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Enhancing evaluations of future energy-related product policies with the Digital Product Passport

Antoine Durand[1,], Thomas Goetz[2], Tim Hettesheimer[1], Lena Tholen[2], Simon Hirzel[1], Thomas Adisorn[2]*
[1]Fraunhofer Institute for Systems and Innovation Research ISI, Germany
[2]Wuppertal Institute for Climate, Environment and Energy, Germany
**antoine.durand@isi.fraunhofer.de*

ABSTRACT

The concept of a Digital Product Passport (DPP) has recently been developed. A DPP is a structured collection of product related data (e.g. on energy consumption, sustainability, circularity) with predefined scope and agreed data ownership and access rights conveyed through a unique identifier. In the EU, it will be a decentralised system with a central registry and the DPP is of considerable strategic relevance in the implementation of the European Green Deal, of the Circular Economy Action Plan and of the proposed Ecodesign for Sustainable Products Regulation (ESPR). Against this background, the aim of this paper is to explore the possibilities that DPPs may offer to future evaluations of product-oriented energy/environmental policies.

The paper presents the rationale behind and the origins of the DPP. Then, the evaluation approaches for the current product policies are summarized. Later, options and requirements for the technical implementation of a DPP are briefly explained to show the general infrastructural requirements. Thereafter, the DPP is considered concretely in its integration and role in the context of the future Batteries Regulation, which will be the first regulation with a DPP. Based on this case and the forthcoming ESPR, the paper explores the possibilities but also discusses the limitations of using DPPs for evaluation purposes, and drafts a further outlook on other potential fields of application. In general, the DPP is expected to enhance and facilitate the data collection and the evaluation of product policies, however, this will have to be proven after the implementation of the first DPP.

Introduction

Evaluations of product policies are essential to verify the efficiency and effectiveness of public interventions on the energy and environmental performance of products. The current cornerstones of the European Union's product policies in this domain are the Ecodesign Directive (2009/125/EC) and the Energy Labelling Regulation (EU) 2017/1369. The Ecodesign Directive establishes a common framework for setting requirements for the environmental performance of energy-related products. Only products that comply with these requirements are allowed on the EU market. The complementary Energy Labelling Regulation sets the rules for product-related information that shall enable customers to choose particularly efficient products.

Evaluations are needed to understand the impact of such product policies. They concern both product-specific regulations as well as the framework itself. The availability of data on products and markets is a crucial point for any such evaluation. Supporting tools such as the EU Product Registration database for Energy Labelling (EPREL) (Berwald et al. 2019) contribute here, yet they mainly focus on features of new products and thus only cover some of the required data. A very promising more comprehensive approach is the Digital Product Passport (DPP). The proposal for an Ecodesign for Sustainable Products Regulation (ESPR) presented by the European

Commission in March 2022 foresees a DPP "to electronically register, process and share product-related information amongst supply chain businesses, authorities and consumers. This is expected to increase transparency, both for supply chain businesses and for the general public, and increase efficiencies in terms of information transfer" (European Commission 2022).

Despite its current relevance in the political setting towards a circular economy, the scientific debate on the DPP still seems limited (Adisorn et al. 2021). Prior works concentrate on the potential role of a DPP and its challenges and opportunities in a circular economy context (Walden et al. 2021; Berger et al. 2021), and design options for a DPP (Adisorn et al. 2021). The technical implementation of the DPP is very technical and well explained (Susanne Guth-Orlowski 2021). Other works focus on material passports (Luscuere 2017; Honic et al. 2019), particularly in the context of buildings. These papers also mostly address the DPP from a rather technical perspective, in particular as seen from an actor in the value chain. Yet the DPP could also offer completely new options to obtain product-related data that is required for the diverse ex-ante and ex-post evaluation activities in European product policy making. Against this background, this paper aims to explore and analyse these potentials for future evaluations. More specifically, it seeks to answer the following question: what is the potential to enhancing future evaluation of product-oriented energy/environmental policies with the DPP and what are the conditions that it would need to fulfil? In order to answer this question, the challenges of the current approaches to product regulation and monitoring are outlined below. This is followed by a more detailed explanation of the options and requirements for implementing a DPP. Its potential design and use is illustrated using the example of the forthcoming Batteries Regulation. Then, the paper presents how the DPP could also be used in general within the framework of the proposed ESPR, in order to take the evaluation of product policies from the usual ex-ante consideration to a new level. In this context, the requirements and potentials, but also the limitations of the use of DPP for evaluation purposes will be discussed.

