MIDP Mini Study 1: Digital Product Passport Technologies

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ABSTRACT

The report addresses the lack of knowledge on the technology surrounding Digital Product Passports (DPPs), focusing on the EU's Circular Economy push. It targets novel methods for conveying DPP info, particularly in electronics due to extensive Electronic Waste. It explores Digital Battery Passports (DBPs), highlighting parallels with DPPs. Technological options like SmartTags, RFID, AI Image Recognition, and Icons/Labelling are explored and discussed. RFID is identified as promising due to fast transfer, familiarity, and adaptability. Following the report, with a suggestion of taking RFID forward for further development, there is a need for expert interviews to refine the design specification.

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TABLE OF ABBREVIATIONS

AI	Artificial Intelligence
BIM	Building Information Modelling
CE	Circular Economy
DBP	Digital Battery Passport
DPP	Digital Product Passport

EU	European Union
EV	Electric Vehicle
EVB	Electric Vehicle Battery
RFID	Radio-Frequency Identifier
WEEE	Waste Electrical and Electronic Equipment

1 INTRODUCTION

Internationally there has been a growing demand for sustainable business models and design practices (Bartlett, 2012). In recent years this has resulted in many European Union (EU) policymakers creating legislation to enforce a shift to a more sustainable Circular Economy (CE) business model (European Commission, 2020) where products and materials are treated as more of a service than a purchase and waste is reused or repurposed (Figure 1) (European Parliament, 2023a). This helps to retain the value of the product which means that a CE model also contributes economically (Steinbrecher, 2021).

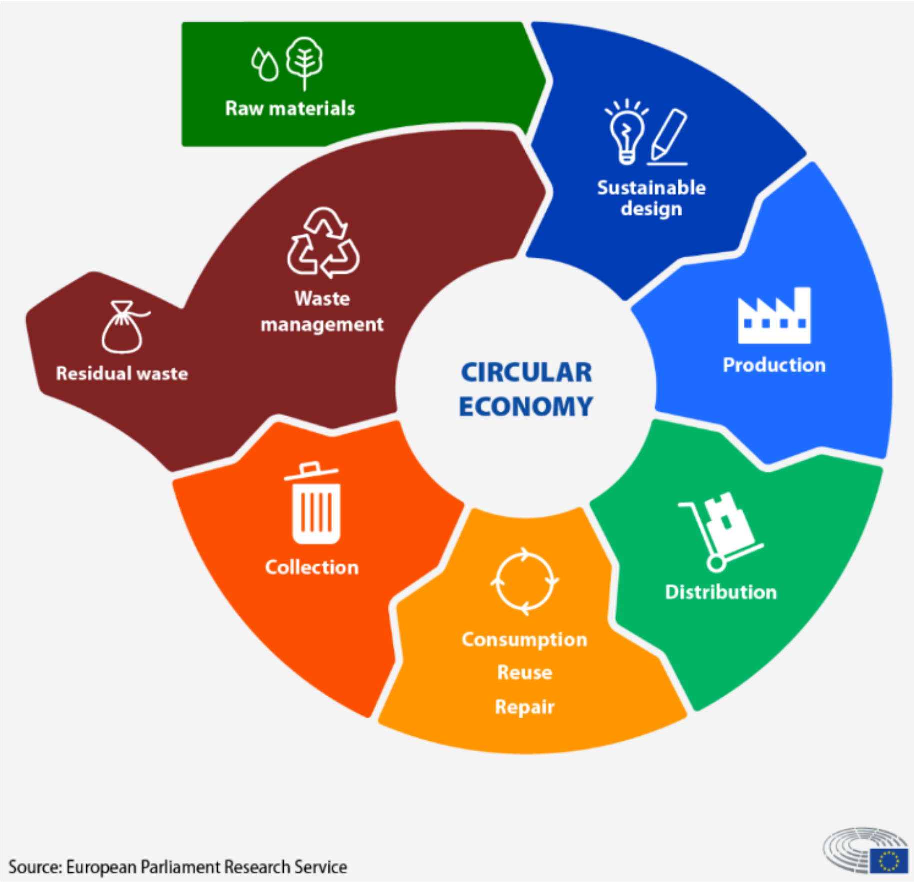


Figure 1: A diagram depicting the stages of a Circular Economy (European Parliament, 2023a).

One of the methods to enable this that has been brought to the forefront is Digital Product Passports (DPPs) (Berger, 2022). This is often considered to be a “digital twin” of the product and is speculated to contain data relating to the origin, manufacture, material, usage, disassembly, and recyclability (European Parliament, 2023b) (Steinbrecher, 2021). The DPP concept is especially relevant due to the global digitization of most data (Ekudden, 2022). One of the big goals for any DPP is to have a system that automatically updates the information in the passport to match the product.

The aim for this project is to develop a novel method for conveying the information contained within a DPP. A goal for the project is to avoid use of existing scanning technologies such as QR and barcodes due to limitations such as the need for an external database to be updated and maintained as well as the lack of flexibility in information. For this project the issue of data privacy, security, and ownership will not be addressed.

The EU suggests that all products should eventually have DPPs to enable customers to make informed decisions as well as reduce waste (European Commission, 2020). Due to the constraints set by the project's timeline a decision was made to focus on electronics allowing for a more developed result. This has been singled out due to the large amount, annually 53.6 Megatonnes, of Electronic Waste (E-Waste) that is generated (Forti et al., 2020). Often lots of the rarest materials are used and lose all their value when discarded. Also, many of these materials can be toxic to life so should be handled correctly, however typically they are not.

Recently the EU imposed legislation on batteries that aimed to circularise their production and use to reduce toxic materials in their production (European Commission, 2023). The anticipated effect of this legislation and the implementation of Digital Battery Passports (DBPs) will be analysed to draw parallels between DBPs and DPPs.

