Industrialization of the French Repair Index – Overview of the Regulations, Analysis of the B2C Constraints and Conclusion

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Abstract.
Facing the European environment Regulation tsunami with Ecodesign for Sustainable Product Regulation (ESPR), the United States Right to Repair (R2R) jurisprudence and laws, Original Equipment Manufacturers (OEMs) are struggling with some new challenges for the next decade. On one hand, countries are creating specific regulations to protect the environment and consumers. The French Repair Index is the first example followed by other countries such as Belgium and Argentina. The European Commission is also reinforcing its regulation through consumer protection by creating a suite of regulations on the Environment. The Energy Labeling and Ecodesign directive enlarges its perimeter for concerned product groups with additional criteria. On the other hand, the standardization activity is implementing product-specific rules for Life Cycle Assessment and the latest revisions are implementing rules to assess material efficiency aspects for dedicated products.

This article aims to establish projections on industrial power electronics products, based on the study of regulation already available for Business-to-Consumers (B2C) products. Comparing the French Repair Index and the European energy and ecodesign labeling for smartphone regulation, this article analyses the trends and the criteria applicable to this first group of products. The way of choosing criteria and related levels provides too much variability and misleading in comparing products. The criteria chosen by Europe address durability, reparability, and robustness whereas the French index is only focusing on repairability. This competition between indexes in the same area can no longer continue from the point of view of the European Commission.

The industry constraints are different from those of B2C domain. Our industrial customers are waiting for us on safety, reliability, and services. Power electronics, especially variable speed drives are part of a system and usually, the end-users or the industrial asset managers do not imagine repairing such a small part of machineries or processes. Consequently, this article proposes some preliminary questions to answer before communicating on the repairability of variable speed drives.

Material efficiency assessment, according to EN 4555X series, aims to guide users on communication with customers. Applying this series gives rules to create product-specific assessments, this article will investigate specifically the repairability assessment. For Power Electronics, the customer's main priority is to maximize the uptime, way before the aspects of repairability, durability, or serviceability. Material efficiency criteria, taken apart from one to the other, may not be relevant to reducing resource depletion. In order to maximize the impact, the material efficiency topics should be hierarchized.

In conclusion, this study proposes to use environmental value analysis to prioritize for each product group the most relevant material efficiency topic. Based on value management, this methodology compares the material efficiency topics one to another to achieve a ranking of the environmental functions by environmental benefit, customer interest, and economic viability. The value analysis may be introduced into a product-specific rules standard for material efficiency, justifying for a product group, like variable speed drive, the list of relevant material efficiency items.

Keywords:
Material efficiency aspects ; environmental objectives ; circular economy ; repairability index; sustainable economy ; product and systems' life cycles ; durability; regulation; ESPR; Ecodesign for Sustainable Regulation; Right to repair; B2B; B2C; Product Specific Rules; PSR; PCR; European commission; Environmental benefit; Value management; Energy labeling

Facing the Regulation tsunami regarding the environment in Europe with Ecodesign for Sustainable Product Regulation (ESPR), in United-States with the Right to Repair (R2R) jurisprudence, Original Equipment Manufacturers (OEMs) are struggling with some new challenges for the next decade. The repairability assessment is certainly the first difficult topic to address in material efficiency assessment for Power Electronics. This Repair index popping out of France may not be the solution to all the issues, especially in the industrial business-to-business market.

1 Regulation and Standards Overview

Business as usual in large companies is under pressure from the national regulatory institutions trying to protect customers against material scarcity and climate change effects.

1.1 Short History of European Regulation for Sustainable Products

European institutions have been among the first to embrace sustainable development, putting in place directives and regulations to steer their member countries towards progress since 1992. The launch of the EU Ecolabel[i] in 1992 marked an important voluntary step on the part of the European Parliament

and Council, approving environmentally excellent products and services based on standardized processes and scientific evidence.

In this context, the "Green Deal" for Europe, whose ambitious goal is to make Europe the first climate-neutral continent, encompasses a comprehensive set of policies known as the "Green Pact". This pact, introduced in December 2019, aims to concretize the EU's commitments on the global platform, addressing various areas of EU competence, including energy, waste management, mobility, and agriculture, thus defining the framework for all sustainability directives and regulations for the coming decades in Europe.

Therefore, the European Commission has taken over the regulation of all energy-related sectors. The latest regulation aims to reduce Europe's energy consumption by 11.7% by 2030, compared with 2020. The regulation targets every energy-consuming sector, including buildings, transport, water, information, and communication technologies (ICT), agriculture and the financial sector.

1.2 Ecodesign Directives to Regulations

Parliament and Commission from Europe tend to provide more and more Ecodesign-related requirements. It means that soon, it won't be enough to provide energy consumption information or neither just reduce polluting waste. Ecodesign directive provides guidance and requirements concerning the whole life cycle of a product, impacted by the design phase. Since 2009, the Ecodesign Directive for Electrical-related Products (ErP) gives requirements to improve the energy efficiency of Electrical equipment.

The next generation of ecodesign directives and regulations is challenging the capacity of a product to respond to all objectives of the Sustainable development of the Europe market. Ecodesign for Sustainable Product Regulation (ESPR) is the latest evolution of the 30-year-long journey of European regulation on the Environment.

This directive is so efficient[ii] that the European Commission's regulation willingness is extending to material efficiency. That is why the European Commission is extending the scope of the ecodesign directive to 56 requirements in Annex I of the proposal for a Regulation regarding Ecodesign requirements for sustainable products[iii] and to extend the number of product categories in the perimeter.

The topic of repairability, a crucial aspect in the drive towards sustainable and circular economies, is detailed in 11 out of 56 specific requirements. The objective of the European Commission is to have products put on the European market encouraged by regulation to keep the highest value for the longest time and be improved to lead to zero waste, aligning with the broader sustainability goals of the region.

