VARTA's position on the ECHA PFAS Restriction Consultation

VARTA AG produces and markets a comprehensive battery portfolio ranging from micro batteries, household batteries, energy storage systems to customised battery solutions for a variety of applications and sets the industry standards as a technology leader in key areas. As the parent company of the Group, it is divided into the segments "Micro Batteries", "Lithium-Ion CoinPower", "Consumer Batteries", "Energy Storage Systems" and "Other".

The "Micro Batteries" segment includes micro and hearing aid batteries, "Lithium-Ion CoinPower" small-format lithium-ion round cells for OEM applications. "Consumer Batteries" represents the business with household batteries, rechargeable batteries, chargers, portable power (power banks) and lights. "Energy Storage Systems" includes energy storage solutions for primarily private, but also for commercial applications. The "Other" segment includes the "Lithium-Ion Battery Packs" and "Lithium-Ion Large Cells" business units (high-performance lithium-ion round cells for industrial applications in the automotive and non-automotive sectors).

Through intensive research and development, VARTA sets global standards in many areas of lithium-ion technology and in micro batteries, making it a recognised innovation leader in the important growth markets of lithium-ion technology and in primary hearing aid batteries. VARTA plays a vital role in paving the way for achieving the Science-Based Targets for climate change mitigation and effecting positive change towards sustainability – including the development of environmentally benign products. The VARTA AG Group currently employs around 4,200 people. With five production and manufacturing facilities in Europe and Asia as well as distribution centres in Asia, Europe and the USA, VARTA AG's operating subsidiaries are currently active in over 100 countries worldwide.

Batteries have been identified by the European Commission as a strategic value chain and represent a key element in the transformation towards a carbon neutral mobility, decarbonized energy generation and digitalization – thus batteries represent a critical building block of the European Green Deal. Batteries power a wide range of general public applications such as smartphones, tablets, power tools, hearing aids, defibrillators, safety lighting in public buildings, and provide many services to industry such as back-up power for mission critical industrial assets such as nuclear power plants and internet data centres. Battery storage helps renewable generators reliably integrate with existing grids by storing the excess generation and by smoothing the energy distribution. Batteries also provide power to an increasing number of mobility solutions such as electric vehicles, forklift trucks, e-bikes and e-scooters. The importance of batteries will grow in future in the development of decentralized energy generation and smart grit applications. They generate significant economic growth and provide jobs for millions of people. Batteries are essential to ensure the sustainable development of society and provide critical environmental and social benefits.

The manufacturing of batteries within Europe on the other hand is a challenging business environment. Especially, as a German mid-sized company facing high energy, raw material and labour costs, shortage of skilled workers, high investments required in a rapidly changing market and in general a highly competitiveness against large companies, specifically from Asia. The current threat of a generalized PFAS restriction is another hurdle the industry has to face. VARTA clearly commits towards the avoidance of critical components and is pursuing several collaborative research activities to substitute Fluorine binders or toxic solvents, *e.g.*, NMP since long.[1][2][3][4] The current approach of a generalized PFAS ban seems to be a rather ineffective procedure, though, as it is comprising many hazardless and unreplaceable substances, including for the battery production process.

In accordance with article 68 of REACH an unacceptable risk shall be demonstrated for a substance to be restricted. As defined by the CEJU case law a risk assessment is consisting of three elements: hazard, exposure, and risk. In that sense and as a science-based company, we must express our concern about the current generic approach of per- and polyfluorinated alkyl substances (PFAS) restriction as it is based only on a general chemical structure similarity. The category "PFAS" comprises more than 10.000 substances showing a variety of properties and thus a variety of risk profiles. Only for some substances hazardousness has been proven. Especially these chemicals are often known to be highly reactive. It is undebatable that for such matters a strong protection of human and environment shall be implemented. VARTA fully understands the concern behind the regulatory action and support all efforts to restrict PFAS which are widely used across the EU and pose unacceptable risk to human health or the environment such as perfluorooctanoic acid (PFOA). Other substances are known for their chemical inertness, though. In most cases these substances have also been scientifically declared non-hazardous. A generalization of a hypothetical risk for all PFAS substances therefore gives the impression of an exacerbating regulation. Similar situation is for the evaluation of exposure. Exposure strongly depends on the specific application. It is reasonable that PFAS in *e.g.*, food packaging leads to a higher exposure during use as well as part of municipal waste as it is for example a polymer membrane applied in a battery of medical devices. We therefore strongly endorse the implementation of a risk assessment of each of the PFAS substances under evaluation of hazardousness and exposure. The reversal of the burden of proof for each company and use-case is periodically causing an enormous bureaucratic effort and extra expenses. Specifically, for *e.g.*, polymers used in batteries this process might not be required as these substances are scientifically evaluated to be non-hazardous, and the batteries designed to avoid any exposure.[5]

Despite VARTAs concern about the current procedure we'll follow the consultation structure and provide information to the best of our knowledge. Although following these guidelines we believe that the basis for transition periods and derogations proposed by the Dossier Submitters (even with

[1] https://www.varta-ag.com/fileadmin/varta/about/images/innovation/Pressemitteilung_FKZ03XP0401_OEkoMatBatt_final.pdf
[2] https://www.tu-braunschweig.de/en/blb/research/projects/oekomatbatt
[3] https://www.novoc.eu/
[4] https://iopscience.iop.org/article/10.1149/1945-7111/ac2861/pdf
[5] Henry, *et al* (2018) *Environ. Assess. Manage.* **14**(3), 316–334 [DOI: 10.1002/ieam.4035]

review clauses) implements an uncertainty for the European battery industry that transition periods and derogations may not be renewed. This uncertainty is putting a high risk on the current investments in Europe, which could jeopardise the future European battery value chain. In that sense VARTA is following to a large extend the statement of the RECHARGE Association, submitted to ECHA under the reference number bf0cd08d-0ff3-44c7-8df9-e33d0dc31396, but specified in accordance with our experiences and products. Several statements throughout our position paper align on the document of RECHARGE's second submission.