This report will investigate the application of DBPs, Technologies that have been proposed for DPP alongside other technologies put forward by the author and finally a discussion on good and bad aspects of standout technologies.

2 Digital Battery Passports

The EUs introduction of regulations on the circularity of batteries, alongside the creation of the European Battery Alliance, will ensure that batteries need less raw materials, are contained within the EU economic zone, use minimal harmful substances, and have a low carbon footprint (European Commission, 2023a) (European Commission, 2023b) (European Commission, 2018) (European Battery Alliance, n.d.). Due to the rapid growth of the Electric Vehicle (EV) sector and the large size of Electric Vehicle Batteries (EVBs) many in this industry have developed DBPs as a solution to these regulations. However, as with all batteries, there are many challenges in the EVB value chain that need to be addressed with the implementation of the DBPs (Figure 2), across not only the environmental scope but also, social and governance (PSQR, 2023) (European Battery Alliance, n.d.).

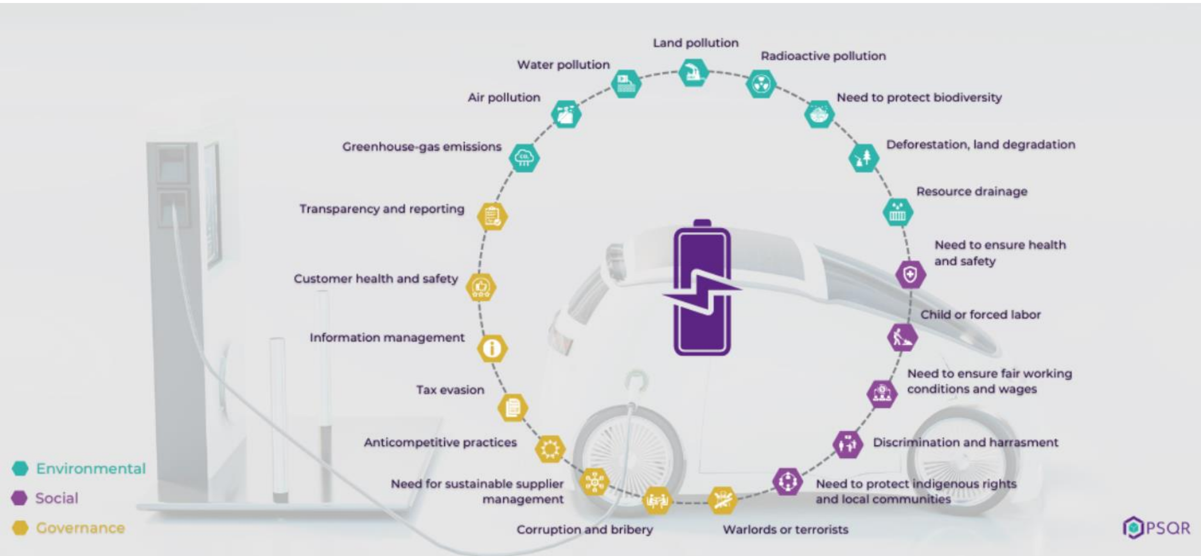


Figure 2: Diagram depicting challenges faced in EVB value chain (PSQR, 2023).

To understand what data a DPP for electronics might need to contain, a concept for DBPs will be adapted to an E-waste use. It is generally proposed that each battery should require a unique passport that contains data on the battery composition, production process, and environmental impact (Berger, 2022) (European Commission, 2023a). Berger analysed what stakeholders to involve and the information they might require making informed decisions (Berger, 2022). This allowed them to develop a concept (Figure 3) for what a DBP might include, shown is a high-level diagram with the full breakdown found in Appendix A.

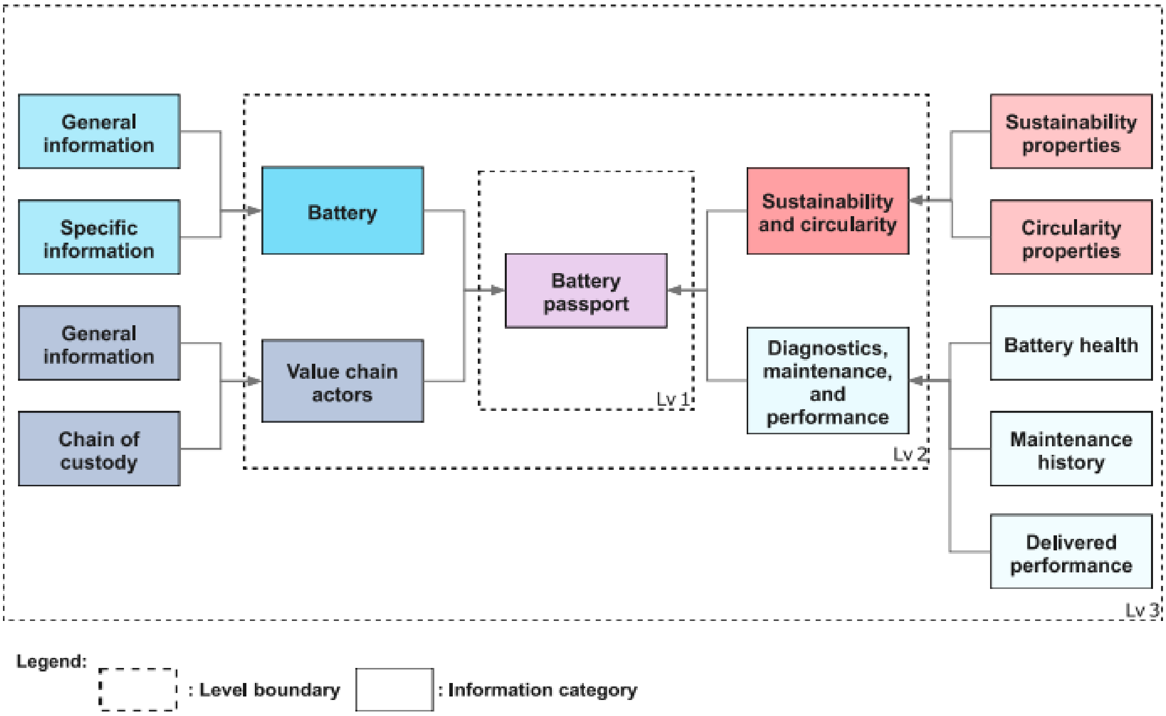


Figure 3: A high-level diagram showing a concept for a DBP (Berger, 2022).

