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Legal framework for sustainable battery-operated products

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Abstract
The analysis of battery-powered products from different industries shows how sustainable they are. The focus is not only on the batteries, but also on the charging infrastructure and the devices themselves. In addition to the customer's point of view, in particular user behavior, the problem of manufacturers and government intervention options are discussed. Solutions from individual industries are examined for transferability. The modular product architecture and the advantages and disadvantages of standardization are highlighted.

Keywords: Sustainability, battery-operated, modular product architecture

1. Introduction and Motivation

"People want to be flexible and mobile - people don't like cables." This statement is made by the head of a power tool company [1]. Even products such as toothbrushes or headphones, which can be operated by a cable without any problems, are often preferred by buyers to be cordless. For the power tool industry, products with batteries are a benefit-generating trend. The company Bosch states that the share of battery-powered products is already at 40 percent and will probably increase to up to 60 percent in the next five years [2]. The industry for power tools and garden equipment not only recognizes the trend for battery-operated products, but also uses it adequately to strengthen customer loyalty through battery standards, both internally for the company and across companies. However, advantages result not only from the proven brand loyalty of customers [3], but also from internal production cost reductions through standardized batteries. Product diversity that leads to process complexities can be reduced through battery standards.

This development shows that battery systems are now so established among private and commercial users that those users already own batteries and therefore often buy additional power tools without batteries. The industry is reacting, with individual manufacturers increasingly opening up to competitors' rechargeable batteries. This will certainly continue to boost sales of cordless power tools without batteries [4]. Companies in the garden and power tools sector are proving to be among the first compared to other business sectors to standardize on battery systems, and thus with a more customer-focused and greener image. The government also makes regulations in this regard, according to that companies must ensure that the negative impact on the environment is kept to a minimum. Accordingly, every manufacturer of portable batteries is obliged to introduce a self-recovery system and to achieve the prescribed collection rate of 50 percent [5]. The new ecodesign regulations for EU member support to repair instead of throwing away. In order to make products last longer, manufacturers are obliged to provide spare parts for up to ten years. Provided that the product can be disassembled with standard household tools, this will support the lifetime of the products. Also, an extension of the warranty obligation is envisaged, as this will create competition to develop longer-lasting products.

2. Scope and objective

What similarities and differences can be identified with regard to the standardization of secondary batteries in different business sectors and what potentials for sustainable development can be identified?

That is the research question of this study covering battery-operated products and their environment, especially:

- the product itself and its architecture,
- its battery, more precisely the secondary battery or often called accumulator and
- the related charging device resp. infrastructure

A variety of small and large appliances of different business sectors were therefore investigated and compared with each other (Tab. 1):

Table 1. Overview of battery-operated products of different business sectors.

Business sector	Investigated examples
Audio/Video	music box, camera
Gaming	consoles, controller
Personal care products	toothbrush, shaver
IT	cell phone, portable computer
Household appliances	window cleaner, vacuum cleaner, security technology, lighting
Garden and power tools	hedge trimmer, lawn mower, screwdriver, hammer drill
E-Mobility	scooter, bicycle, vehicle, truck

For the analysis the following stakeholders were taken into account with their specific interests:

- Customers (personas, case studies)
- Industry (original equipment manufacturer (OEM), supplier, supply chain)
- Government
- It became apparent that sometimes the requirements and objectives are in line, but often also conflicts arise between and within a group of stakeholders
- For a deeper understanding Germany was used as examination area and the research work was focused onto the topics shown in Tab.2

3. Market - Individualization, modularization and standardization

Individualized products are necessary in order to meet the specific requirements of customers. Usually, those products are built up from individual stand-alone components or from modules out of a modular kit of variants. The product individualization shows however economical limits, since complexities have to be managed efficiently and profitable at the same time. The possibility to change variants decreases along the development process. Therefore, this is only feasible in the early product development phase. Accordingly, an optimal balance between customer requirements and revenue should already be achieved in the early product planning phase.