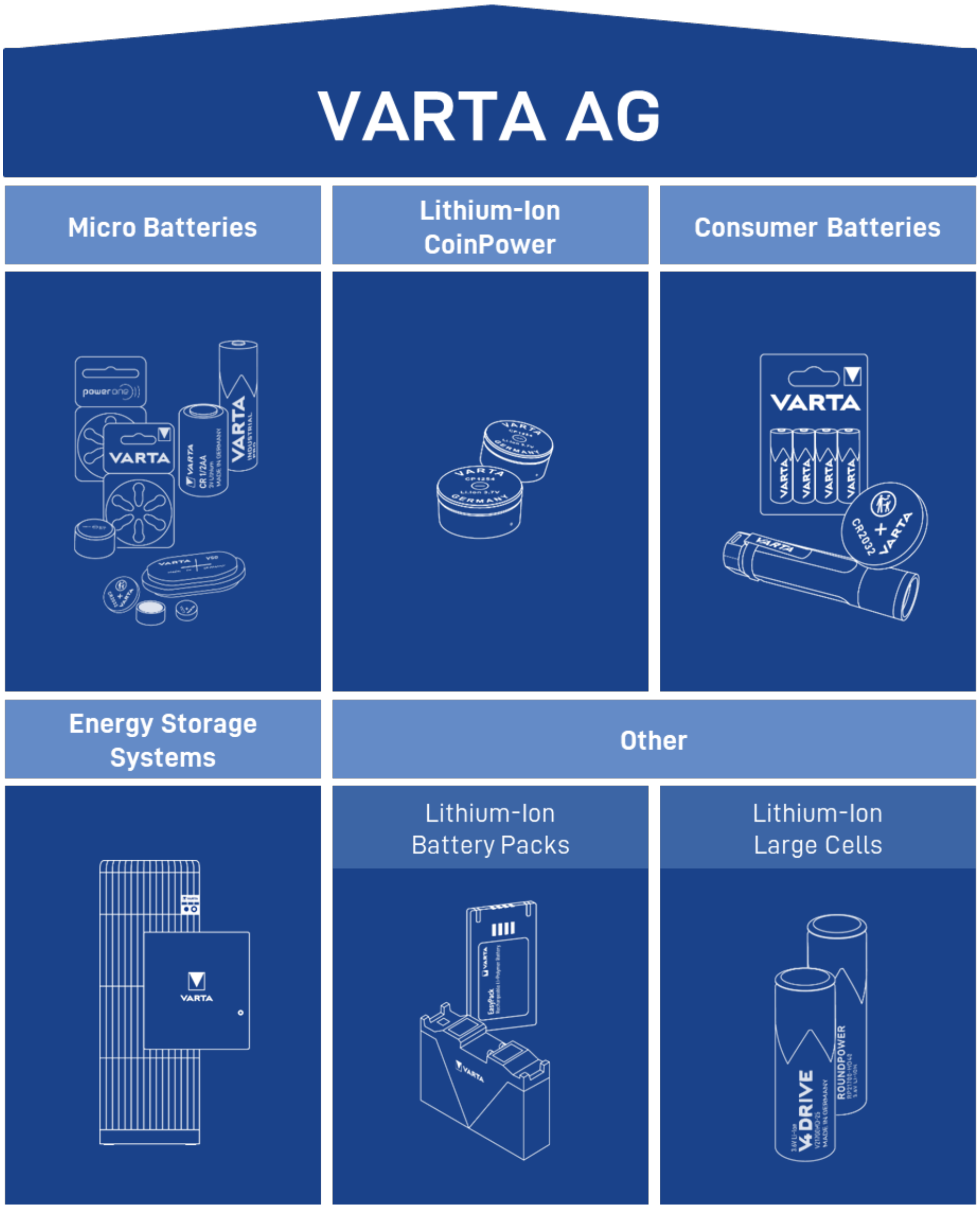

Figure 1 Overview of VARTAs battery products.

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1. VARTAs battery products and related applications affected by the PFAS restriction

Table 1 displays VARTAs battery products and related applications affected by the PFAS restriction.

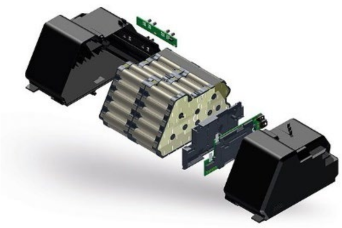
Table 1 Overview of VARTAs battery portfolio and incorporated battery technology

Battery Type			Application
CoinPower®[6] **Li-Ion Hearing Aids accu[7]**		Li-Ion battery	• Bluetooth headsets • Fitness tracker • Energy harvesting • Smart and IoT-applications • Hearing aids • etc.
PowerOne®[8] **VARTA Hearing Aids[9]**		Zinc-Air battery	• hearing aids • Cochlea Implants
VARTA Nickel-Metal Hydride[10]		Ni-MH battery	• Alarm systems • Electronic devices • Emergency lights • Memory Back Up (MBU) • GPS terminal • Smart home applications • etc.
Silver Oxide[11]		Ag_2O battery	• Blood sugar indicator • Insulin pump • Smart Capsules • Watch (digital & analog) • etc.

[6] https://www.varta-ag.com/en/industry/product-solutions/lithium-ion-button-cells
[7] https://www.powerone-batteries.com/products/li-ion
[8] https://www.powerone-batteries.com/
[9] https://www.varta-ag.com/en/consumer/product-categories/hearing-aid-batteries
[10] https://www.varta-ag.com/en/industry/product-solutions/nickel-metal-hydrides
[11] https://www.varta-ag.com/en/industry/product-solutions/silver-oxide

Battery Type			Application
Primary Lithium[12] **ULTRA LITHIUM**[13]		Li-primary battery	• Smart home device • Smoke detector • Alarm systems • IoT-applications • health monitoring • car key • etc.
VARTA Gas Generation Cell[14]		H_2-gas generation battery	• analysis • Mechanical energy reservoir and gas pressure source • automatic pipette • drug delivery • fuel cells • calibration systems • etc.
V4DRIVE® [15] **RoundPower®** (in pilot-scale development under the 1st IPCEI on batteries – 16BZF105)		Li-Ion battery	• premium EVs • sports cars • PHEV • Fuel cell EVs • Power tools • Drones • etc.

[12] https://www.varta-ag.com/en/industry/product-solutions/lithium
[13] https://www.varta-ag.com/en/industry/product-solutions/ultra-lithium
[14] https://www.varta-ag.com/en/industry/product-solutions/gas-generating-cells
[15] https://www.varta-ag.com/en/v4drive

Battery Type			Application
Portable Power[16] **Li-ion battery packs**[17] **Application specific batteries**[18]	  	Li-Ion battery	• Powerbanks • Custom-made battery packs • Forklifts • LEV • Electronic devices • Agriculture • Robotics • etc.
Energy Storage Systems[19]	 	Li-Ion battery	• Home storage • Industrial storage • Backup power • Grid storage

[16] https://www.varta-ag.com/en/consumer/product-categories/portable-power
[17] https://www.varta-ag.com/en/industry/product-solutions/lithium-ion-battery-packs
[18] https://www.varta-ag.com/en/industry/product-solutions/lithium-ion-battery-packs/asb
[19] https://www.varta-ag.com/en/industry/product-solutions/energy-storage

2. VARTAs specific use of PFAS in batteries and request for derogation period under RO2

The Table 2 below summarises the use of PFAS by VARTA, the availability of alternatives for various PFAS types and follows the time periods proposed by the 5 Member State dossier submitters of 6.5 years transition period and 13.5 years derogation period for these applications. However, this does not mean that we believe the time periods proposed by the 5 Member States are sufficient. Therefore, we propose an additional review process to reassess for alternatives before the expiry of derogation periods.