As DBPs, similarly to DPPs, are in their infancy there is no data on their successes or failures, however, the EU expect that they will improve transparency, reduce environmental impact, increase recycling, and increase safety (PSQR, 2023). While these are mostly beneficial for the environment, increased transparency will allow companies to differentiate in a competitive market (Berger, 2022).

To adapt the concept for electronics and E-waste, due to the many electronic devices containing a battery, the DBP developed can be reused here when needed and it can be supplemented by information on the rest of the electrical product. Figure 4 shows how this as a DPP concept can be visualised. The DPP for each product should go into the detail that Appendix A does however it is hard to display this within the report as each product requires different parameters.

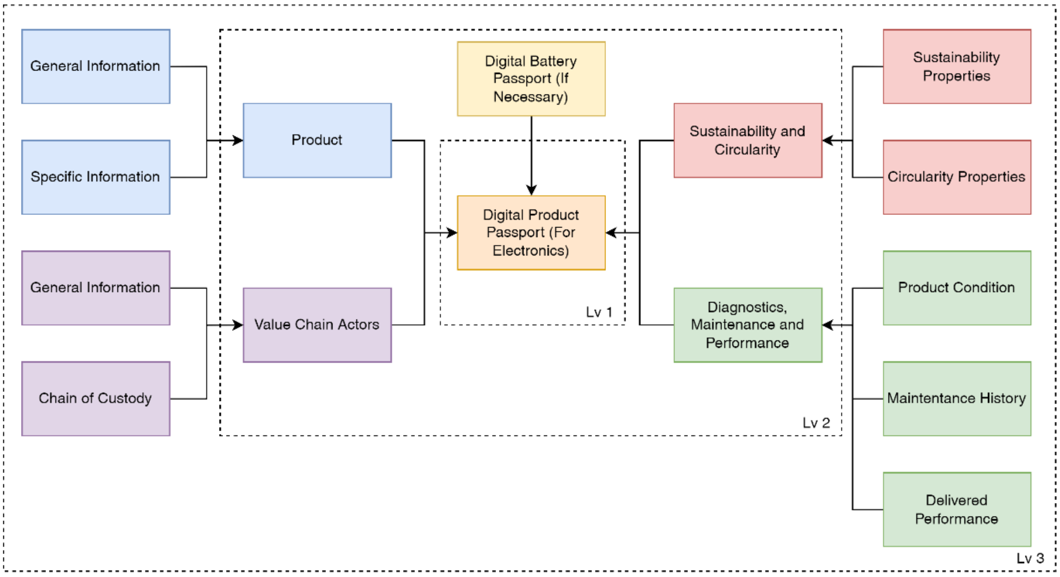
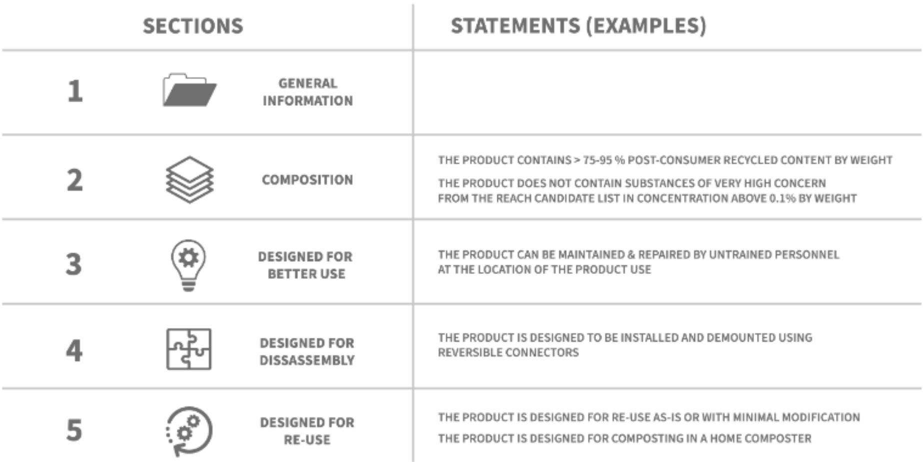


Figure 4: A high-level diagram showing a concept for a DPP.

Currently, the most advanced implementation of a DPP is the Product Circularity Data Sheets (PCDS) in Luxembourg (Luxembourg Government, 2023). This is used for products containing hazardous or toxic materials with a goal to provide a trustworthy source of information that can be verifiably linked to the product. The main issue found with PCDS however, was that it often did not provide enough detail about each product (Mulhall et al., 2022), the information it contains shown in Figure 5. This solidifies the fact that the detail seen in Appendix A is necessary.