Figure 1 shows the correlation between costs and revenue as the number of variants increases. The difference between costs and revenue results in a parabola, in which the determination of the optimum indicates the range for the optimum number of variants. The increasing product variance offers the customers a higher number of options, which leads to an increase in sales figures. After the revenue has reached a maximum, consumers begin to feel overloaded. A continuously growing variety of products does not offer customers any added value [6].

Table 2. Focus topics of research work.

Focus topic	Examples
Market	individualization, standardization, unique selling propositions, buying criteria
Product architecture	Modularization, disassembly possibility, exchangeability
Legal framework	BattG, ElektroG, ProdSG, KrWG, LkSG,
User behavior and requirements	Area, degree and duration of usage, duration, convenience
Existing standards	Cordless Alliance System, Power for all alliance, discounter solutions, market dominating companies
International supply chains	lithium, cobalt, graphite
Sustainability	economic, environmental and social aspects

Figure 1 shows the correlation between costs and revenue as the number of variants increases. The difference between costs and revenue results in a parabola, in which the determination of the optimum indicates the range for the optimum number of variants. The increasing product variance offers the customers a higher number of options, which leads to an increase in sales figures. After the revenue has reached a maximum, consumers begin to feel overloaded. A continuously growing variety of products does not offer customers any added value [6]. For the economic model, too much product variance results in smaller batch sizes and a smaller spread of unit costs, until finally the production costs increase rapidly. The aim is to achieve optimal variant management with efficient use of resources. A further instrument, in order to fulfill an optimal product variance with simultaneous management of the complexities, represents the standardized parts strategy. Standardized components can thus be used across different series.

Basically, the motivation of companies to establish a standard is self-initiated and without governmental influence. This is due to the associated cost savings in the manufacturing process. The strategic establishment of standards can even be of great value for companies and thus the gaining of a competitive advantage. On the other hand, cross-manufacturer standards have the disadvantage for companies because of the fact that market entry becomes easier for competitors. The loss of market share goes hand in hand with this.

A fundamental motivation for the introduction of a standard is consumer demand. From the customer's point of view, there are two types of purchasing criteria. Firstly, the investment savings associated with compatibility standards are crucial. Secondly, customers are guided by the market success of the product. In Fig. 2 an investigated example is shown.

If different products have a compatible standard, the users of these products form a so-called installed base. Positive system effects arise as soon as benefit of the product rises. Future demand developments are also important in this context. As the size of the compatibility system of products increases, the number of complementary products also grows.

For competitors, it is difficult to achieve competitive advantages against market leaders in a system technology. The so-called lock-in effect prevents the loss of customers to another technology. For customers, switching to a competitive technology standard means additional costs. The greater the general product variance within a compatibility standard is, the higher the customer loyalty is. System purchasers will decide in favor of the compatibility standard which has the most diverse range of products and accessories. As soon as a company achieves a monopoly-like market position by establishing a standard, it can control the price level for the respective products. The price elasticity of demand corresponds to the level of costs for a technology change to the competitor. With a price increase of 5-10%, customers will tend to replace the product with a substitute. Therefore, if the price of the products is raised above the switching costs, there is a risk of losing customers to competitors.

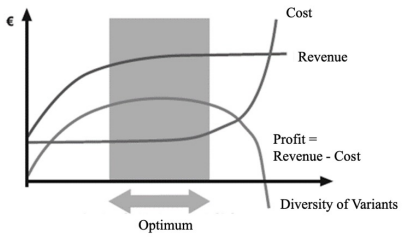

Fig. 1. Optimal diversity of variants

Market leadership for compatibility standards is often formed when the market is entered as a pioneer function and there is no substitution option for consumers. Pioneer companies and the aforementioned switching costs act as barriers to market entry for competitors. The lock-in effect can be overcome by a more optimal price-performance ratio of the competitor's product. This reduces or even compensates the switching costs for consumers.