Table 2 Overview of PFAS usage in VARTAs battery portfolio

PFAS type	Use in battery	Type of battery	Products	Available alternatives?	Alternatives in R&D?	Derogation period
PVDF	Binder in active material mass	Current: Li-Ion cathode material; Future: Na-Ion, Li-metal, solid-state batteries	10 types of CoinPower® Li-Ion large: V4Drive®[20], RoundPower® 2 VARTA Li-ion hearing aids accu[21] 3 Portable Power[22] 6 Li-ion battery packs[23] 4 Energy Storage Systems[24]	No Proposed alternatives are not industrial processable and are leading to less cycle life and lower performance	R&D on a TRL[25] of 3-4	13.5 years
PVDF	Separator coatings	Current: Li-Ion battery products; Future: Na-Ion, Li-metal products	Same product range as above for PVDF as active material binder	Yes Initial testing initiated	Yes	6.5 years

[20] https://www.varta-ag.com/en/v4drive
[21] https://www.powerone-batteries.com/products/li-ion
[22] https://www.varta-ag.com/en/consumer/product-categories/portable-power
[23] https://www.varta-ag.com/en/industry/product-solutions/lithium-ion-battery-packs
[24] https://www.varta-ag.com/en/industry/product-solutions/energy-storage
[25] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

PFAS type	Use in battery	Type of battery	Products	Available alternatives?	Alternatives in R&D?	Derogation period
PTFE	Oxygen permeable membrane	Zinc-Air batteries, Gas Generating Cells	11 types of PowerOne®[26] 4 types of VARTA hearing aids batteries[27] 2 types of VARTA H_2-Gas Cells[28]	No Hydrophobic properties of PFAS membrane facilitates Oxygen /H_2 permeation and prevent alkaline electrolyte leakage	No	13.5 years
PTFE	Binder in active material mass	Current: Li-primary, Silver Oxide, Ni-MH, Zinc-Air, Gas Generating Cells Future: Li/Na-ion (semi-)dry process, Zinc-Ion, Li-metal, solid-state batteries	11 types of PowerOne®[29] 4 types of VARTA hearing aids batteries[30] 16 types of Ni-MH[31] 2 types of VARTA H_2-Gas Cells[32] 25 types of Li-primary[33] 37 types Ag_2O[34]	No	No	13.5 years

[26] https://www.powerone-batteries.com/
[27] https://www.varta-ag.com/en/consumer/product-categories/hearing-aid-batteries
[28] https://www.varta-ag.com/en/industry/product-solutions/gas-generating-cells
[29] https://www.powerone-batteries.com/
[30] https://www.varta-ag.com/en/consumer/product-categories/hearing-aid-batteries
[31] https://www.varta-ag.com/en/industry/product-solutions/nickel-metal-hydrides
[32] https://www.varta-ag.com/en/industry/product-solutions/gas-generating-cells
[33] https://www.varta-ag.com/en/industry/product-solutions/lithium
[34] https://www.varta-ag.com/en/industry/product-solutions/silver-oxide

3. Uses where alternatives are not available today

3.1. PVDF and PTFE use as binder of the active materials

The used fluoropolymers PVDF and PTFE meet the OECD criteria of polymers of low concern[35][36] they are not water soluble, not mobile, not bioavailable and not toxic and thus are considered not to pose risks to human health or environment.

In Lithium-Ion batteries (LIB) PVDF is currently the worldwide state-of-the-art (SoA) binder for production of the cathode electrodes via a solvent dispersion route. The SoA cathode material for competitive high energy batteries is a Lithium Nickel-Manganese-Cobalt-Oxide (NMC) or Lithium Nickel-Cobalt-Aluminium-Oxide (NCA) of various transition-metal ratios. The common procedure is to dissolve PVDF in the solvent n- methyl-pyrrolidone (NMP), disperse the active material, carbon-based conductive additive and in some cases special additives, applicate this slurry onto a metal current collector and dry under controlled atmosphere. The target is a very high cathode active material share in the dried electrode, about 98%. Thus, the PFAS-binder content is in the range on 1-3% of the whole electrode mass. In a whole battery the share strongly depends on the cell design but is roughly about 0,5% or below. PVDF is used due to its high voltage stability, high chemical resistance, high temperature stability and possibility to effectively use for high adhesion at low concentration.

Used solvent NMP is classified in the EU as toxic to reproduction and its use is restricted under entry 71 of REACH Annex XVII. As a result, the use of NMP requires expensive solvent extraction and recovery systems. NMP also has a high boiling point of 204°C and so the curing and drying process has a high carbon footprint. Moreover, PVDF binder material is expensive (about 8-10 Euro/kg) as is NMP (about 2-6 Euro/kg). Therefore, the battery industry and VARTA specifically is highly interested to substitute this route by alternatives, as it was achieved for the graphite anode production several years ago (negative electrode). For the positive electrode, all attempts to replace PVDF binder materials with other polymers have caused cell performance and manufacturability issues.

Nevertheless, VARTA is continuing its effort. For example, as partner or coordinator in collaborative projects under research programmes of HORIZON EU and German Ministries. Our intention is to support the whole European battery community in the search for alternatives. We have to realize that the current stage of research cannot surpass a technical readiness level (TRL) of 3-4[37]. As of now any demonstrator reaching TRL6 is lagging in performance as compared to samples using SoA PVDF. In the following we'll present the present research achievements to the best of our knowledge.

[35] B. J. Henry *et al* 2018 *Integrated Environmental Assessment and Management* **14**(3), 316–334. [DOI 10.1002/ieam.4035]

[36] S. H. Korzeniowski *et al* 2023 *Integrated Environmental Assessment and Management* **19**(2), 326–354. [DOI 10.1002/ieam.4646]

[37] https://ec.europa.eu/research/participants/data/ref/h2020/wp/2014_2015/annexes/h2020-wp1415-annex-g-trl_en.pdf

To our opinion one of the most advanced studies in PFAS-free water-based binder processing of high-energy NMC has been performed by Radloff *et al.*[38][39][40] under the project DigiBatt Pro 4.0[41] funded by the German Federal Ministry of Education and Research. As part of this research, positive electrodes in pilot scale (roughly 1/100 to 1/50 the scale of mass production) have been produced using a nickel rich NCM cathode active material, LiNi0.83Co0.12Mn0.05O2. The demonstrator cells of common 21700 format could be successfully charged and discharged 1,000 times at 25°C before they fall below 80% of initial capacity. Whilst this research project appears to show promising results for very high nickel content batteries, the research papers clearly proof the main challenges still present today:

- Positive electrodes manufactured using water-based binder materials show increasing impedance/resistance with increasing numbers of charging and discharging cycles,
- The rapid increase in pH alkalinity of the water-based binder materials results in a very short shelf life for the mixed slurries, *i.e.*, out of specification for an industrial process for mass production which requires shelf life of 12-24hrs,
- The cycling stability is substantially lower than state-of-the-art positive electrodes using PVDF binder materials,
- Higher initial capacity losses due to side reactions.