SECTIONS		STATEMENTS (EXAMPLES)
1	GENERAL INFORMATION	
2	COMPOSITION	THE PRODUCT CONTAINS > 75-95 % POST-CONSUMER RECYCLED CONTENT BY WEIGHT THE PRODUCT DOES NOT CONTAIN SUBSTANCES OF VERY HIGH CONCERN FROM THE REACH CANDIDATE LIST IN CONCENTRATION ABOVE 0.1% BY WEIGHT
3	DESIGNED FOR BETTER USE	THE PRODUCT CAN BE MAINTAINED & REPAIRED BY UNTRAINED PERSONNEL AT THE LOCATION OF THE PRODUCT USE
4	DESIGNED FOR DISSASSEMBLY	THE PRODUCT IS DESIGNED TO BE INSTALLED AND DEMOUNTED USING REVERSIBLE CONNECTORS
5	DESIGNED FOR RE-USE	THE PRODUCT IS DESIGNED FOR RE-USE AS-IS OR WITH MINIMAL MODIFICATION THE PRODUCT IS DESIGNED FOR COMPOSTING IN A HOME COMPOSTER

Figure 5: An image showing the sections of information in a PCDS (Luxembourg Government, 2023).

3 Suggested Technologies for DPPs

In this section technological options for how DPPs could convey information will be investigated. It will start with a review to see what has already been tested for DPPs then the potential of other technologies will be investigated.

3.1 Existing DPP Tests

3.1.1 SmartTags

One potential technology that could form part of a DPP is SmartTags. These are a technology based on a combination of printed sensors, which make use of functional ink, and a modified barcode standard (Gligoric et al., 2019). The functional inks used in the study analysed were thermochromic and photochromic which allowed for the creation of dynamic QR codes where not only the product's information was recorded but also, it's state. Figure 6 shows how this might work on an ice cream tub, where once the temperature reached a threshold the thermochromic QR code would change permanently indicating product safety.

Figure 6: A comparison of a SmartTag before (left) and after (right) activation (Gligoric et al., 2019).

However, while this is very useful for identifying product safety, this would not apply often in the E-waste sector and this technology uses QR codes with limitations in automatic tracking. Furthermore, while the functional ink part of the SmartTag works completely autonomously (Gligoric et al., 2019), it only detects one variable but in a DPP many parameters need to be recorded (European Parliament, 2023b) (Steinbrecher, 2021).

3.1.2 Radio Frequency Identification (RFID)

Another technology that could be used to convey DPP information is RFID. This works using a chip and antenna (RFID tag) that sends data using radio waves to a reader when it is prompted to (Derakhshan et al., 2007). This has benefits over the previously mentioned scanning technologies as it doesn't require a line of sight and has a far faster detection rate (Henrici et al., 2010), with detection rate being important due to the speed of supply chains.

While RFID technologies are already used everywhere in payment cards, it hasn't been explored for a DPP. However, the use of RFID in a remanufacturing operation has been simulated, where researchers found that there was a 11-15% reduction in processing times (Ferrer et al., 2011). It is worth noting that to use of this technology a retrofit of equipment would be needed. Types of RFID tag are shown in Table 1.

Table 1: RFID tag types alongside a description of each (Henrici et al., 2010).

RFID Tag Name	Description
Tag with identifier and voluminous data	Intends to keep all data relevant to an object directly on the tag to avoid use of database. Tag can be identified with unique identifier.
Tag with identifier and few additional data	A unique identifier is stored on the tag alongside a few other fields of data. These are usually limited to the lifecycle of the object.
Tag with multi-structured identifier	The tag contains a unique identifier for the object however this is stored in separate parts, typically three.
Tag with unstructured identifier	The tag holds a serial code and an identifier which can only then be used by the manufacturer to identify the correct product.
Tag with changing identifier	The tag's identifier constantly changes so that only those authorised can recognise the tagged object.

For a DPP, a Tag with Identifier and Voluminous data is best as this will allow storage of all information required. A Tag with Identifier and few additional data could be used but due to the changing information needs of a DPP this would not suit every scenario.

In terms of how this could be applied to an electronics DPP, the manufacturer could preload all of the product and sustainability data onto the device with the use data being added as the tag interacts, for example when a phone is placed onto a wireless charging pad, the charger could modify the RFID data to show that the device has been charged for a length of time.

3.2 Other Applicable Technologies

While the previously explored technologies have been applied to the DPP or parts of, there are others that should also be considered. While they might not work, they could help provide insight into how information can be conveyed.

3.2.1 AI Image Recognition

With the integration of DPPs and the shift to CE not expected until 2050 it would help to also consider emerging technologies (European Parliament, 2023b). Some of the most prominent, and likely applicable, technologies that align with this are Artificial Intelligence (AI) and Augmented Reality technologies.

A prime example of these is the Google Lens. Some of the functionality it contains includes the ability to, after photographing a frame, image search, find similar clothes and furniture, copy and translate text, solve maths and science problems and identify plants and animals (Wang, 2023) (Pichai, 2017).

As this technology is free and widely available, its effectiveness as a recognition software can be tested. Figures 7 – 10 show the results of the testing. These examples were taken by the author throughout the period of a day to generate a wide sample of electrical goods.

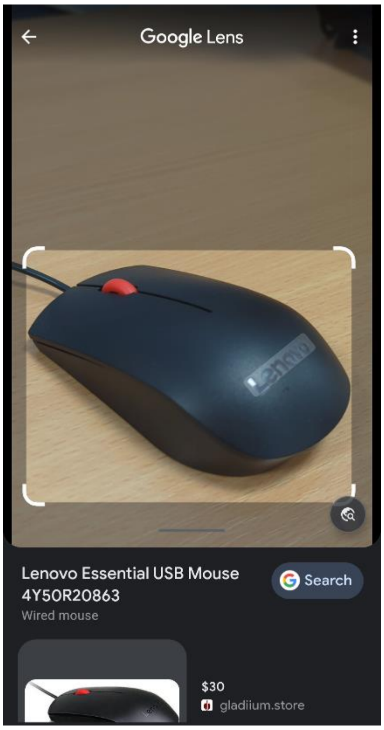


Figure 7: A Lenovo mouse being detected by Google Lens.