The trend in Europe is increasingly leading to a minimum level of requirements based on scoring and performance class, demonstrating a proactive approach to enhancing the environmental impact of products. Since 1994, the design of household

goods has seen an improvement in their energy efficiency based on the impact of energy labeling[iv] on the market. This efficiency improvement has led to a rescaling of the label[v] on the 1st of March 2021, indicating a significant shift in consumer awareness and market dynamics. The European Commission was convinced during this initial long period of experimentation that labeling and the visualization of the impact by a scale are indeed efficient in orienting the market[vi], signaling a potential paradigm shift in consumer behavior.

In 2024, the Ecodesign for Sustainable Product Regulation is aimed to be published, and the European Commission has shared its vision on how to make products last longer by influencing durability, repairability, upgradability, and refurbishing. This forward-looking approach underscores the commitment to holistic product lifecycle management and sustainable consumption. The next generation of regulations is intended to be harmonized to fit the diversity of identified product groups, reflecting a comprehensive and inclusive strategy toward sustainability and environmental stewardship.

1.3 Standards and Harmonized Standards

Ecodesign for Sustainable Product Regulation is just one regulation in the "Regulation tsunami" that the Original Equipment Manufacturers (OEMs) are currently facing. The EU Declaration of Conformity currently lists nearly 10 regulations and standards per product, depending on its usage (ATEX[vii], Machinery, etc.) and functions (EMC[viii], RED[ix], Battery regulation, RoHS[x] etc.). Conformity assessment in the EU is based on an established list of rules and standards that ensure the presumption of conformity of products sold in the EU.

The self-declaration should be based on product or regulation-specific design rules, controls, and tests. For each regulation, the list of applicable requirements is transformed into a verification and validation plan to establish the product's conformity. These plans should take into account the interactions and border effects of each regulation. This exercise requires a high level of expertise to avoid any safety or compliance issues. Currently, certification experts are handling this complex work, assisted, and controlled by notified bodies[xi].

From an environmental regulation perspective, the EU Declaration of Conformity "only" needs to consider the RoHS EU 2015/863 Directive and the Ecodesign Directive for Electrical-related Products (ErP) 2009/125/EC with its 49-regulation suite[xii]. Other environmental regulations do not follow the same conformity assessment scheme; for example, the Waste Framework and Waste from Electrical and Electronic Equipment (WEEE) 2012/19/EU is not mandatory in the EU Declaration of Conformity, but the Wheelie Bin is required. Even the substance regulation CLP[xiii] REACh[xiv] conformity assessment is based on a third scheme. The scheme below provides a non-exhaustive overview of the regulations currently in force and those expected in the coming years concerning the environment and ecodesign regulations for ErP OEMs.

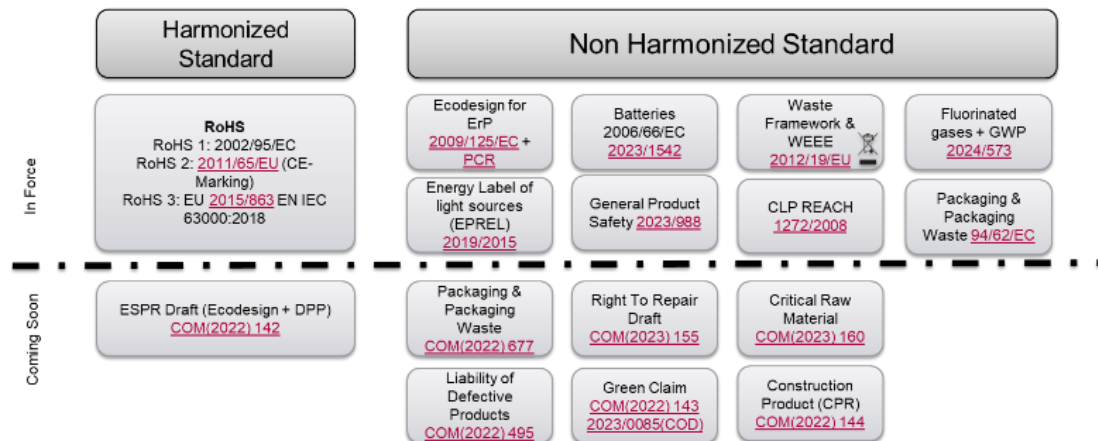**Env/Eco European Regulation constellation**

Figure 1: Non-exhaustive overview of Environmental and Ecodesign Regulations for ErP OEMs

The majority of the regulations mentioned above pertain to the Business-to-customer market (B2C), such as General Product Safety or EPREL regulation. For new products being introduced to the market, the certification manager must check each regulation to verify applicability and the requirements for compliance. This activity demands a high level of expertise in environmental regulation and certification.

The scheme also illustrates the harmonized standards for RoHS compliance, which assist certification activity in ensuring compliance with regulations. Harmonized standards by product category should help to optimize conformity assessment stemming from multiple regulations and address border effects.

In summary, harmonized product standards play a pivotal role in simplifying the identification of applicable requirements and streamlining the conformity assessment process. Harmonization catalyzes enhancing product compliance within the EU market. The multitude of extensive regulations with varying scopes and perimeters can potentially lead to inadequate compliance and safety concerns. Monitoring and adhering to regulations become a substantial undertaking with a high risk of misinterpretation or non-compliance.

The presence of numerous regulations with various scopes and perimeters can lead to poor compliance and safety issues, posing challenges for businesses seeking to navigate the regulatory landscape. As a result, the meticulous monitoring and interpretation of regulations become crucial tasks, necessitating a comprehensive understanding of the diverse regulatory requirements to ensure adherence and safety. Therefore, Environmental expertise is now required in certification teams in addition to Cybersecurity, EMC and Safety.