Similar results are presented by the thorough studies of Hoffmann *et al.*[42][43]. The publication *Hofmann_2020_J._Electrochem._Soc._167_140535* describes the formation of water-induced surface species such as NiOOH and Ni carbonates for NCA on the cathode materials upon contact with water, which drastically degrade the electrochemical performance (more species with increasing exposure time). Moreover, *Hofmann_2020_J._Electrochem._Soc._167_140512* demonstrates the leaching of lithium ions from various NCMs/NCA (pH value increase = aluminium corrosion) using water based binder alternatives. Consequence of both mechanisms is a poor performance of H_2O/CMC-based electrodes *vs.* NMP/PVDF-based electrodes.
Approaches to modify the particle surface with a coating (in this cases phosphate coating) can only partially protect the particles from the side effects of water[44][45]:

- Still significant pH-increase leading to Li/Ni-leaching, current collector corrosion,
- Lower cycle life, only 737 cycles at 25°C to reach 80% of initial capacity,
- Increased amount of binder was used; active material amount is below SoA (>96%).

The ÖkoMatBatt project[46] coordinated by VARTA and funded under the German Federal Ministry of Education and Research is investigating possible alternatives to fluorinated binder materials and of toxic solvents such as NMP in the context of battery cell production. Here, fluorine-free

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[38] S. Radloff *et al* 2021 *J. Electrochem. Soc.* **168** 100506 [DOI 10.1149/1945-7111/ac2861]
[39] S. Radloff *et al* 2022 *J. Electrochem. Soc.* **169** 040514 [DOI 10.1149/1945-7111/ac6324]
[40] [40] S. Radloff *et al* 2023 *Journal of Power Sources* **553 232253 [DOI** 10.1016/j.jpowsour.2022.232253]
[41] https://www.ipa.fraunhofer.de/de/referenzprojekte/DigiBattPro40-BMBF.html
[42] M. Hofmann *et al* 2020 *J. Electrochem. Soc.* **167** 140535 [DOI 10.1149/1945-7111/abc6ca]
[43] M. Hofmann *et al* 2020 *J. Electrochem. Soc.* **167** 140512 [DOI 10.1149/1945-7111/abc033]
[44] M. Hofmann *et al* 2021 *J. Electrochem. Soc.* **168** 060511 [DOI 10.1149/1945-7111/ac054f]
[45] M. Hofmann *et al* 2020 *ChemSusChem*, **13**, 1– 11 [DOI 10.1002/cssc.202001907]
[46] https://www.tu-braunschweig.de/en/blb/research/projects/oekomatbatt

elastomers as well as reactive resins are analysed and further developed as new binders (see also comments on the Annex XV under reference 5dd6ac7f-6cba-4be4-83cf-89f4dd1b0b4a). The research topics include the structure-property relationship between binder and active material, wetting behaviour of the new component, processing of the reactive resins compared to commercial binders using scalable processes, and the life cycle assessment of these substitutes. In ÖkoMatBatt's investigations, it is evident that it is not possible to replace all the properties of PVDF right away, especially if nickel-rich cathodes are involved (such as NMC 811). A step-by-step approach to new materials is the goal. Furthermore, the process-related properties are also a very important point, which makes a short-term material change from PVDF to an alternative binder system impossible. The simple factor of slurry pH stability, for example, makes a direct implementation into the process very challenging. As of now, the neither the alternative solvents nor binders provide comparable battery performance. Moreover, temperature requirements, drying properties or processing times of the new materials are way different than SoA and cannot be implemented in an industrial process at the current development stage. Results show that while alternative materials might have a future in this regard, they are still at an early stage of development (TRL4), as evidenced by most publications, so still require significant further research to safely establish them in the industrial process. In addition, a significant time component is required before substitute materials are validated and qualified for each application-specific battery format, as well as in the use of the corresponding application for performance, lifetime and safety. Another issue that has also not been clarified yet for alternative materials is an established value chain, *i.e.,* the accessibility and securing of the alternative raw materials that will be used as an alternative to PVDF.
To our knowledge only for low voltage / low energy cathode materials as $LiFePO_4$ (LFP) positive results were achieved. For some compatible LFP grades aqueous processing can be considered SoA. High performance LFP is still processed via PVDF/NMP route. Moreover, the suitability for common high energy materials as NMC and NCA has not been investigated here.

In general, there is a lag of scientific studies on pilot scale under industrial relevant conditions. Most reports in literature are processed using lab techniques and small coin-cell tests. For many reports several factors are not fully considered:

- Effect of different industrial relevant cell formfactor,
- cycle life, calendar life and impedance growth under wide range of temperatures,
- swelling, fast charge cycling and safety properties,
- electrode processibility under industrial conditions,
- comparing properties for different active materials,
- Relevant electrode loading and uniformity of coating.

Replacing the PVDF cathode binder with new binder and solvent might require new active materials and Al current collector foils with, *e.g.*, protective coatings. also requires development of a compatible electrode and cell manufacturing process and equipment. The necessary process and equipment change at mass production scale is unknown at this point.

The performance of mass production line produced PVDF free battery may have significant performance gaps compared with current batteries. Addressing these performance gaps may require a significant number of iterations of materials improvement, production process change and cell performance testing.

Given the above, we estimate that efforts to develop and commercialise high performance non-PFAS cathode binder, Al foil, active materials and corresponding cell manufacturing processes would take longer than the dossier submitters' proposed basis for derogations. Nevertheless, to align with the dossier submitters' basis for derogations, VARTA is applying for at least 13.5 years of derogation for this application with a review clause if alternatives are not available when this derogation approaches expiry.

Li *et al*[47] indicate that PVDF as a latex can be used as the binder for the positive electrode with water as the solvent instead of NMP. Next generation Lithium-ion battery developments are focussed on producing positive electrodes using a dry or semi-dry process which avoids the need for toxic NMP solvent. This dry process will significantly reduce energy consumption and lower the environmental footprint. Therefore, the worldwide battery industry is investing in techniques to achieve a stable dry process route for its products. For the battery industry in Europe, it could bring an economically and ecologically advantage as compared to competitors. However, these processes still require the use of PTFE or PVDF as the binder material for the positive electrode. Specifically, in the dry process route there are currently no alternatives to PTFE due its unique combination of properties that are essential for the performance and durability of these batteries, especially for the:

- fibrillation properties, which produce an excellent mechanical electrode surface without covering the surface of the active material,
- chemical properties, including chemical stability in very aggressive environments,
- Potential stability for cathode,
- hydrophobic properties.

Due to above mentioned properties of PTFE the material is also the binder of choice for Li primary, Ni-MH, Zinc-Air (any metal air), Silver oxide (Ag_2O), Zinc-ion rechargeable, Lithium metal rechargeable and solid-state batteries.