The introduction of a holistic industry standard, i.e. a standard represented on the market for a product or component, has significant competitive advantages. On the one hand, manufacturing costs for companies are reduced, since large quantities can be produced. On the other hand, interconnectivity between companies is strengthened. The market-leading company can license the standards for complementary products to other manufacturers and thus generate revenue. At the same time, cartel regulations must not be forgotten. When implementing a standardization strategy, the relevant market must first be analyzed in order to avoid restraints for the competition. Every substitutable product means a loss of market share for the competitor. In this context, mutually compatible products exhibit higher substitutability.

Fig. 2. Product range of the Power for All Alliance [2]

4. Conclusion and outlook

The currently existing legal requirements (BattG, ElektroG, KrWG, ProdSG, LkSG) for a sustainable battery industry, among other things, are elementary requirements. The separation of batteries and electrical waste by type, the waste disposal and take-back concept, the recycling of materials, the ban on certain hazardous substances, the registration and responsibility of manufacturers and the "design for disassembly" are requirements that must result in action. At present, these requirements are not met or are only partially implemented. In current draft of laws and initiatives, such as the LkSG and the "Green Deal", responsibility towards people and the environment therefore plays a major role and is clearly gaining the attention of governments. Increased legal certainty and the implementation of risk management are fundamental measures that must be included in legislation. It is becoming clear that the relevant authorities must carry out more stringent and continuous controls on companies.

Although the legal framework is in place battery recycling, its efficiency and disposal concepts are still a challenge in certain aspects. The automotive industry's challenges can be overcome, for example, by automated disassembly. On the other hand, standardization of batteries is a solution and simplifies their recycling. Concepts such as "design for disassembly" can also be applied to the separation of the components of electrical and electronic equipment and can also contribute to simplifying recycling in this area. However, it remains to be seen to what extent the possible concepts are implemented by manufacturers or are in the interest of manufacturers, or whether compliance with the law is monitored. Not only must the responsibility of the OEMs be strengthened, but also that of the consumers. The careful separation and the correct allocation of the batteries by the customer, should be more strictly controlled. In addition, communication between supplier and customer must be strengthened to avoid incorrect battery disposal. Incentives from product manufacturers in the form of increased take-back systems can promote correct disposal.

The analysis and subsequent evaluation have shown that a standardized system across all fields of application is unrealistic. Nevertheless, it is desirable to implement standardized batteries within individual industries, also under aspects of sustainability and customer satisfaction. A standard system with regard to the batteries that are used is possible, as can be seen in the example of gardening and power tools. Implementation within individual industries can be achieved with the help of cooperation, collaboration and government support. The results of the meta-analysis show, very large differences for the investigated properties of the products.

Without further standardization of batteries, customers will not only dump the battery at the end of its life, but also the entire product, since technical progress makes the replacement battery generally uneconomical. This behavior generates both battery waste and waste of electrical equipment. The standardization of batteries can therefore not only help to avoid battery waste but also contribute significantly to the reduction of electrical waste.

The disadvantage of standardizing batteries, however, can be that innovation in the further development of battery technologies is thwarted, since state regulation cancels out competition.

The battery's exchangeability does not only depend on the field of use, but also on the size and/or price of the device. If a product is very large or expensive, then it is likely that a replaceable battery can be found. This is one of the important findings that could be obtained from the data set. An exception is the electric car, since here a high complexity for the exchange of the battery is given and the battery cannot be exchanged without special equipment. The differences between large and small devices could also be observed in other categories. The difference in power consumption between the products in both categories indicates that a cross-industry standard for a uniform charging infrastructure, such as the USB C standard, is not possible. The differences within the small devices, on the other hand, are very small, which is why a standardization of the battery and the charging infrastructure can be considered here. This would enable the development of recycling methods and a closed economic cycle for the batteries.

Despite the barriers, the evolution of battery technology will continue to be an important factor in the future. Not only government recognizes geological limits of resources, but also companies. Investing in innovations and cooperation at an early stage will certainly pay off for reputation and cost reasons. It was shown that exchangeability of standardized batteries can contribute significantly to the sustainability of battery-operated products.