In conclusion of this introductory section, it is noted that the CE certification serves as an established method for ensuring the safety of individuals in the use of products, providing consumers with a recognizable symbol of quality and safety. The safety of individuals is currently well regulated within the harmonized standards for products, reflecting the ongoing commitment to ensuring high safety standards. The full support of OEMs is being provided to the EU Commission in the endeavor to safeguard the safety of users, underscoring the collaborative efforts to uphold safety measures. However, new regulations unrelated to the CE marking, particularly those on access to product repairs, are emerging for the protection of individuals. This assessment derives from the consumer protection out of the consumption codes.

2 Overview and comparison of regulations on repairability

Part I outlines how regulations are guiding methods and introducing innovations to improve material efficiency, particularly focusing on product reparability and the repair index. European regulations are extending the perimeter of action to maintain the highest value of the products circulating in Europe.

The encompassment of a broad spectrum of considerations on repairability is observed across diverse global regulatory frameworks. The regulation pressure is increasing in Europe as well as in other regions, and the right to repair is pushing the manufacturers to ease access to repair.

As the overview and comparison of regulations on repairability is undertaken, it becomes evident that significant variations exist in the definition and scope of repairability. The standards do not give enough guidelines to make the repairability of all ErP comparable on a global scale.

The next years will be important to create a new way of assessing material efficiency, the product-specific rules will help to create a consensus by category of product. Lead by value analysis the relevant material efficiency criteria can be found. The repairability index could be not enough for the end-user in the B2B market context. This can be compensated by the combination of two assessments.

2.1 Right to repair regulation pressure on manufacturers

Right to repair in the USA

Industrial ErP can be safety related product, like for example circuit-breakers. Repairing this type of product requires a high level of competency in electricity and specific training[xv] dedicated to the repair and maintenance operations of this product. In case of misunderstanding or misapplication of the repair instructions, the operation can cause injuries, or the functionality of the breaker can be affected.

The Right-to-repair movement fed by iFixit and DIY[xvi] Repair Lobbies, push to give the repair means to every user or

independent repairer. This trend from the USA[xvii] is arriving in Europe, based on a fundamental law in the USA that the owner of a good shall have complete control over it. Started in 2003, the iFixiT foundation is fighting against Apple's non-reparable goods or programmed obsolescence of PCs, laptops, or cell-phones.

On the 10th of October 2023, the California government passed a Right to Repair Act[xviii] (SB 244, Eggman. Right to Repair Act.), after Minnesota and New York, which is the third state of the United States to legislate on the Right to repair.

Even if the movement is still concentrated on BtoC goods, the latest judgement John Deere vs Farmers[xix] is close to machinery and industrial goods. There is no doubt that a possible expansion to the BtoB sector is yet to come.
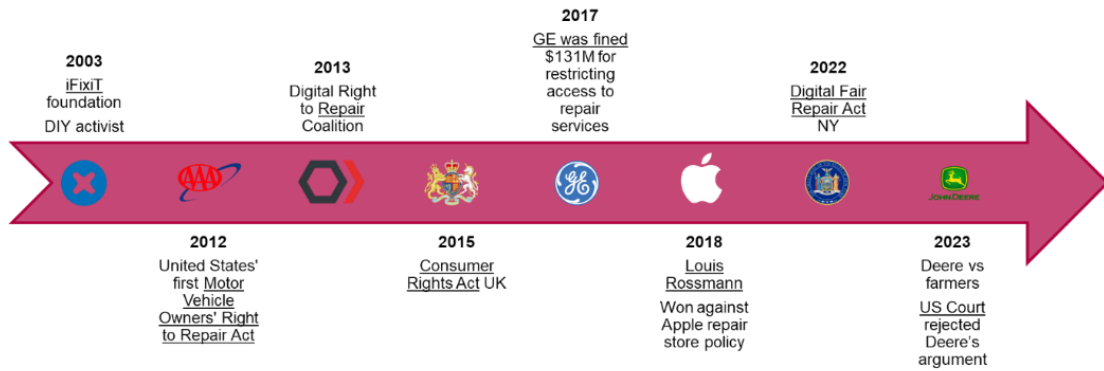

Figure 2: Right to Repair influence genesis in Anglo-Saxon aera

The latest news from the USA shows that the right to repair laws is becoming mainstream for states, a majority of states[xx] are currently in the process of legislating. Oregon State gets, on the 28th of March 2024, the most restrictive regulation ever in the USA by prohibiting the pairing of spare parts to products[xxi].

European Right to repair

Regarding the Right to repair, Europe is also building a strong regulation to increase the protection of consumers. On one hand, on the 25th of October 2023, IMCO[xxii]'s latest report on the pro-posal of regulation on the Right to repair was published. The fu-ture directive on the right to repair has been approved in com-mittee, the text has been agreed[xxiii] at first reading interinstitu-tional negotiations on the 22nd of February 2024.

This future directive[xxiv] will amend 3 major directives and regulations already in force on Consumer Protection Regulation (EU) 2017/2394[xxv] on cooperation between member states to ease repair of household goods, Directives (EU) 2019/771[xxvi] ex-tending the manufacturer's guarantee of one year and (EU) 2020/1828[xxvii] on consumer protection. This text will mandate the manufacturers to communicate to the consumer a repair in-dex for Household washing machines and Household washer-dryers; Household dishwashers; Refrigerating appliances; Elec-tronic displays; Welding equipment; Vacuum cleaners; Servers and data storage products; Mobile phones, cordless phones and slate tablets; Household tumble dryers, Goods incorporating light means of transport batteries.

On the other hand, Directive 2024/825[xxviii] regards empower-ing consumers for the green transition through better protection against unfair practices and through better information published on the 28th of February 2024, mandates manufacturers to give access to information and documentation useful to repair goods. This directive reinforces the regulation around greenwashing and sustainability labels. The European Commission is pushing for transparency and clarity in communication between manu-facturers and consumers.

