequently if any changes in the temperature, leakage, etc.
FROM VEHICLE TO CELL LEVEL
FROM BATTERY PACK TO CELL LEVEL
FROM MODULE TO CELL LEVEL


FROM VEHICLE TO CELL LEVEL
FROM BATTERY PACK TO CELL LEVEL
FROM MODULE TO CELL LEVEL
Will battery pack be dismantled to modules?
YES
Move battery pack onto a pallet on a forklift
Move forklift with the battery pack to the working area
Keep the pack on the forklift or move the pack on an insulated table
Pick the right tools and dis-mantle the battery pack lid
Move the battery pack to the dicharging zone
Discharge battery pack
Pick the right tools and dismantle each module
Remove any remaining cooling liquid from the modules to a special bucket
Will module be dismantled down to cell level?
NO
Pick modules for shipping according to instructions
YES
Pick the right tools and dis-mantle moddule to cell level

In case vehicle/battery catches fire:

Dump battery in water and let it stay there for two weeks

↓

After two weeks, lift up the battery and monitor it with thermo camera and observe compliance safety measures

↓

Leave the battery in a safety zone for a few days to see if it starts fire again

↓

Check each module to see if there is any voltage

↓

If all modules are without voltage, you will need an expert help to short-circuit them and put in a container for dangerous goods

Some additional comments when handling a battery:

- Be careful and always measure before you do any work
- Use proper tools
- Be at least two people
- Be aware of fire risks
- Have good ventilation
- Use proper PPE and high voltage gloves

Ergonomics/work environment guidelines

Content:

1 General points

- Safe and ergonomics-wise work is about having a good workplace, with working area optimized for the operators; safe and ergonomic tools; tools available as close as possible to the working zone, good working postures and body movements.
- Also work organization is the key – having a frequent work rotation to engage different muscle groups, sharing work tasks with co-workers; having micro-breaks for quick stretches during the work shift.
- Operators should be trained on good ergonomic work techniques.

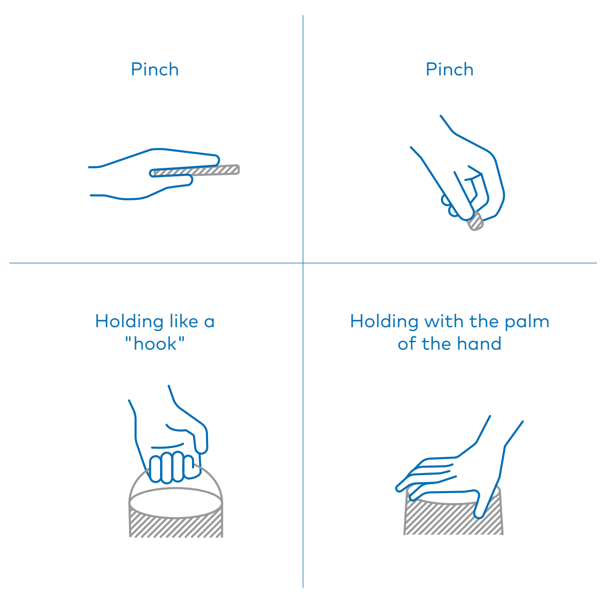
PHYSICAL WORKLOADS AT WORK = **WEIGHT** of objects × **DURATION** to work with × **FREQUENCY** (how often you lift, carry...)

2 Working postures, angles and motions

General recommendations

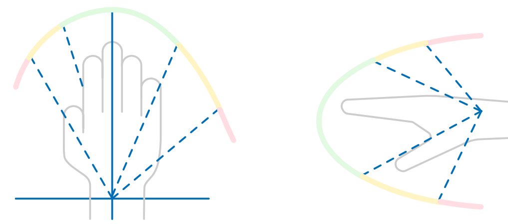
Hands/fingers:

- Pinching/pulling/pressing with fingers will influence loads on the arms.
- Pinching postures as on the picture should not occur frequently; maximum 3 hours/workday.
- Hitting items/tools with the wrist and palms should not occur.