Figure 8: A HP Laptop being detected by Google Lens.

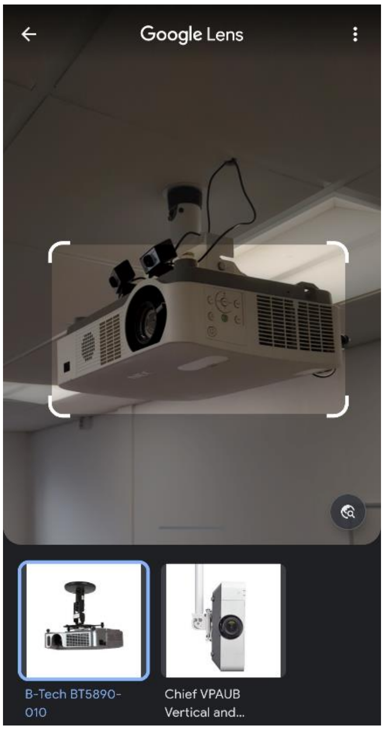


Figure 9: A NEC projector failing to be detected by Google Lens.

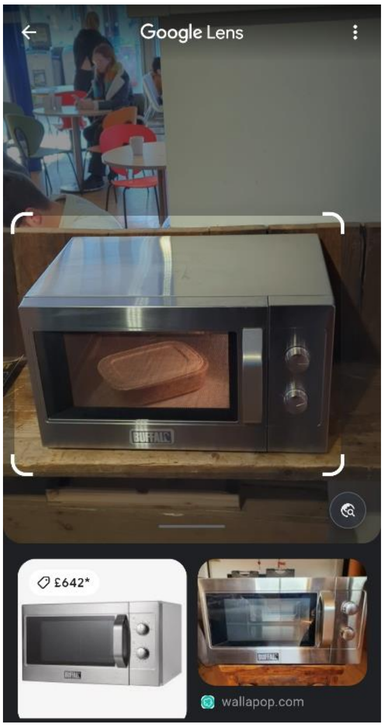


Figure 10: A Buffalo microwave being detected by Google Lens.

As can be seen, while the technology is great at detecting what an object is, for example in Figure 8 it detected a HP Laptop, it is not always able to detect the exact model, critical to a DPP as each unique product may differ (Steinbrecher, 2021). Additionally, Figure 9 shows that if an unclear picture is taken of the product, Google Lens struggles to detect what the product is. This shows it does not have the required functionality for a DPP; however, AI is developing exponentially so there is a possibility that it grows to be perfect for the DPP use case (Wu et al., 2022).

Another downside to image recognition is it would access a database, one of the main downsides of scanning technologies.

3.2.2 Icons and Labelling

Opposite from cutting edge AI technology there are icons and labels. These physical methods of communication have been widely used since the early 1700s to identify the contents of objects (Bouton, 2020). There are practically no limitations on the information that can be stored within a label, the only one potentially being space, meaning that there all data required for a DPP could be stored. Some examples of Icons and Labelling will now be explored:

Waste Electrical and Electronic Equipment recycling (WEEE)

The WEEE mark (Figure 11) has been heavily used across the electrical goods market as it was brought in as part of regulation in 2013 (UK Government, 2013). The aim of the regulation was to tackle E-waste going to landfill. However, the WEEE directive has not had the effect policymakers were hoping for and this is likely down to lack of organisation and education (Mayers et al., 2011).

Figure 11: The WEEE mark that is applied to electrical goods (Your Europe, 2023).

Design for Disassembly in Electronics

To aid with repairs and the recycling process some manufacturers embed instructions for how to disassemble their products. This means that anyone, regardless of knowledge, can work on the product keeping it in use. This is a great example of how simply information can be conveyed, something to focus on later in the project. Figure 12 embodies this, providing instructions on how to remove a laptop battery.

Figure 12: A photo showing instructions for how to remove a battery on a laptop.

While these icons and labels can be very useful at conveying information in a simple accessible way, the first is too simple as it does not contain much detail. Also, there is no way to automatically update a label, one of the main asks in a DPP. Furthermore, they are subject to damage or fading, due to environmental factors, over time which would render them useless.

3.3 Building Information Modelling (BIM)

In the construction industry there has been a shift in many large projects and companies to use BIM which helps with digitisation of projects, streamlining workflow and interdisciplinary coordination (Smith, 2014). At the end of a construction project the BIM package will contain all information about the building and, to increase circularity in the industry, companies are looking into material passports for buildings. One scheme pushing for this is BAMB (Buildings as Material Banks) which hopes that material passports will help building owners and demolition companies save much of the value contained in the building materials (BAMB, 2019). This a similar system to DPPs but on a bigger scale for buildings.

4 Discussion

With each of the technologies understood, to enable progression of the project, one much be chosen to take forward. Table 2 lists the positives and negatives related to each one with a goal to identify common good and bad aspects that can be used in the concepting process.

Table 2: A table comparing the forms of technology that have been analysed.

Technology	Description	Positives	Negatives
SmartTags	Use standard scanning technologies with functional ink to detect changes in environment and link user to a database of information	Can link user to unlimited information Very adaptable Familiar technology Easily retrofitted	Require online database Only able to detect one environmental factor Unable to provide automatic update of usage information Requires sight of the code Not applicable to many electronics
RFID	Radio Frequency transmitter that documents its interaction with other readers or transmitters and can contain product information	Fast information transfer and detection rate No line of sight required A familiar technology (used in payment cards) Able to hold any form of data Allows for automated use data collection	Requires retrofit and redesign of production lines Adds to electronic material in a product Not much data security Required extra technology to access the data contained
AI Recognition	AI Object detection algorithm that can find what an object is from an image and direct users to information on it	Can perform other functions alongside object recognition New technology that is rapidly developing Product does not require modification	Does not provide information for each individual product Requires online database Unable to provide usage information Not perfectly accurate Slow to detect object
Icons and Labelling	A physical technology where information needed is printed or embossed onto the product	Often easy to understand Information can be very flexible Already a very common conveyance method	Requires space on the product Can be overlooked without proper education Unable to update automatically with usage information Slow to transfer information

Some of the standout point from this table are:

- *Update of Usage information* – Many of the technologies analysed do not have any functionality for automatic update of usage information. This does not align with the idea of a DPP as the tracking of a products usage should be automated keep as accurate as possible.