2.2 Multiplication of the repair/durability indexes over the world

In April 2024, 69 regulations regarding the right to repair are in force around the world. North America and especially the USA are active with 45 laws proposed (Annex 4.1).

The right to repair is about consumer protection and infor-mation, the previous part was about customer protection whereas the next part will be about customer information on repairability. The ability to be repaired should be comparable from one prod-uct to the other and from one manufacturer to the other. The fol-lowing paragraphs overview the proposed ways to assess repair-ability on business-to-customer goods especially smartphones. This product category, such as BtoC and Electronic devices, is particularly interesting as a pioneer. The experience gained with this type of product will help to acquire knowledge for Power Electronics applications. The way to create a common scale for one product category can influence how the user of the product perceives repairability.

French Repair Index

From the French repair index's[xxix] first appearance in 2021 for Smartphones and laptops to the latest European Commission regulation on Durability and Energy Labeling for Smartphones on the 16th of June 2023, the velocity of the regulatory organizations is increasing. France has started this journey on repairability assessment, this country's regulation is pushing a dozen household product types to give documentation and access to spare parts. This way assessing material efficiency created new constraints on manufacturers.

French-specific regulations are creating trouble in the European regulation landscape, this new trends in environmental regulations, eg. The triman regulations in france, vs the Packaging Italian marking. For large companies, the number of requirements can be multiplied by the number of countries where the product is distributed. In this case, there is a high risk of misleading the regulation. For instance, the current scope of the latest Repair Index is B2C, which also poses issues with adapting the tool to the B2B sector, as the product complexity is higher.

The repair index has been implemented in France through the AGEC Law (Anti-waste for a circular economy) and is mandatory data since 2021 and must be presented during a consumer's purchase online or in retail of a product. It aims to sensitize customers on the possibility of repairing their product, but also sensitize manufacturers on making that repair easier. It is currently on the B2C Scope on household products (TV, Washing Machine, etc...).

The repair index consists of the assessment of different criteria according to monindicederéparabilité.fr :

— Availability of different data on documentation of the product,
— The depth of disassembly of each spare part of the product assessed,
— The availability of spare parts,
— The tools used for dismounting the different parts,
— The support available for the customer in case of failures or specific requests.

The assessment starts with the definition of two spare parts lists dubbed Priority Parts, discriminated by their likelihood to fail and their importance in the main functions of the product:

— List 1 (Weakest Parts): The 3 to 5 parts that is the most likely to fail
— List 2 (Functional Parts): A part that isn't in List 1 but is necessary for the product to work

The result of the calculation is a grade that ranges from 0 to 10. 10 for the most repairable product, 0 for the least repairable product.

This repair index has evolved since its first release and in response to new ambitions of the European Commission to support expectations from customers. This firstmandatory repair index in the world aims to lead the sustainable transformation of the B2C market to promote independent and DIY repairers. This French initiative aims to keep highly valuable materials close loops inside France to reduce the impact of material scarcity and lake of mines.
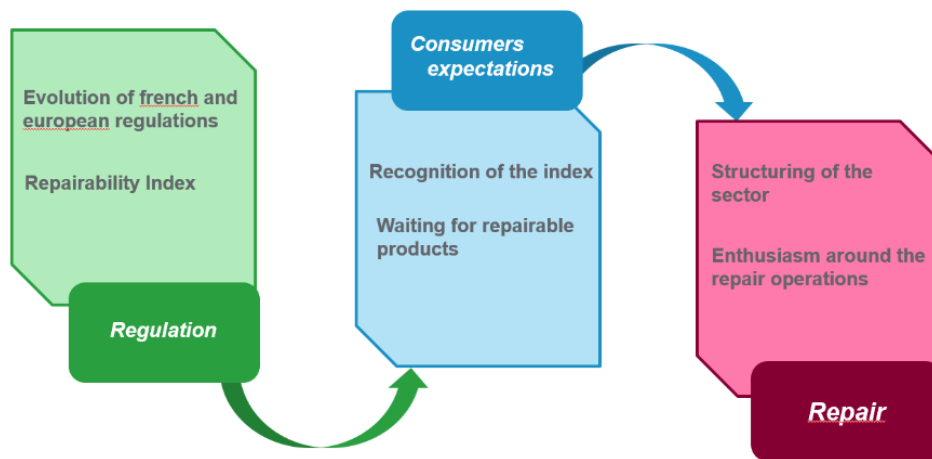

Figure 3: Illustration of the influence of the Repair index on repairability of the products

Repair index variations over the world

Following France example, many countries have the willingness to create and promote their own Repair index. In Europe, Belgium is copycatting the Freench version. And we can see also outside europe some initiatives, Argentina has proposed to mandate the repair index in addition to the energy efficiency label on some B2C products. But Argentina's proposition has been withdrawn since the 28th of Nov 2023 (CF. Annex 4.2). The regulations proposals around the world have been supported by the French initiative on repair index for BtoC products.

Belgium regulation[xxx] proposal is mainly based on the French repair index regulation with a reference to the cost of repair. This

parameter has not been considered by the Joint Research Center[xxxi] due to high volatility and variability over the times and regions.

Finally, each European country should create its own Repair index evaluating different criteria with various scales and proper weighting.

This push by governments to encourage the repairability of products seems to encounter difficulties in generalizing it. Indeed, it is particularly complex to find the criteria and rating scales that will make it possible to maintain and develop the value contained in the products. In this exercise, the European Commission is proposing a set of specific measures for smartphones that take into account, addition repairability, battery durability, and energy efficiency.

In addition to EN 45554, some standardization process are on going at international level.