Alternative non-PFAS materials such as Polyvinyl alcohol (PVA, CAS 9002-89-5) and Poly(acrylic acid) (PAA, CAS 9003-01-4) have been tested as potential binder materials for the positive electrode and have been found to fail due to performance and manufacturability issues. The degradation of these alternative binder systems in the electrolyte has been demonstrated. Moreover, no alternative binder has been found to provide the required fibrillation properties.

Besides this, no research has been concluded on whether some of non-PFAS alternatives that are being investigated intensively as potential replacements for PVDF as binders in Lithium-ion rechargeable batteries may also be applicable. As a consequence, the timescale needed to

[47] Li *et al* (2020) *iScience*, **23**(5), 101081–101081 [DOI 10.1016/j.isci.2020.101081]

investigate, develop and qualify alternatives for PTFE binder of the active material mass for the mentioned batteries would be even longer than in the case of Lithium-ion rechargeable batteries. Moreover, VARTAs batteries produced with PTFE are commodity products with very small margins. The need for extensive investments might lead to a full stop of production. Thus, to align with the dossier submitters' basis for derogations, VARTA is applying for at least a 13.5 year derogation for this application with a review clause if alternatives are not available when this derogation approaches expiry.

3.2. Use of PTFE in oxygen permeable membranes in Zinc-Air batteries

There are no known alternatives for use of PTFE in oxygen permeable membranes in Zinc-Air batteries or other types of alkaline metal-air batteries. Zinc-Air batteries operate by allowing oxygen to access the battery and react with the Zinc. The oxygen is reacted on a catalytic surface inside the cell. Air permeable PTFE membranes are necessary to allow air to enter the battery whilst also preventing the release of the harmful alkaline electrolyte from the battery. Zn-Air batteries provide the highest capacity of current commercial cells, are environmentally benign, are no dangerous good in transport regulations and at end-of-life used cells will be directly disposed into the same recycling stream as established successfully worldwide for alkaline batteries.

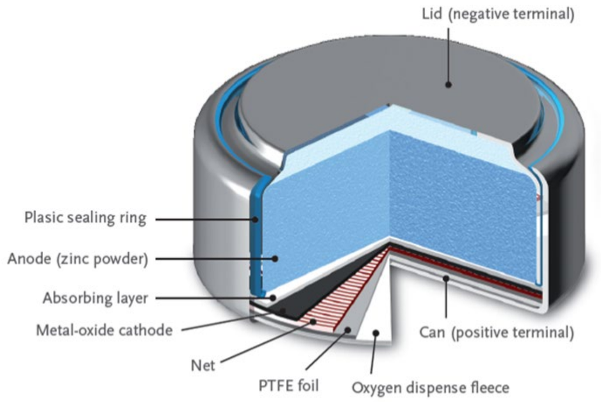

Figure 2 cross section of a typical Zn-Air cell

Due to its high energy and low hazardousness Zinc-Air batteries are primarily used in medical devices like hearing aids and hearing implants. PTFE has unique hydrophobic properties and air permeability properties which allow gas molecules to pass through the membrane whilst at the same time preventing the release of the alkaline electrolyte. Extensive research would be needed to find alternatives. To align with the dossier submitters' basis for derogations, VARTA is applying for at least a 13.5 year derogation for this application with a review clause if alternatives are not available when this derogation approaches expiry.

4. Uses where substitution is technically feasible but more time is required

4.1. Use of PVDF in separator coatings

Coatings containing PVDF on separators are widespread. To provide better thermal and mechanical stability, commercially available ceramic coated separators have been developed. Ceramic particles, such as alumina, silica, or zirconia can be mixed with polymeric binders and slurry-coated onto the polyolefin separators. In comparison to PP layers, ceramic coatings offer a better electrolyte wettability, which translates into better Li-ion transport through the separator and therefore a better performance of the battery. Although ceramic coatings have proven effective in improving the thermal stability of separators, the effectiveness of the protection is still limited by the thermal stability of the polymeric binder used. Therefore, the temperature stable PVDF is often favoured for the ceramic coating. However, there are nowadays alternative binder components that allow PVDF to be dispensed within this application. Further research and testing are necessary to determine the viability and effectiveness of these replacements. A transition to PVDF-free separators seems feasible in mid-/long-term. Although there might be no effect on the battery lifetime under normal conditions, the temperature stability, *i.e.,* safety could still be negatively affected. As the testing of first samples has just been initiated and as the product qualification process needs quite some time per each sample, we apply for 6.5 years derogation for this application with a review clause if alternatives are not available when this derogation approaches expiry.

5. VARTAs PFAS consumption in tonnes

For data under this topic kindly be directed to VARTAs document submitted under confidential conditions.

6. Emissions during battery life cycle

According to slide 28 from the presentation[48] of ECHA webinar on the PFAS restriction (5th April 2023) batteries belong to the energy sector. Slide 24 highlights that the energy sector represents between 0 and 1% of the total emissions of PFAS. In the following we present an analysis to the best of our current knowledge of the emissions over the battery life cycle. Studies performed by Desotec, demonstrate that all sources of emissions (not just PFAS) during the entire battery life cycle are tracked and controlled.[49]

As stated previously on page 10 PTFE and PVDF meet the OECD criteria of polymers of low concern, they are not water soluble, not mobile, not bioavailable and not toxic and thus are considered not to pose risks to human health or environment. The aforementioned points are the specific reasons why the United Kingdom PFAS RMOA[50] has proposed a specific exemption for fluoropolymers, classified in the low hazard groups. The potential emissions as well as the end of life of fluoropolymers can be effectively managed through alternative regulations such as the Waste

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48 https://echa.europa.eu/documents/10162/21388210/2023_04_05_ECHA_UPFAS_infosession_all_presentations.pdf/e4d9932e-4c6f-5950-601c-0cb8b5d8c441?t=1680584224744

49 Kirchhoff, M. & Reichert, D (n.d.). Emission Compliance in Battery Manufacturing and Recycling. Presentation slides of Desotec Activated Carbon, www.desotec.com

50 Analysis of the most appropriate regulatory management options (RMOA). Substance name: Poly- and perfluoroalkyl substances (PFAS) (March 2023). https://www.hse.gov.uk/reach/assets/docs/pfas-rmoa.pdf

Directive (2008/98/EC), the Landfill Directive (1999/31/EC) and the Industrial Emissions Directive (2010/75/EU. Moreover, the new European Battery Regulation[51] (REGULATION (EU) 2023/1542) implements strict recycling rules on the battery sector. Thus, VARTA position is that there are no unintended or uncontrolled emissions of PFAS during the battery manufacturing process and beyond.