- *Data Flexibility* – Being able to hold any amount of data in would be very useful in the context of DPPs as for each product a different selection of information is required.
- *Unobtrusive* – Being unobtrusive and requiring little effort to apply and retrofit was a big positive in most technologies. This point would allow for a much faster rollout as not much would need to be changed in existing systems.
- *Quick and Easy to understand* – The technology being quick and easy to understand is an important point as it would cause a DPP to be more effective and allow a greater take up.

To apply this to the project, a chart of Ease of Use against Functionality has been created for these technologies (Figure 13). This was done with the goal of identifying which technology has the most potential to become both easy to use and functional.

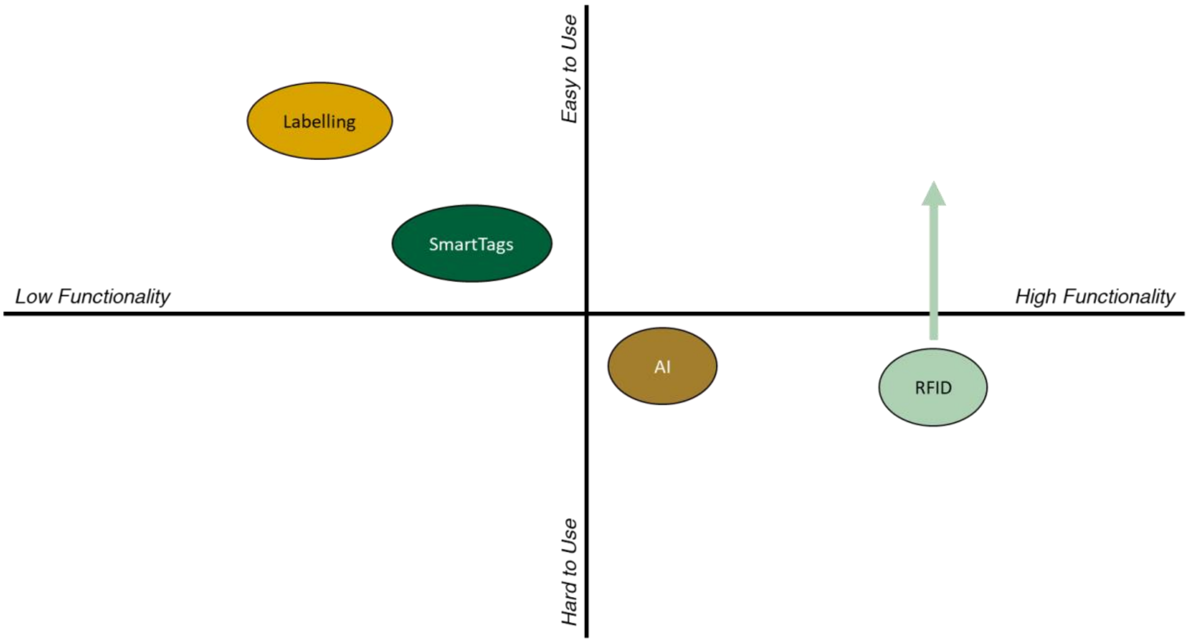


Figure 13: A graph comparing the ease of use and functionality of technologies.

As the graph shows none of the technologies chosen expressed high functionality combined with easy to use. To fill this space RFID should be developed as the aim for the project is to convey information, something that is linked to how easy to use a technology is.

5 Conclusion

To conclude, looking into DBPs proved very beneficial as a concept for the information in a DPP was generated. This helped analyse technologies for their applicability in the DPP concept and should help later in the project when prototyping. Out of the technical analysis it was possible to generate some key points that give a head start on a design specification alongside singling out RFID as a technology with potential. The next step in the project will be to interview manufacturing engineers and DPP experts on how they feel interaction with a DPP should go and how it can be made easy to use.