ISO 59040 standard covers product circularity data sheet considering partialy fonctional user requirements related to the circular economy principles and do not weight the importance of those requirements. The CEN/CLC JTC10 WG02 dealing with durability assessment method is looking for a scoring to widely consider functional weighted requirements. There is interest in establishing a link between product material efficiency and their potential efficiency, with ongoing actions in standardization for products, including seeking a durability index and identifying items for reuse. Additionally, efforts within CEN CENELEC JTC10 WG2, and WG8 for EN 45560 for ESPR and CEN/CLC advisory group (SHRAG[xxxii]) are relevant to this initiative.

2.3 Comparative analysis of the criteria to assess repairability between French and European index

However, more indexes started showing up in different european countries, and this may create conflicts in ideas and complications for manufacturers that sell their products in different countries. As a response to that, the European commission released a first draft of a "European Repair Index for Smartphones".

The European regulation[xxxiii] on smartphones integrates an Energy labeling, durability, and repairability index was published on the 16th of June 2023. The regulation applicable in June 2025 presents a very good maturity in the assessment of cell phones' durability and repairability. For example, the index considers the IP protection index. This is a very important criterion for durability, but the sealing of the components has an impact on repairability. By showing both the IP and the Repair index, the EU Index for cell phones allows the customer to make the choice between repairability and durability.

This energy, repairability, and durability labelling enters directly in competition with French repair index. In this journey the European regulation is taking the lead and mandate France to repeal their own regulation[xxxiv]. From EU commission this way of regulating repairability is not acceptable and goes against[xxxv] 2015/1535 Directive.

Since the European Commission has repealed the Repair index from France, many initiatives to create repair indexes around the world seems to have been no longer supported.
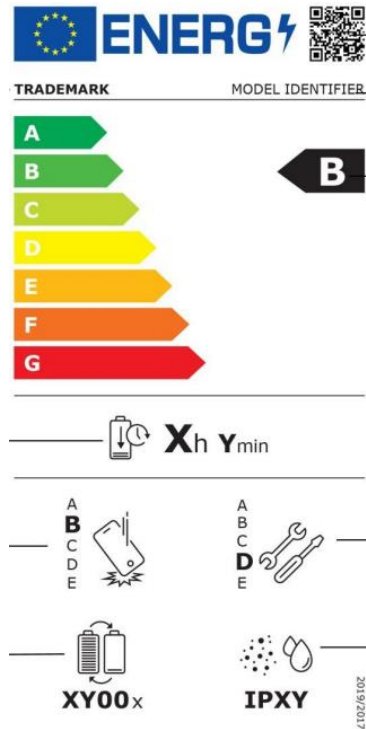

Figure 4: European Regulation on Energy labeling and customer information on Smartphones

Comparative Analysis of European and French Indexes

Although, an assessment has been made to compare the European Repair Index[xxxvi] with the French version. Different points deserve to be enlighted :

— The use of a single generic list, which can both facilitate the creation of a single range list and help define the list without discriminating "functional" from "weakest".

— A new Software Updates criteria, that can help secure a part of the final grade as most of products can use the same software.

The possibility to add a weight for each spare part in the list can be put into place by analyzing Criticity vs Weakness and not considering the spare parts that are not present in some of the product's categories, as shown in Figure 5 below where the folding mechanism is not considered for the calculation of a non-foldable phone

	Not foldable	Foldable
	Part weighting	Part weighting
Battery	0,3	0,25
Display assembly	0,3	0,25
Back cover assembly	0,1	0,09
Front-facing camera assembly	0,05	0,04
Rear-facing camera assembly	0,05	0,04
External charging port	0,05	0,04
Mechanical button	0,05	0,04
Main microphone(s)	0,05	0,04
Speaker	0,05	0,04
Hinge assembly or Mechanical display folding mechanism	0	0,17

Figure 5: Weight for each spare part of a foldable and non-foldable phone

The European Commission made this "EU Repair index" to prevent countries from having their own indexes and creating

conflicts and overwork load on manufacturers. This repair index tends to be more and more in favor of the customers and independent repairers that are called in the European regulation: "professional repairers". They are defined as "operator or undertaking which performs repair and professional maintenance of smartphones or slate tablets, either as a service or with a view to the subsequent resale of the repaired device". This definition has an impact on 2 criteria of the Repair Index:

— Access to maintenance/repair information and
— Availability of spare parts which will be discussed below.

Comparison 1 Documentation:

Detailed information that must be contained in the product's documentation to obtain the best grade in it is provided by the French repair index. It is different in the case of the European RI (EU RI), as the repair documentation with electronic board diagrams (Figure 6) must be provided by the manufacturer for free to get the highest grade.

	ACCESS TO MAINTENANCE AND REPAIR INFORMATION	
Grade	Professional Repairers	End users
A	With electronic board diagrams	Without electronic board diagrams
B	With electronic board diagrams	No access
C	With electronic board diagrams	No access

	COST	
Grade	Professional Repairers	End users
A	Free	Free
B	Free	
C	Reasonable fee	

Figure 6: Assessment of the documentation in EU Repair Index, A is the best grade and C the worst.

The shareholders are also different in this criterion, on the EU RI, the information must be shared between "professional repairers" and "end users", whereas the documentation criterion is evaluated on 4 levels in the French repair index (FR RI): Manufacturer, Repairers authorized by the manufacturer, Independent repairers, and the consumer.

The latter evaluation is relevant as all proprietary information and sensitive data are accessed by the manufacturer, whereas regrouping both the authorized repairers and the independent repairers (EU RI) can be a struggle because it means they must have the same level of access to information. Both may not have the same level of skills and technology, which can pose a threat to the safety of those who will perform the repair operation without proper training.

At the level of information requested by this EU Repair Index, it can pose threats, especially in the case of safety products the lack of training and skill can lead to dangerous situations and injuries.

Different versions of the repair index in different countries can lead to some discrepancies in product compliance. At the end of the day, the customer can suffer some misinformation due to variations between indexes.