Wrists:

- The wrist work is around its neutral position (max 30º flexion/extension and max 20º deviation; green area on the figures) for most of the time at work.
- A straight wrist is good.



<30° all the time during work	30° - 60° for 10% - 30% of time at work	>30° for more than 30% of time at work

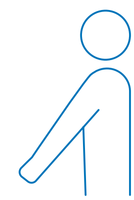
Hand-held tools:

- Hand-held tools are:
  - Adapted for right and left handed operators
  - Good grip; max 40 mm diameter
  - For frequent gripping, compression the force is max 25N
- Wrist works in its neutral position.
- Gripping and handling (tools) is in the range 20-40 mm (diameter), with hand in neutral position, without sharp edges or slippery surface.

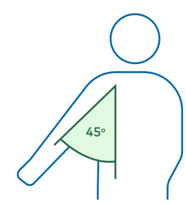
Arms:

- Upper arms are elevated maximum 30º during most of the time at work.
- Maximum abduction (arms lifted to the sides) is 45º for most of the time at work.
- Maximum extension (arm reaching behind) is 20º for most of the time at work.

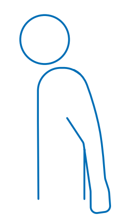
<30° all the time during work
30° - 60° for 10% - 30% of time at work
>60° for more than 30% of time at work



<45° all the time during work
>45° for 10% - 30% of time at work
>45° for more than 30% of time at work



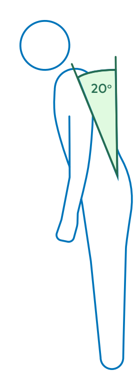
<20° all the time during work
>20° for 10% - 30% of time at work
>20° for more than 30% of time at work



Back:

- Back bending forward and to the sides and back rotation is between 0-20º most of the time at work.

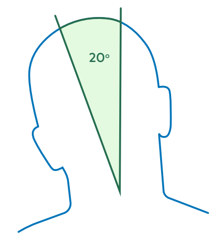
<20° all the time during work
20° - 45° for 10% - 30% of time at work
>45° for more than 30% of time at work



Head/neck:

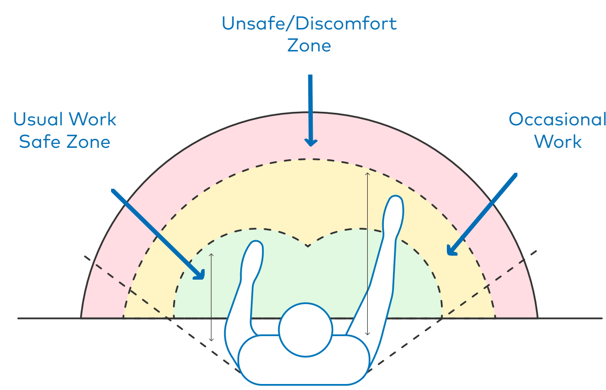
- Maximum neck flexion and bending head to the sides while working is 0-20º.

<20° all the time during work
>20° for 10% - 30% of time at work
>20° for more than 30% of time at work



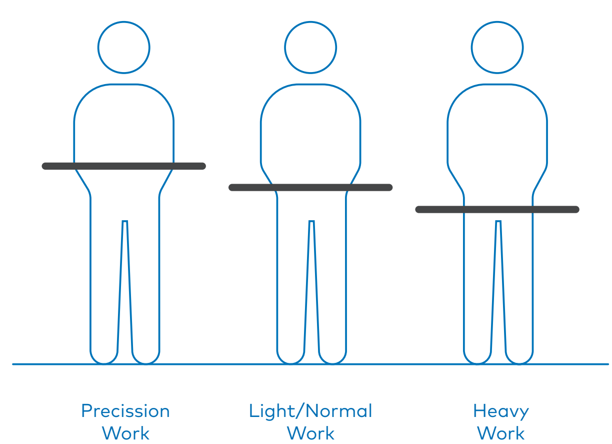
Reach zones:

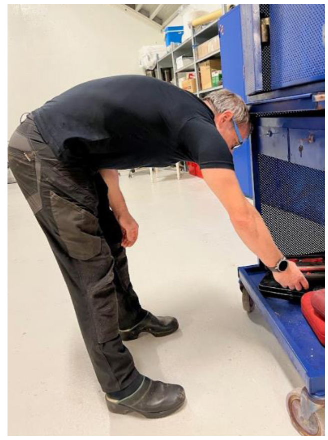
- The primary work zone (usual work safe zone) with the work piece is max 25 cm from the table edge.
- The secondary work zone (occasional distance to material shelves/compo-nents is max 40 cm.