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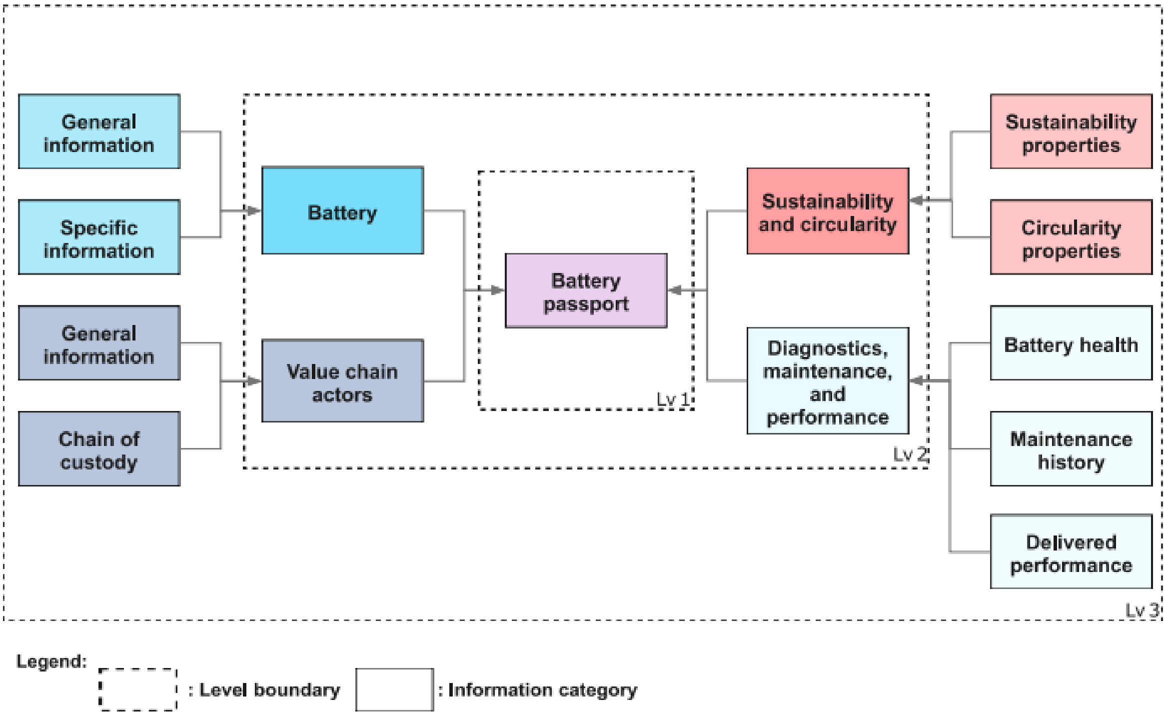
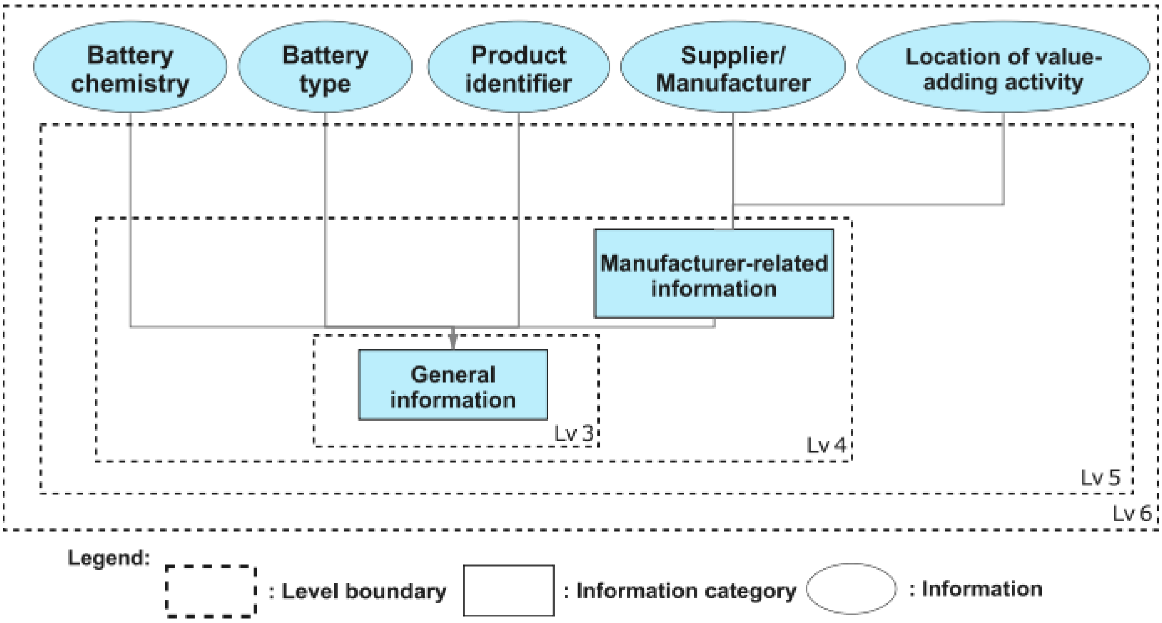
7 Appendices