Finally, it could be counterproductive to create competition between the regulations of the countries in the European Union, in such a situation the primary objective of improving the environmental quality of products circulating in the union would be much more difficult to achieve.

Comparison 2 Spare Parts:

This criterion is composed of 2 different sub-criteria on the French repair index, which are both evaluated on the same shareholders specified in Criterion 1. The first sub-criterion deals with the duration of availability of the different priority parts list. The duration of availability of the spare parts is mandated up to 8 years[xxxvii] and can be asked during the complete lifespan (14 years for the washing machines[xxxviii]).

The second criterion deals with the commitment of delivery for each spare part from the priority parts list. The scales for the sub-criterion are from 3 to 10 days to deliver a spare part. These scales are challenging for large companies with distributed supply chains. This criterion can lead to an artificial increase of dead stock of spare parts only to be able to comply with this criterion. Not only it depends on the type of product but also the location of the nearest point of distribution.

However, the EU Repair Index mandates the availability of each spare part for both consumer and professional repairers. Then the difference between the worst grade "E" and the best grade "A" can only be linked to the efficiency of the supply chain and the ease to order a spare part for a end-user.

	A	B	C	D	E
Battery	R + U	R + U	R + U	R + U	R
Display assembly	R + U	R + U	R + U	R + U	R + U
Back cover assembly	R + U	R + U	R + U	R	R
Front-facing camera assembly	R + U	R + U	R	R	R
Rear-facing camera assembly	R + U	R + U	R	R	R
External charging port	R + U	R	R	R	R
Mechanical button	R + U	R	R	R	R
Main microphone(s)	R + U	R	R	R	R
Speaker	R + U	R	R	R	R
Hinge assembly or Mechanical display folding mechanism	R + U	R	R	R	R

Figure 7: Scoring for Spare Parts criterion in the EU Repair Index

Detailed information that must be contained in the product's documentations to obtain the best grade in it is provided by the French repair index. It is different in the case of the European RI, as the repair documentation with electronic board diagrams must be provided by the manufacturer for free to get the highest grade.
The Figure 7 illustrates well how the availability and efficiency of the supply chain can influence the Grade of repairability.

The spare part criteria is not a criterion linked to environmentally conscious design and will encourage the multiplication of local stocks, damaging the resources and/or airfreight to deliver

8

parts in less than 3 days, damaging the global warming efforts of the companies.

2.4   Concerns and limits of the repair index

Since 2021, the Agec Law of France imposed a repair index for household appliance-related products. The regulation pushback from Argentina shows a sense that the topic is not enough mature to be deployed around the world. From the European point of view, national initiatives are fighting against the European parliament. No harmonization is ready in the standards to accompany the manufacturers in the environmentally conscious design. Material efficiency as Energy efficiency is the result of a complete set of design actions on multiple levers like raw materials, modularity, and reliability. That means repairability is a small piece of the journey to material efficiency.

The repairability gives only partial information about the material efficiency of a product, it is one lever out of 8 (Durability, Repairability, Reusability, Recyclability, Remanufacturing, Recycled Content, Reused Components, Critical Raw Materials according to the EN4555X Series). Depending on the product, the repair will not be suitable regarding the safety impact of a misoperation. The repairability assessment can highly influence the buying decision and the design of the product; the way to assess should well fit the product category and the customer expectations.

The cell phone example shows that many ways to assess repairability can lead to a good level of information for the final user. This way to assess repairability cannot be copy-pasted on the Power electronic domain without a huge rethinking. The power electronics and especially drive systems are often a small piece in a whole system. From the B2B customer's point of view, the repairability of one small part of the system may not be the most interesting attribute for material efficiency, and cost-effectiveness.

Power electronics are part of a process to provide functions to the end customer. The material efficiency is only a part of the information needed to make the buying decision. In addition to repairability, the customer also needs cybersecurity, service, and remote diagnosis. The B2B market constraints are higher on the efficiency of the process supported by the Power electronic product than in B2C applications. The information given shall fit the customer's needs.

The cost of ownership is another key driver for the customers, then the question is how to link material efficiency and cost of ownership. The MEErP approach gives a part of the solution with the Least Life Cycle Cost (LLCC). The LLCC includes all the costs of ownership especially to support Green Public Procurement[xxxix]. This methods embed both material and energy efficiency. The cost of ownership can be influenced by the repairability of a product but there are a lot of other parameters influencing it. The durability of the product is another main means to decrease the LLCC.

2.5   Adapt the assessment to the customer expectations

Customers are intended to be protected from limitations of repair, planned obsolescence, and over-costs to maintain the products by regulatory organizations. From the OEMs' perspective, offering a high level of service with corrective, preventive, and increasingly predictive maintenance is seen as a way to ensure the lowest downtime of the installations to the user.

The use of modular design helps to enable quick repair and commissioning, as well as the take-back of broken parts. In the industrial world, the overall productivity of the application serves as the primary driver for the maintenance and repair teams, and the first one is the reduction of downtime to a minimum. At the factory level, considering product-level repair online may not be relevant.

From a system perspective, for example, in a pump application, the failure of one drive in the complete pumping chain can be regarded as a system part failure, then a plug and play remplacement can be preferred to an on-line repair. On-line repair can potentially lead to a longer period of downtime compared to the exchange of a part of the system. Repair in a workshop environment enables the minimization of the number of parts changed and is facilitated by more relevant and accurate diagnosis tools. On-site repair can be more dangerous and time-consuming than an exchange. Additionally, the manufacturer or the user can maintain a pool of repaired products, which can be used for quick exchanges to help minimizing downtime, increasing customer satisfaction, and reducing production losses.