Height to the work piece:

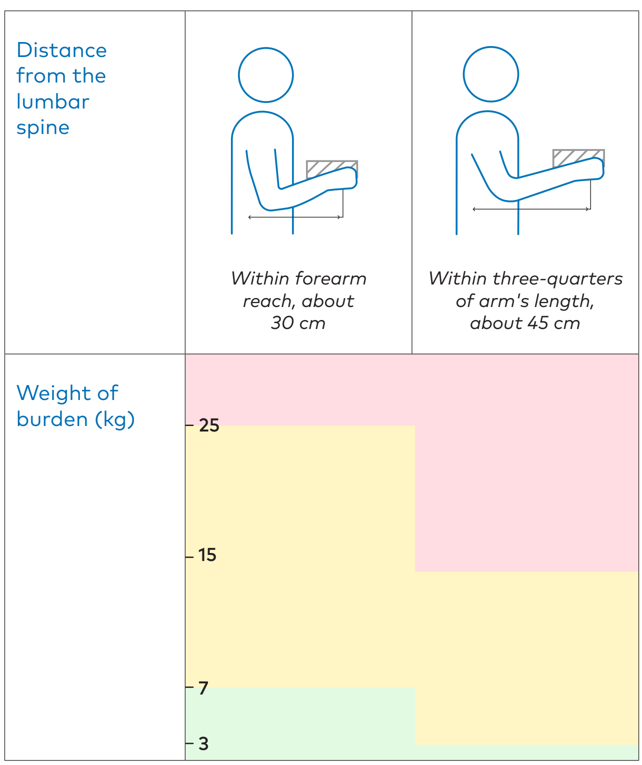
- As a guideline, the height to the workpiece (where the hands work) during light/normal work should be between 980-1080mm.
- For heavy work (when some force has to be applied) the height should be 100mm lower than the height for normal work.
- For precision work the height should be 100mm higher than the height for normal work.





Reaching up and down:

- Avoid postures while positioning of items, tools, jigs, material that require reaching above shoulder level.
- Avoid postures during working/reaching below knee height.
- These postures are OK, if they do not occur too frequently



Source: Swedish Work Environment Authority

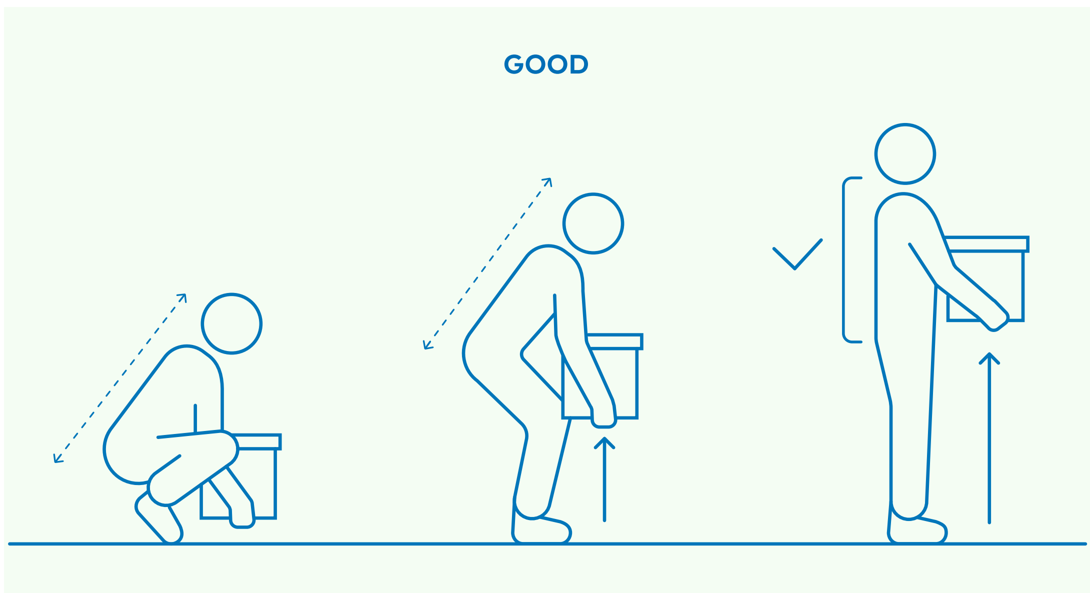
Heavy weights/lifting:

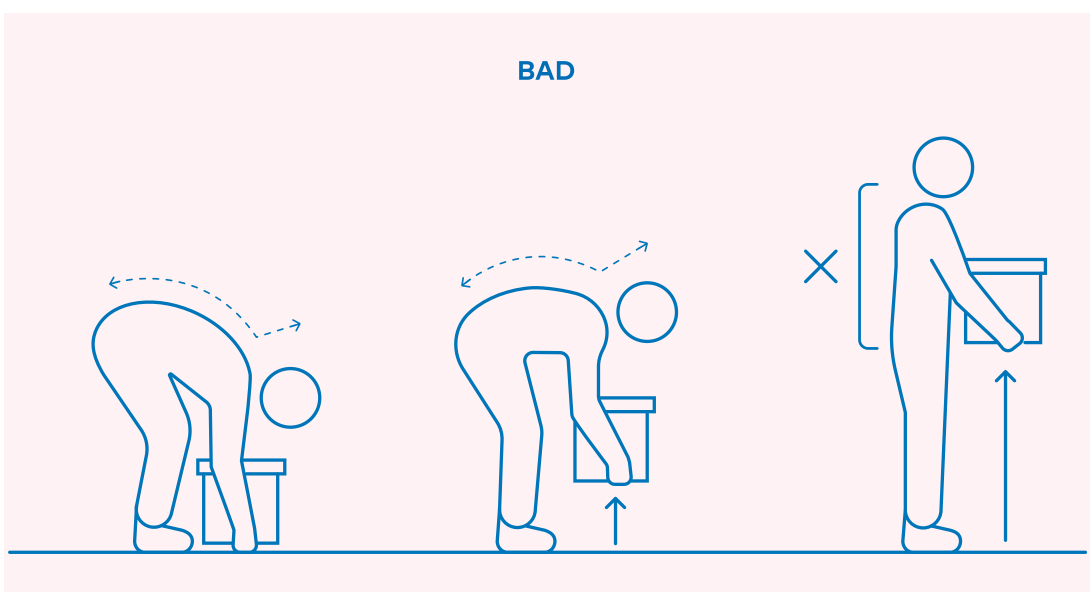
- The model for the assessment of lifting work concentrates on two main factors: the weight of the load and the distance of its centre gravity from the body.
- Model for assesment of a symmetrical lifting operation using both hands in a standing position and under ideal conditions.

LIFTING FREQUENCY (Times/Hours)			
	1-10	**10-60**	**60-130**
Within Reach of Forearm	7kg	2kg	0.5kg
Beyond Reach of Forearm	5kg	0.5kg	

- For one hand lifting follow the guidlines in the table.

- When lifting weights from the floor/low levels use your legs to squat and help to lift, instead of flexing your back.