Methodology

To explore the potential of the DPP in policy evaluations, we follow a five steps approach, which is based on policy analysis. Step one: we analyse in detail the current approach of product regulation. In particular, we focus on Ecodesign and Energy Labelling Regulations and highlight the main obstacles in terms of data availability. Step two: we describe the concept of DPP, from a theoretical point of view as no DPP has been set up yet for energy-related products. Step three: we analyse the Batteries Regulation, which includes the Battery Passport and which is the first DPP having been conceptualized and is therefore the most elaborated/accomplished example of what could be a DPP. Here, we look at the specific requirements, which have been set. Step four: we analyse the benefits and limitations of a DPP. Step five: based on the information gathered, we elaborate a possible DPP-based evaluation approach within the ESPR framework. As the DPP is a new concept, which is mentioned in EU policy proposals but has not yet been implemented on this level, the paper explores theoretically the potential of DPP for product policy evaluations.

The work considers the policy cycle, which underlines the role of evaluations in these policies: concerning the implementation of the Ecodesign Directive, two interlinked policy cycles can be distinguished (Figure 1). One overall cycle concerns the Ecodesign framework while a second cycle deals with interventions on individual product groups within that framework. The overall implementation along these cycles is operationalized by different types of studies. A common starting point on the level of the framework are working plan studies that aim to establish an indicative list of relevant product groups as priorities for further investigations. They typically determine the product groups on the agenda for the next three to four years. These studies screen a wide range of product groups and the prioritized products are investigated further per product group in Ecodesign preparatory studies. In these preparatory studies, legislation, markets, user behaviour and technologies to identify potential levers for improving environmental performance are analysed. If the results are deemed promising for product-related policies, implementing measures, i.e., voluntary agreements with manufacturers

or mandatory minimum requirements for new products follow. Their potential impacts are investigated in impact assessment studies when the implementing measure is drafted.

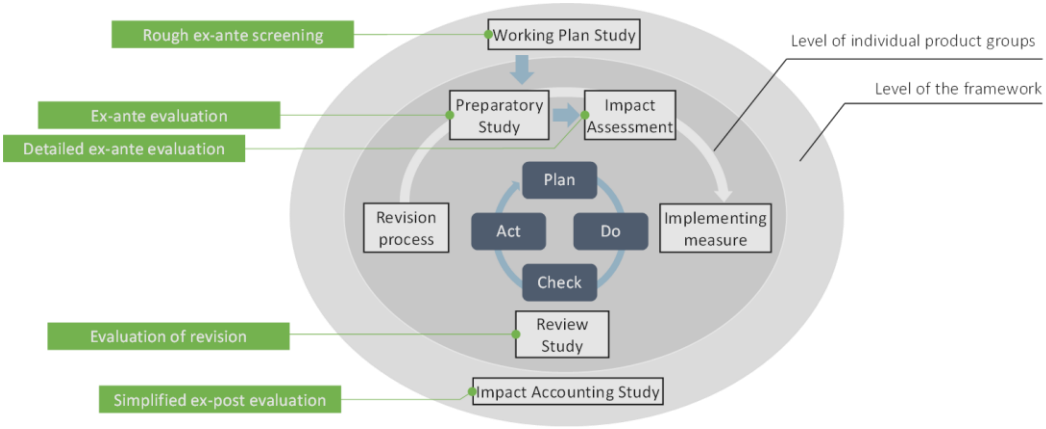

Figure 1. Policy cycles in the Ecodesign context. *Source: Fraunhofer ISI.*

A couple of years after adoption, the implementing measures are given scrutiny in review studies that seeks to update and enhance established mechanisms. These review studies may result in revised implementing measures. On the framework level, impact accounting studies seek to investigate the overall impact of the various measures for products in place. Although a product can be regulated by an implementing measure for Ecodesign (Commission Regulation) and/or Energy Labelling (Commission Delegated Regulation) based on distinct legal documents, they will usually be covered in the same process.

All mentioned studies contain elements that can be considered in part as evaluations since they seek to identify or review efficient and effective ways to enhance the energy or environmental performance by product-related policy interventions. In case of the working plan, preparatory and impact assessment studies, these are ex-ante elements of potentially forthcoming policy measures. The review and accounting studies tend further towards ex-post elements.

The current approach of product regulation

With regard to the supply of product related information to end-users and market actors, the Ecodesign and the Energy Labelling regulations are based on different types of requirements. The Ecodesign Directive (Annex I, §2, 2009/125/EC; (European Commission 2009)) states that "implementing measures may require information to be supplied by the manufacturer that may influence the way the product is handled, used or recycled by parties other than the manufacturer". Data to be provided within Ecodesign present a major problem for policy evaluators: the information should be provided on the product itself wherever possible, some data might also be available on the product fiche of the product, in the documentation/booklet and on the website of the seller or of the manufacturer. However, in contrast to the Energy Label, there is so far no centralised product database for Ecodesign, which is an issue not only for policy makers but also for Market Surveillance Authorities (MSA).

Within the Energy Labelling Regulation, the energy class and the label are provided on the product and in the documentation. In addition, one of the main features of the latest Energy Labelling Regulation (2017/1369/EU) (European Commission 2017) is the EPREL database (European Commission 2021a), which obliges suppliers to enter in the public and compliance parts of the product database the information for that model, before placing a unit of a new model covered by a delegated act on the market. The online database has a public and a compliance part. While the public part consists of information on the energy efficiency class and the other parameters of the label as well as of the product information fiche, the compliance part contains the

technical documentation. In addition, the Regulation requires in Annex I that the information shall be machine readable, sortable and searchable, respecting open standards for third party use, but this is limited to the public part. Accordingly, there are no functional criteria for the compliance part.