Thus, the criteria chosen to assess repairability shall be the same for each product type. The power electronics industry can contribute efficiently to find the relevant and accurate criteria to reflect the repairability of products. The power electronic domain covers a large portion of the market but the main part of the business is dedicated to BtoB application. The usage of BtoB power electronics is dedicated to trained people with specific skills on electricity safety.

The protection of the end-user is always the main priority for Power electronics OEMs. The power transformation for industrial applications requires in addition a high level of availability [xl] of the devices. Defined as the portion of uptime during one period:

$$Availability = \frac{Uptime}{Uptime + Downtime}$$

Availability depends upon the combined characteristics of the reliability [xli], recoverability[xlii], and maintainability[xliii] of the item, and the maintenance support performance[xliv]. Repairability is fully supporting availability, the design, the ability to be repaired, the modularity are contributing to a high level of availability. The services (diagnosis, remote assistance, and predictive maintenance) proposed by the manufacturer can also support the availability of the function of the product for the end user.

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3   Conclusion

For each category of product, the ecodesign requirements and the way to assess the compliance need to be defined. To find the best relevant ecodesign values for each product category, functional analysis is a well-recognized way to hierarchize the environmental values regarding a product, a market, or a mission profile. For example, reparability is not relevant for the smallest electric safety products, it would be preferable to have not repairable products that last longer and are dismantlable and recyclable.

When the environmental values specifically relevant to a product category are defined, the next step is to find and characterize the most relevant criteria to assess the environmental value. Durability assessment criteria for a transformer can be different than for a lightning lamp.

3.1   Value analysis to determine the relevant index by product category

The repair index is a good example of criteria non relevant for all types of products. Regarding the design, the usage, and the possibility to be repaired safely for certain categories of product, designing a product which last longer without failure can be more relevant. Independently of the repairability, the ability to function without failure can be a real incentive to drive the market to more sustainable products.

Thus, a functional analysis linked to the application constraints lead to the mission profile and a relevant design to fit the best to the customer needs. Now the material and energy efficiency add a layer in the functional analysis studied by the design. In the objective to improve material and energy efficiency the repairability should be considered as a key function to achieve the longest lifetime.

$$VALUE^a = \frac{SERVICES^b \ PROVIDED \ FOR \ SATISFACTION \ OF \ THE \ NEED}{RESOURCES \ USED}$$

a. European Commission, Directorate-General for the Information Society and Media, Value management handbook, Publications Office, 1995,
b. Materialized services are products (Product : any good or service SOURCE ISO 14050:2020)

Figure 8: Value from products and services

Figure 9 shows the aspects that should be considered during environmentally conscious design optimizing the value creation for all stakeholders met along the life cycle[xlv]. The same aspect should be considered for circular economy being defined as follows [SOURCE ISO 14009:2020 modified by IEC TC1 JWG2]:

"Economic system that contributes to the sustainable development whereby value is maintained or increased by optimizing the use of natural resources, keeping the resources in a circular flow and minimizing the overall losses".
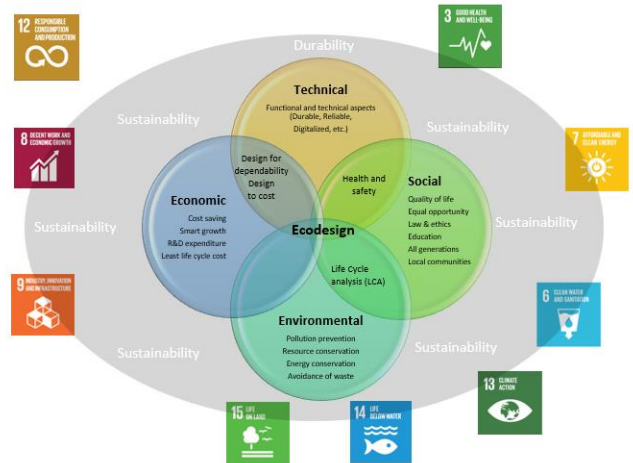

Figure 9: Environmentally Conscious Design (ECD)

Then, the circular economy based on values created throughout the life cycle while avoiding resource consumption and waste generation, eco-design as described above holds the keys to circular design. This topic is covered by CEN CENELEC JTC10 WG8 through EN 45560 currently being drafted and by IEC TC111 WG20 on Guidance on material circularity considerations in environmentally conscious design. The process of the Figure 10 has been applied to the functional requirements creating values over a life cycle shown Figure 11 for users.
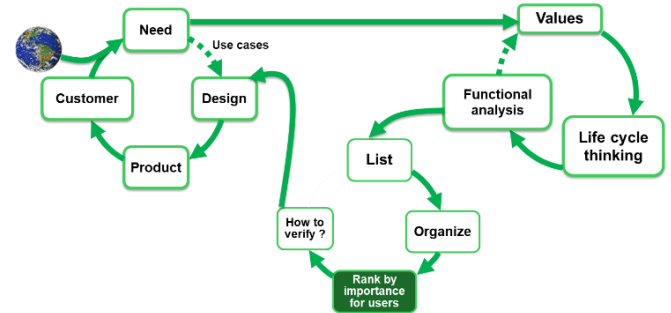