We would like to express our concerns about the potential restriction of PFAS within our industry from an additional perspective. While we understand the importance of addressing environmental and safety issues, it's crucial to consider the broader implications. One critical aspect is our supply chain, where we currently lack complete visibility into the use of PFAS by our suppliers, particularly Tier-n suppliers, and whether PFAS is present in their products. This has raised inquiries from our customers who are rightfully seeking transparency.
Imposing a prohibition on PFAS could have far-reaching and adverse consequences for the entire upstream value chain of the battery industry in Europe. Such restrictions could disrupt established supply chains, increase costs, and potentially lead to shortages, impacting our ability to meet the growing demand for batteries in various sectors. We believe it is essential to strike a balance between environmental objectives and the sustainability of our industry.
We are committed to working collaboratively with regulators, suppliers, and customers to find solutions that address these concerns while ensuring the continued viability and growth of the battery industry in Europe.

6.1. Emissions during battery manufacturing process

All of VARTAs manufacturing operations are conducted in facilities which are permitted by the competent authority of Germany, where any release of emissions is controlled and must be below regulation threshold limits. Process as well as material and waste flows are strictly controlled and comply with applicable standards. Processes are implemented to avoid any unintended emission of production components, including PFAS. Controlled threshold limits include those set by the Industrial Emissions Directive[52] which sets limits on preventing and limiting levels of pollution. Moreover, we follow the European Chemicals Directive (1907/2006/EG), the Waste Directive (2008/98/EG), the Persistent Organic Pollutants Directive (850/2004/EG) as well as national laws and regulations like the German Chemical Act (ChemG), the German Recycling law (KrWG) the German Waste Shipment law (AVV) addressing PFAS from different perspective. Under the EU Green Deal (EGD) this Directive is in the process of being amended with a proposal released last year[53], which not only addresses PFAS limits but also clarifies requirements for reviewing and updating permits to comply with environmental quality standards, measures under the water legislation permits as

[51] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1542
[52] Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (integrated pollution prevention and control), https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A02010L0075-20110106
[53] Proposal for a Directive of the European Parliament and of the Council (COM(2022) 156 final/3) amending Directive 2010/75/EU and Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, https://eurlex.europa.eu/resource.html?uri=cellar:32d55555-c550-11ec-b6f4-01aa75ed71a1.0001.03/DOC_1&format=PDF

well as reducing emissions of pollutants and greenhouse gases emissions. The proposed IED specifically addresses the importance of the sustainable growth of batteries outlining all EU legislations in alignment to make this happen. In addition, the Chemicals Strategy for Sustainability Towards a Toxic-Free Environment[54] directly addresses the production of safe and sustainable chemicals for batteries.

As described above on page 10 PVDF is mixed with its organic solvent NMP and other electrode components. This slurry is coated on an Al foil. This electrode is further heated below the melting or degradation temperature of PVDF. The dried electrode is then further used for cell manufacturing. The PVDF polymer has a high melting point of 175°C, thus is thermally very stable. Evaporated NMP-solvent is completely recovered as required under the restriction of 71 REACH Annex XVII. Due to the large difference in vapor pressure and boiling point no PFAS emission is expected during the solvent evaporation process. Empty bags of PVDF, PVDF containing residues from the processes as well as scrap cathodes are collected as (chemical) wastes and disposed of according to applicable European regulations. Scrap cathodes are currently entirely given to recycling operators. Our recycling operators use as recycling method only the pyrometallurgical process on an industrial scale. Thus, no PFAS emission is expected as the operating temperature lays between 1400 – 1600°C[55] (see also 6.3). Additionally, VARTA in collaboration with two renowned universities and two companies has recently initiated a project application at the German Federal Ministry of Education and Research for an innovative direct recycling route to be implemented at our facility. This project will also evaluate the reactivation and full reuse of the PVDF-binder material. Moreover, we're involved as associated partner in two research topics[56][57] under the state funding of the Ministry of Economy, Labour and Tourism Baden-Württemberg to investigate possible direct recycling processes. Despite our highly efficient and controlled processes, we're confident for the coming years to advance our recycling even further for all components.

Similar applies for battery technologies using PTFE as binder. In the dry or semi-dry process, PTFE powders or dispersions are mixed with electrode active and conductive materials. These electrode mixtures are subsequently calendered onto the current collector foils, expanded metal mesh or metal foam. In wet processes, PTFE dispersion is mixed with electrode components and carbon black. This wet mix is then processed and heated below the degradation temperature of the PTFE. The dried mix is then further used for cell manufacturing. Some of the scrap material is directly reused as active material mass. Empty drums of PTFE dispersion, PTFE containing residues from the processes as well as scrap electrodes are collected as chemical wastes and disposed of according to applicable European regulations or given to recyclers. Potential residues of PFAS

[54] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Chemical Strategy for Sustainability Towards a Toxic-Free Environment, 14 October 2020, https://eurlex.europa.eu/resource.html?uri=cellar:f815479a-0f01-11eb-bc07-01aa75ed71a1.0003.02/DOC_1&format=PDF
[55] Table 5 from Bakker, J., Bokkers, B. & Broekman, M. (2021). Per- and polyfluorinated substances in waste incinerator flue gases. RIVM report 2021-0143. https://www.rivm.nl/bibliotheek/rapporten/2021-0143.pdf
[56] https://www.ipa.fraunhofer.de/de/referenzprojekte/prodirec.html
[57] https://www.linkedin.com/posts/fraunhofer-ipa_energieeffizienter-nachhaltiger-rohstoffversorgung-activity-7067152270580178944-HCg4/?originalSubdomain=at

from binders or are always collected as chemical wastes and disposed of according to applicable European regulations. VARTAs can assure that there are no unintended or uncontrolled emissions of PFAS during the battery manufacturing process. Even though there is for the time being no mandatory requirements to measure PFAS emissions in battery manufacturing plants we welcome analytical techniques to proof our statement. Thus, we're currently in discussion with analytical service providers to discuss suitable techniques. New techniques are currently under development for the analysis of PFAS meant in the broader definition of 'Total PFAS' which is still under discussion. It is worth noting that there exists a discrepancy between the definition of total PFAS in the Drinking Water Directive (Directive (EU) 2020/2184) and the PFAS definition in the ECHA PFAS restriction proposal. The development of these techniques may require several months or years.