3 Examples of bad/risky postures

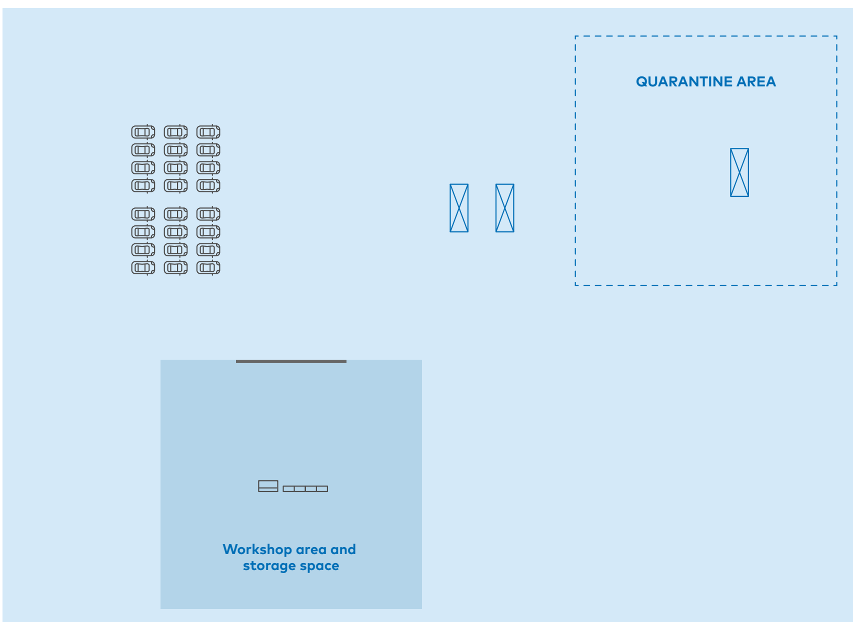
- The wrist is in a very extended posture, and the arms are crossing each other.
- There is pinching posture in the left hand repeated a lot during loosening the screws from battery pack lid.

- Rivets removal – some force to be applied – operator needs to twist the body to be able to see the rivets.

- Left: Higher working table would be recommended.
- Right: Wrist flexed too much - risky.

Work scenarios

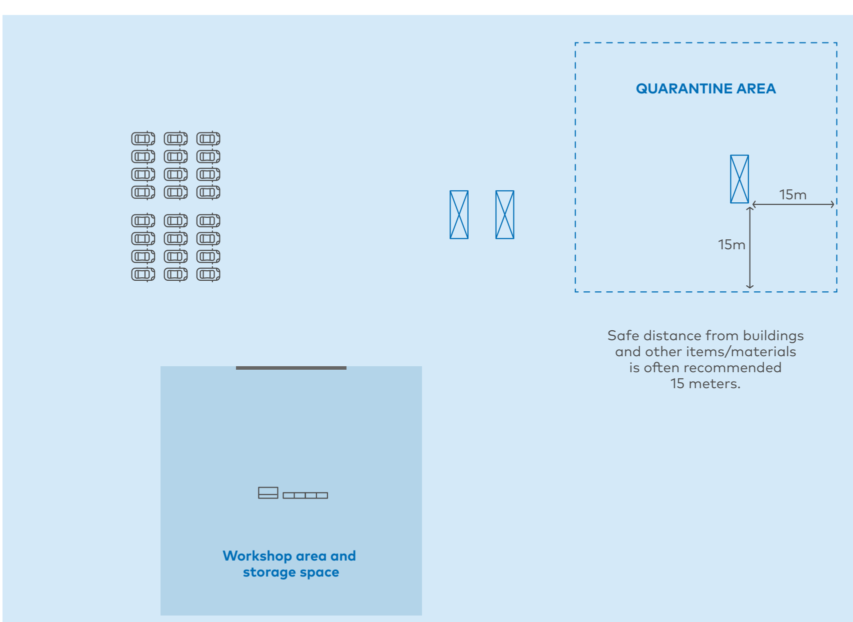
Sketches of different set-ups/ scenarios of workplaces with batteries:



Work area:

Work areas that receive and handle electric vehicle batteries are designed differently depending on the work that takes place. In general, there shall be different containers for different type of batteries:

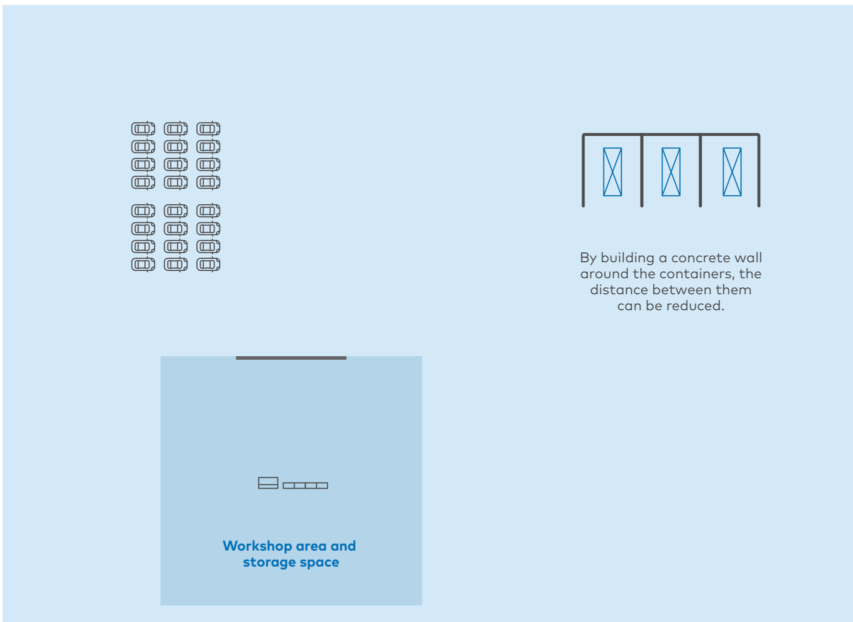
- Good batteries
- Damaged batteries



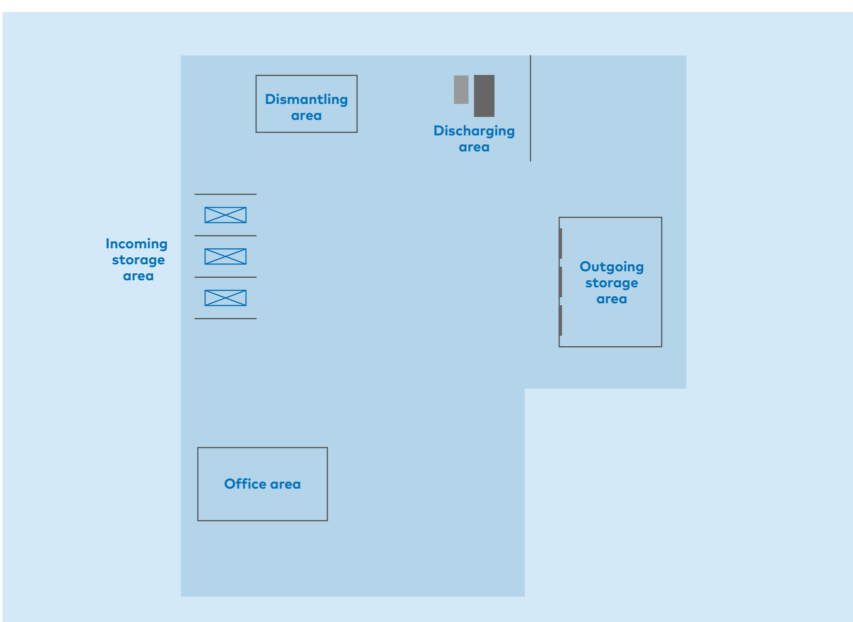
Quarantine area:

A quarantine area is an isolated outdoor space where a vehicle or a battery can be stored and monitored.

The quarantine space must have warning signs and be secured against direct access of un-authorized persons.



Quarantine area/ alternative option:
By building a concrete wall around the containers, the distance between them can be reduced.



Work area:
Depending on the work done with the batteries, different stations/areas can be needed such as storage area for both incoming and outgoing batteries, discharging station, and dismantling station.

The figure is based on a project visit to the Farum Branch, Stena Recycling

References

Wörhl et al., (2021). Crashed Electric Vehicle Handling and Recommendations—State of the Art in Germany.

Skoda training on high voltage cars

Fire fighter (Iceland)

Fire safety of Lithium-Ion batteries in road vehicles, Bisschop et al. 2019 (RISE Report 2019:50)

https://www.elcosh.org/record/document/3838/d001307.pdf