Figure 10: Main steps of a functional analysis

The Figure 12 considers technical functions for all stakeholders, but only functions related to circulation of materials and associated sustainable requirements.
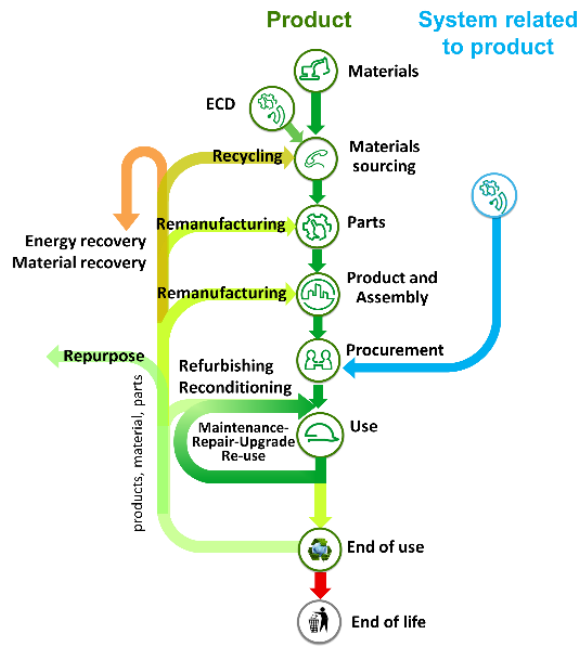
Figure 11: Example of life cycle considered for circular design

Name	Footprint
Avoid any injury and maintain safety, by design under specified conditions	10%
Avoid hazardous substances	18%
Define dependability performance under defined conditions	25%
Extend product lifetime by design and refurbishing	31%
Reduce environmental impact of the product by material selection	38%
Define rules of operating conditions for dependability performance	43%
Avoid of direct substance emissions into the environment during life cycle	49%
Reduce Greenhouse Gaz (GHG) emissions and their avoidance	54%
Get parts to be re-used	59%
Use of re-used part	63%
Provide trusty residual dependability information	67%
Identify substances at end of life	71%
Be lightweighted design	74%
Be able to be easily disassembly and reassembly	78%
Maximize the % of recycled material content	81%
Get materials of product to be recycled (intra sector)	84%
Avoid the use of critical raw materials	86%
Use of re-used material	88%
Get parts to be repurposed	90%
Get transformed material to be re-used	92%
Reduce the volume of product	93%
Provide digital secured and trusty information on circularity aspects	94%
Minimize the number of merged functions inside a same material	95%
Minimize the packaging without dependability alteration	96%
Get materials of product to be recycled (extra sector)	97%
Minimize the number of different materials	98%
Minimize landfill	99%
Avoid emission of indirect releases, e.g. radiation, noise, dust	100%
Use simulation for verification process when possible instead of test	100%
Be energy recovered	100%

Standardisation works should continue to address circular economy and decarbonisation aspects from a global perspective through design rules based on life cycle value analysis that considers associated digital properties.[xlvi]

3.2 Need of consensus on relevant criteria for each index

Highlighted in Figure 12**Error! Reference source not found.**, the top priority for B2B products is the safety of individuals. The TC22X "Power Electronics" Committee, WG9 Team drafts the future En 50743 standard "Ecodesign for power electronics, including approaches for environmental product declarations and specifications for material efficiency assessment," aiming to apply environmentally conscious design principles and maximizing value management according to the application, constraints, and product.

From the ecodesign perspective for power electronics, the main challenge is to be comparable to energy efficiency. The principle of variable speed drives and energy converters is to minimize energy losses during conversion. The Ecodesign Directive 2009/125[xlvii] and 2019/1781[xlviii] regulations have driven significant improvements in the energy efficiency of products in this category. According to the impact efficiency analysis of the European Commission[xlix], these regulations and directives accurately focus on energy consumption. The global warming (GWP[l]) aspect of Power Electronic is centered on Usage losses (more than 95%[li]).

If the European commission wants to influence the material efficiency of power electronic, the energy efficiency could be impacted, that can become counter productive (Lightweighting can lead to energy losses increase). A system including a motor, or a pump variable speed driven should be considered an efficient system from an energy efficiency perspective. Consequently, material efficiency should be considered, and factors such as durability, repairability, upgradability, reusability, etc., should be considered at a system level.

3.3 Need of product specific rules standards

Material efficiency standards EN 4555X series are a good generic methodology to implement assessment on durability, repairability, recyclability, etc. for a dedicated product. These standards are not specific to one type of product. The previous chapters show how the same topic, repairability, can be assessed with significant differences.

Concerning the case of repairability assessment, the application of the EN 45554 Standard gives the guidance to create a repairability index. The application of the standards can be biased by the personal sensitivity of the applicant, the product architecture, and the company policy. This possibility given to the companies will lead to the impossibility of comparing products even if they are very similar. Material efficiency assessment shall be accurate regarding the real impacts of the product assessed. The value management is a relevant method to define the prior topics for the product.

Finally, the material efficiency assessment is not completely mature to define repairability as the first index massively deployed. Power Electronics domain need dedicated criteria and scales to assess the 8 material efficiency topics to communicate to the customer the information they need and to value ecodesign efforts on durability and repairability.

4   Annexes

4.1   Regulation analysis on right to repair around the world

The table below shows the number of regulations in force, approved, and proposed by regions and countries.

Table 1. Number of Regulations In Force, Approved or Proposed around the world regarding the right to repair

Countries by geographical regions[lii]	Approved	In force	Proposed	Grand Total
Africa		3	1	4
Asia		5	4	9
Eurasia		4		4
Europe	1	36	3	40
Middle East		6		6
North America (excluding USA)	1	3	2	6
Center & South America		9	6	15
USA	1	3	29	33
Grand Total	**3**	**69**	**45**	**117**

4.2   Analysis of the regulations on repair Index around the world

The table below shows the number of regulations regarding repair index in force, no longer proposed, and proposed by regions and countries.

Table 2. Number of Regulations In Force, No longer proposed or Proposed around the world regarding the repair index

Countries by geographical regions[liii]	In force	No longer proposed	Proposed	Grand Total
South & Central América		1	1	2
Argentina		1	1	2
Europe	15		7	22
Belgium			4	4
France	15		3	18
Grand Total	**15**	**1**	**8**	**24**

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vii ATEX: Explosive Atmosphere

viii EMC: Electromagnetic compatibility

ix RED: Radio Equipment Directive

x RoHS: Restriction of Hazardous Substances

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