6.2. Emissions during battery use

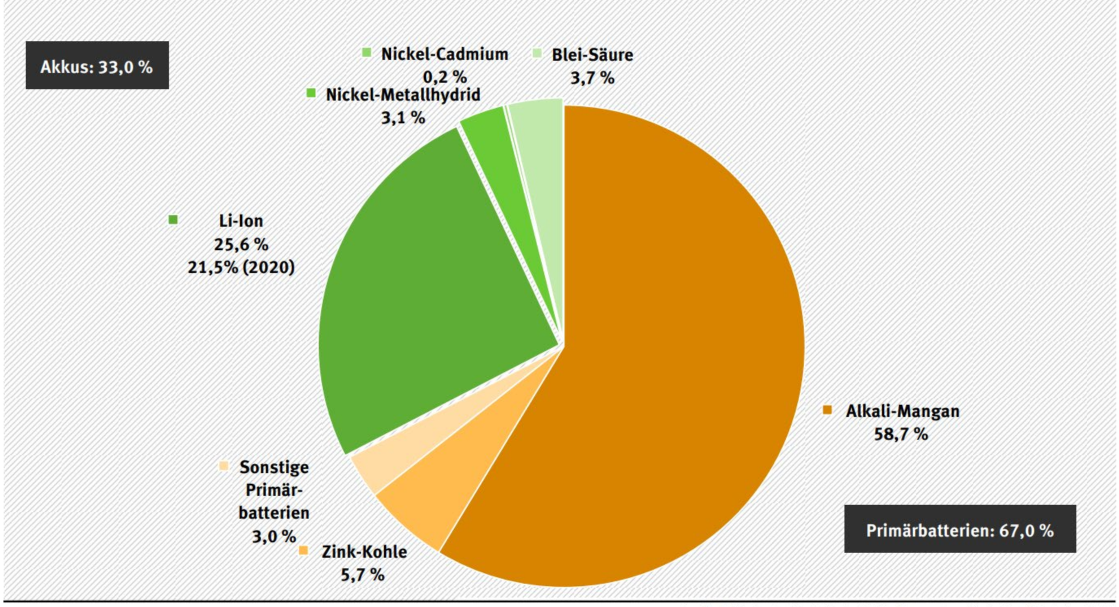
During battery manufacturing, active substances, binders (like PTFE and PVDF) and additives are embedded in a mechanical substrate to form electrodes. These electrodes are then further assembled with the other battery components such as separator, electrolyte, connectors, gaskets, washers and casing to obtain a finished battery. Except for Zinc-Air cells all our batteries are sealed by design and do not have any openings to the environment. As the name already implies Zinc-Air batteries are designed to react with surrounding air during their working life so have a penetration system. This system is specifically based on the properties of PTFE to form a moisture repellent, gas permeable membrane. Although gasses can be transmitted during the working life of these batteries, the membrane is designed to prevent any PFAS liquids or solids emissions leakage. There are no PFAS emissions from any type of battery during normal use of the battery.

6.3. Emissions during battery end-of-life and recycling

All of VARTAs current PTFE or PVDF containing cell products are used in portable (medical) devices or industrial batteries. Our large Lithium-ion cells are currently on pilot scale. They are supposed to be implemented in the categories of LMT and EV batteries, industrial batteries, portable battery packs or stationary storage soon. Thus, the major share of our current battery products are collected via battery recycling systems established under the Batteries Directive 2006/66/EU, as amended by Directive 2013/56/EU[58]. The German Federal Environment Agency published a collection rate for portable batteries in Germany of 48.2% in 2021.[59] The recycling system VARTA's working with reports 51.7% collection rate. Moreover, the collection rate includes by 60% household alkaline batteries as the highest share (see Figure 3). It can be assumed that the collection rate in electronic devices is in the higher end. Moreover, Ag_2O-Batteries are preferably used in either high quality watches, medical devices and precision instruments. Thus, it can be expected that the battery change is performed by a professional with an established recycling system.

[58] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Waste_statistics_-_recycling_of_batteries_and_accumulators&stable=0
[59] https://www.umweltbundesamt.de/daten/ressourcen-abfall/verwertung-entsorgung-ausgewaehlter-abfallarten/altbatterien#die-sammelquote-fur-geratebatterien-stieg-im-jahr-2021-auf-482-prozent

Gerätebatterien: Anteil der in Verkehr gebrachten Akkus betrug im Jahr 2021 33 Prozent
Das Verhältnis Akkus zu Primärbatterien ist im Jahr 2021 gestiegen



Quelle: Erfolgskontrollberichte der Rücknahmesysteme für Geräte-Altbatterien 2021

Figure 3 share of battery type of introduced portable batteries

However stated collection rate does not mean that 48% of portable batteries equivalent to massive PFAS emissions in the EU. According to the European Portable Battery Association[60], a large proportion of these waste batteries are not available for collection because they remain assembled into consumer electronic products which are:

- not discarded by users and are instead stored at home,
- collected and recycled under the Waste Electrical and Electronic Equipment (WEEE) Directive 2012/19/EU,
- exported to regions outside Europe.

The European association of national collection schemes for batteries Eucobat[61] estimates that 19% of the portable batteries placed on the market in the EU are exported in second hand or waste electrical products and therefore are not available for collection and recycling in the EU. Eucobat highlights that achieving a 65% collection and recycling target based on the quantity of batteries placed on the market is actually equivalent to achieving an 80% collection and recycling target based on the quantity of batteries that are available for collection. In the meantime, the new European Battery Regulation[62] will require industry to achieve the following collection and recycling targets based on the quantity of portable batteries placed on the market:

(a) 45 % by 31 December 2023;
(b) 63 % by 31 December 2027;
(c) 73 % by 31 December 2030

[60] https://www.epbaeurope.net/collection-targets
[61] https://www.eucobat.eu/downloads/position-paper-collection-target-waste-batteries
[62] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1542

Achieving these targets will move the collection and recycling of portable batteries towards a closed loop system which minimises emissions.

Made statement that a significant share of batteries in portable devices in stored at home is supported by several surveys. In 2022 a survey[63] of 8,775 households in six European countries found that the average household stores 17% of electronic devices (lamps excluded) without usage – 70% of these hoarded products are still functioning. About 25% of small electronics are no longer in use. The major share of our cell products falls under this category.

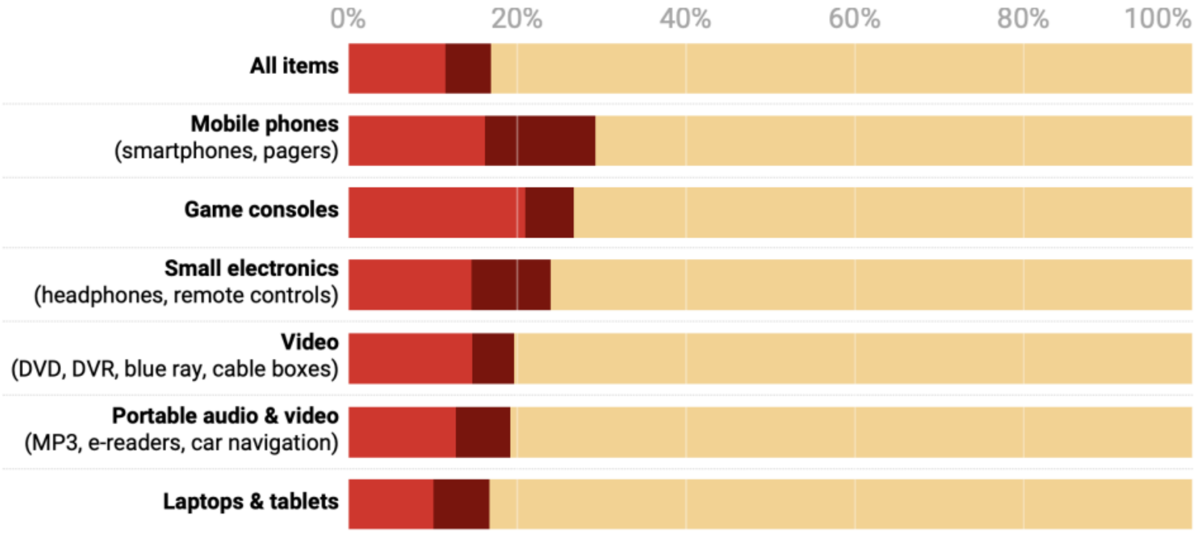


Figure 4 Electronics hoarding rates among European households.