7.1 Appendix A – Digital Battery Passport Concept

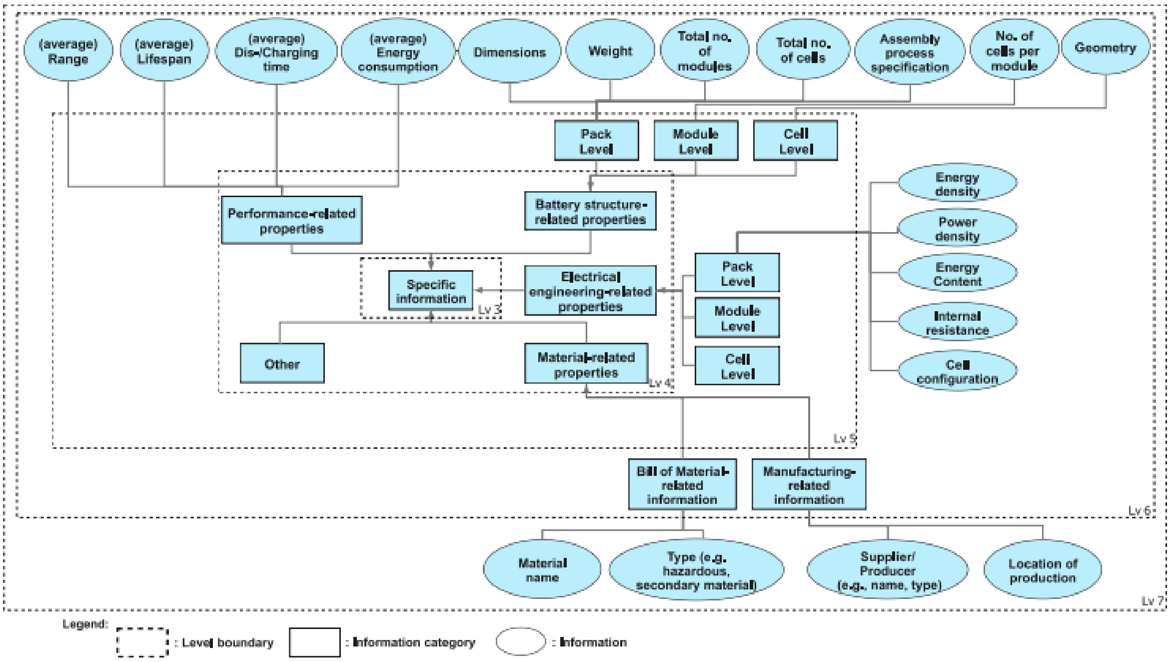
7.1.1 High-Level Model



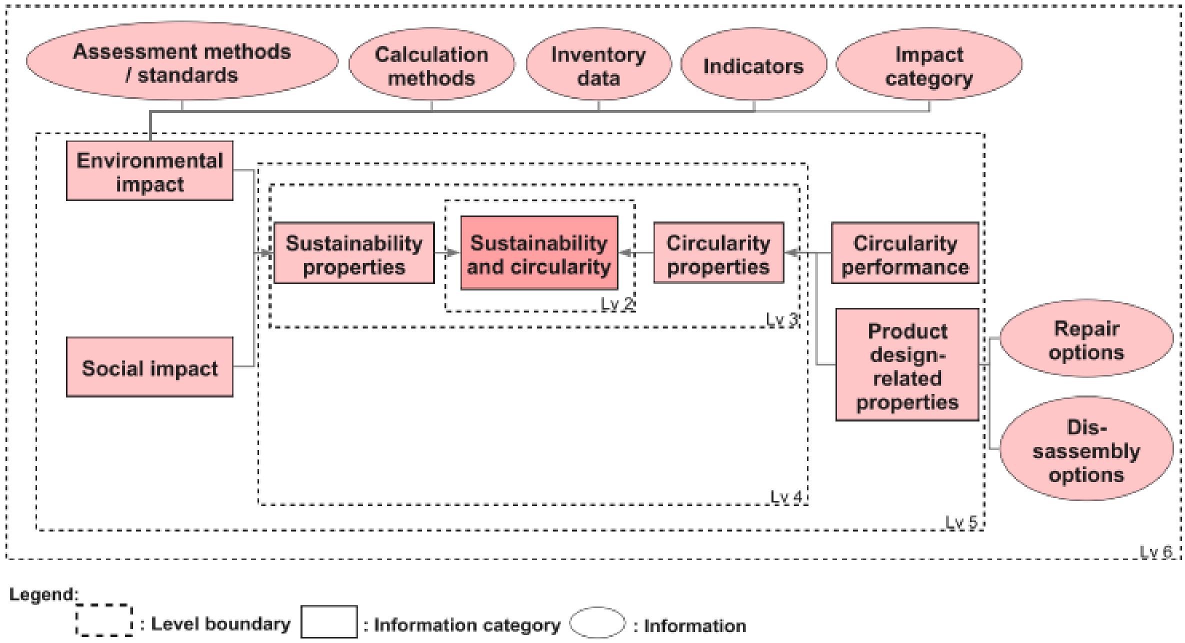
7.1.2 General Battery Information



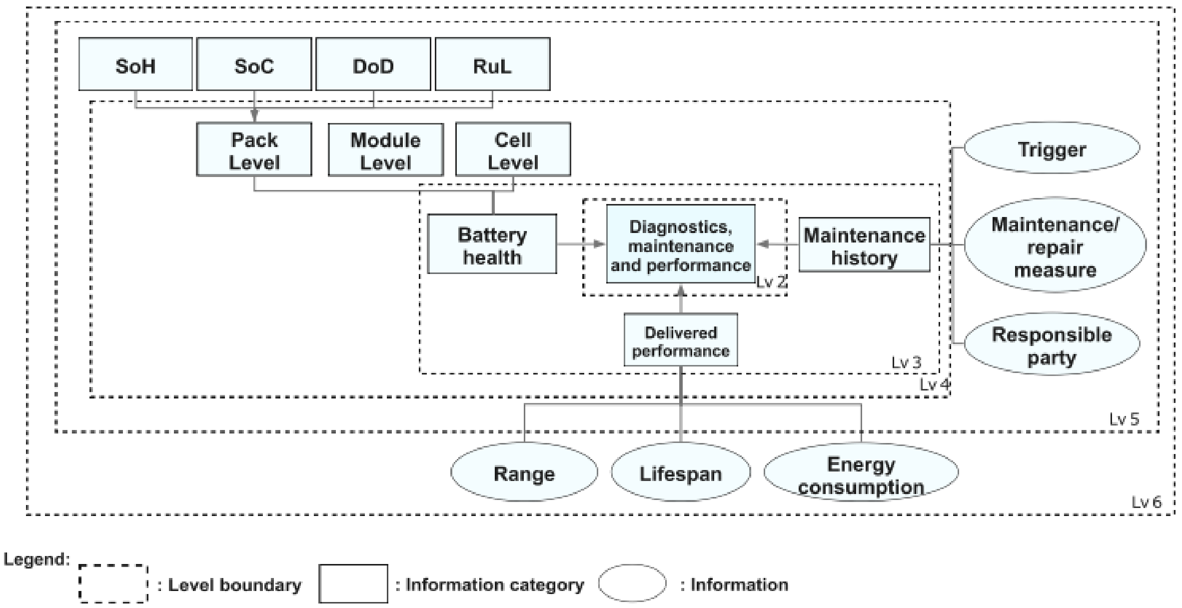
7.1.3 Specific Battery Information



7.1.4 Sustainability and Circularity



7.1.5 Diagnostics, Maintenance and Performance



7.1.6 Value Chain Actor