These data explain why a large proportion of waste portable batteries in consumer electronic products are not available for collection.

Besides all efforts still a share of portable batteries (<10%) will end up in the household waste.[64] In EU most waste batteries are treated in municipal waste incinerators alongside other PFAS containing materials such as waste textiles and waste food contact materials. The operation of municipal waste incinerators is controlled under the Industrial Emissions Directive which includes permitted maximum emission of pollutants such as PFAS emissions.

The new Battery Regulation is an outstanding example of legislation to achieve the circular economy and decarbonization ambitions of the EU for a specific product system. It covers the whole battery life from cradle to grave (or cradle) – from the sourcing of materials all the way through to battery collection, recycling and repurposing. This new Regulation demand that battery manufacturing and recycling meet the highest sustainability standards. On this regard a new industry sector for recycling the expected increasing numbers of Lithium-Ion batteries is establishing. Implemented processes are aiming the highest recycling quotes under a minimized

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[63] https://weee-forum.org/ws_news/of-16-billion-mobile-phones-possessed-worldwide-5-3-billion-will-become-waste-in-2022/

[64] https://www.epbaeurope.net/news/epba-s-feedback-to-the-inception-impact-assessment-on-modernising-the-eu-s-batteries-legislation

carbon footprint. Relatively little information is known about the environmental risk with regards to the emission of persistent (in)organic fluorinated chemicals. Currently the most common LIB recycling process involves pyrometallurgy, which operates at high temperatures (up to 1600 °C), sufficient for PFAS mineralization. However, hydrometallurgy, an increasingly popular alternative recycling approach, operates under milder temperatures (<600 °C), which could favour incomplete degradation and/or formation and release of persistent fluorinated substances. A review suggests that substitution of PFAS-based materials (*i.e.* during manufacturing), or alternatively post-treatments and/or changes in process conditions may be required to avoid formation and emission of persistent fluorinated substances.[65] Moreover, as aforementioned we're currently involved in several research projects among other points investigating the reactivating and reuse of PVDF.

Improper Disposal: There is a residual risk of PTFE and PVFD entering the environment if disposed of improperly. As these polymers are not water soluble, not mobile, not bioavailable and not toxic a risk to human and environment might be considered less critical as compared to *e.g.,* the CMR materials of a LIB cathode.

7. Socio-economic impact assessment

Many of our products support the current mega-trends of our society, like digitalization, mobility, Industry-4.0, Internet-of-Things, aging population (medical products), decarbonization and energy revolution. Any PFAS restriction in batteries would negatively affect these trends in Europe.

As aforementioned the Zinc-Air batteries are mainly used in medical devices (hearing aids and implants). VARTA is producing the major share of worldwide hearing aids batteries. As there is no alternative in sight a full restriction would lead to a severe effect for ~50 M people worldwide suffering from hearing impairment. For this people this would mean serious struggles to participate in (or being excluded off) the society. Thus, persons depending on a hearing aid device will lose significantly quality of living. Additionally, small children suffering from hearing problems will also have difficulties in learning their mother tongue or follow school classes. This can seriously affect their social and later professional life.

Restrictions on per- and polyfluoroalkyl substances (PFAS) in the lithium-ion battery industry can have several socio-economic impacts.

First, there may be increased costs associated with finding alternative materials to replace PFAS in battery production. This could potentially affect the competitiveness of European battery manufacturers compared to their counterparts in regions where such restrictions are not in place. Companies in regions that do not have similar restrictions may initially benefit from lower costs and potentially become more competitive in the short term.

As the majority of VARTAs product is depending on two polymers of low concern (PTFE and PVDF) and as there are no suitable alternatives in reach a high risk occurs that an immediate restriction would place us out of business. Even a restriction with derogation periods and review clause is increasing the production risk in Europe for several products which are commodity and cost sensitive. For VARTA these cells are a crucial business, though. This would not only affect directly

[65] DOI: 10.1039/D2EM00511E

our 4200 employees but also the whole region. VARTA with its 135 years of history is locally one of the largest employer. Moreover, we're very much committed to contract local businesses – from engineering, electrical services to catering.

With respect to Lithium-Ion batteries a PFAS restriction without derogations and transition periods for batteries, and without review clauses, will limit the Green Deal and prevent Europe from achieving a net zero economy by 2050. VARTAs granted Important Projects of Common European Interest (IPCEI) on the industrialization of large LIB in an GWh-scale will be at high risk!

VARTAs CoinPower® Li-Ion cells are market leader, providing the highest energy density of any button cell on the market. A PFAS restriction considering current proposed alternatives would mean a downgrade of battery performance and lifetime to a level of not being commercially competitive. A production side in Europe wouldn't be profitable.

For additional data under this topic kindly be directed to VARTAs document submitted under confidential conditions.

It is important to note that the exact socio-economic impact will depend on various factors such as the extent of the restriction, industry readiness, and the availability and cost-effectiveness of alternative materials and technologies. Assessing the impacts and establishing appropriate policies and measures are crucial for a successful and sustainable transition away from PFAS in the Lithium-Ion battery industry. Finding suitable alternatives may initially pose technological barriers and require substantial research and development efforts. However, overcoming these challenges can create opportunities for companies and researchers to lead in the development of PFAS-free battery technologies, driving economic growth and providing a competitive advantage. As stated above, VARTA is actively pursuing alternative technologies which aim for substitution and elimination of PFAS in future battery products.

Abbreviations

Ag_2O	Silver oxide batteries
Al	Aluminium
IoT	Internet-of-Things
LFP	Lithium-iron-phosphate
LIB	Lithium-Ion battery
NCA	Lithium Nickel-Cobalt-Aluminium-Oxide
Ni-MH	Nickel metal hydride batteries
NMC	Lithium Nickel-Manganese-Cobalt-Oxide
NMP	N-Methyl-2-pyrrolidone
PFAS	Perfluoroalkyl and Polyfluoroalkyl Substances
PTFE	Polytetrafluoroethylene
PVDF	Polyvinylidene difluoride
SoA	State-of-the-art
TRL	Technical readiness level
Zn-Air	Zink-Air batteries