Through EPREL, there is the possibility as evaluator to access data of any model put on the market and covered by a delegated act for energy labelling. Potentially, the EPREL database can deliver a much better picture of the market of products covered by an energy label than in the past. Accordingly, the data quality for ex-post/ex-ante assessment or monitoring purposes can be improved. Yet, there are limitations to the EPREL database. The main one is that entries in the EPREL database are solely model-range-specific and not specific to single products. There are also no figures related to the sales volumes of products of each model-range entering the market. Accordingly, analysis of the EPREL data will be only possible on model-ranges. In other words: while it might be possible to assess the most and the least efficient products theoretically available on the EU market, it is impossible to derive market volumes/shares or to track the trends of the market. Any statistics on the average energy efficiency or size of a product group will remain unknown. Such limitations are a large obstacle for policy evaluation and monitoring. Yet, the primary purpose of the product database was to support the work of MSA, to allow customers to compare model characteristics and choose the most energy efficient products, as well as to provide the Commission with up-to-date energy efficiency information for products for reviewing energy labels, so that a model specific dataset is sufficient. In addition, EPREL only applies to products covered by a specific delegated act for energy labelling. In sum, policy makers and consultants are still lacking reliable figures on the market despite the implementation of the EPREL database.

All studies carried out in the context of the Ecodesign and Energy Labelling framework (see Figure 1) usually require detailed information on the different technologies in use, data on their environmental performance, the actual usage patterns of the products, the demand on the market by type, the existing stock of products, and increasingly data related to circular economy aspects. Experience shows that such information is rarely available in detail; even manufacturers regularly underline their lack of ability to provide such information for diverse reasons. In absence of more reliable sources, the information then needs to be collected from various sources, such as public European statistical databases, national statistics or studies, from market research institutes, scientific publications, earlier investigations, EU projects and other sources. In practice, that information is often fragmented, poorly aligned and sometimes not available at all, confidential or expensive. Consequently, a lack of consistent data collection and monitoring of market developments was reported in the evaluation of the Ecodesign Directive (2009/125/EC) and of the Energy Labelling Directive (CESE and Oxford Research 2012; Ecofys et al. 2014).

At the same time, aspects related to the circular economy are getting increasing attention in the Ecodesign regulations (Barkhausen and Durand 2022). Product policies as well as the related impact assessments and ex-post evaluations increasingly cover material and circular economy aspects: recycled material, reparability, recycling, etc. The Better Regulation Guideline (European Commission 2021b) requires better, more holistic and standardized impact assessments and policy evaluations. Accordingly, the overall EU policy framework requires to gather and monitor a broad set of data in the future. Policy makers and evaluators have to cover a more holistic and more complex scope in terms of impacts as well as of life stages of the product than in the last decade, which was almost limited to energy and climate impacts related to the use phase.

The Digital Product Passport: Background and operationalisation

With the European Green Deal (European Commission 2019a) and the Circular Economy Action Plan (European Commission 2020a), the European Union (EU) has started a new era of EU product policies. Both strategy papers introduce specifically the idea of a so-called ’electronic‘ or ’digital’ product passport (PP) as an essential instrument for more product-focussed policies. Thereby, in EU literature the terms ’electronic‘ or ’digital’ are often used as synonyms, meaning that the PP should contain machine-readable information saved

on a server or in the cloud (e.g., on the origin, composition, repair and disassembly possibilities of a product as well as on its handling at the end of its life (EOL)).

The current demand for a Europe-wide PP was already initiated by the European Resource Efficiency Platform in 2014, among others, with the aim of returning materials from products that are no longer used to the production cycle (European Commission (COM) 2014). Since then, the topic of the circular economy has developed considerably, especially at the European level, and recently there have been increasing calls for the implementation of a DPP within the EU. Accordingly, the DPP has been first introduced in 2020 in the proposal for a new Batteries Regulation (European Commission 2020c) and is also an integral part of EU's 2022 ESPR proposal, which also intends to extend the scope of the Ecodesign Directive on energy-related products to as wide a range of products as possible to set appropriate minimum sustainability and information requirements for certain product groups (European Commission 2022).

The envisaged DPP can therefore be described as a structured collection of product related datasets with predefined scope and agreed data ownership as well as with specific access rights for different target groups (such as consumers, policy makers, recyclers or market surveillance authorities) accessible through a unique identifier (number or code) present also on the product. In the EU, it will be most likely a decentralised system for data storage combined with a lean central registry by the EU only for selected key parameters. See example of the DPP for refrigerator in Figure 2. By this means, the DPP is intended in particular to improve the data availability and accessibility for such purposes.

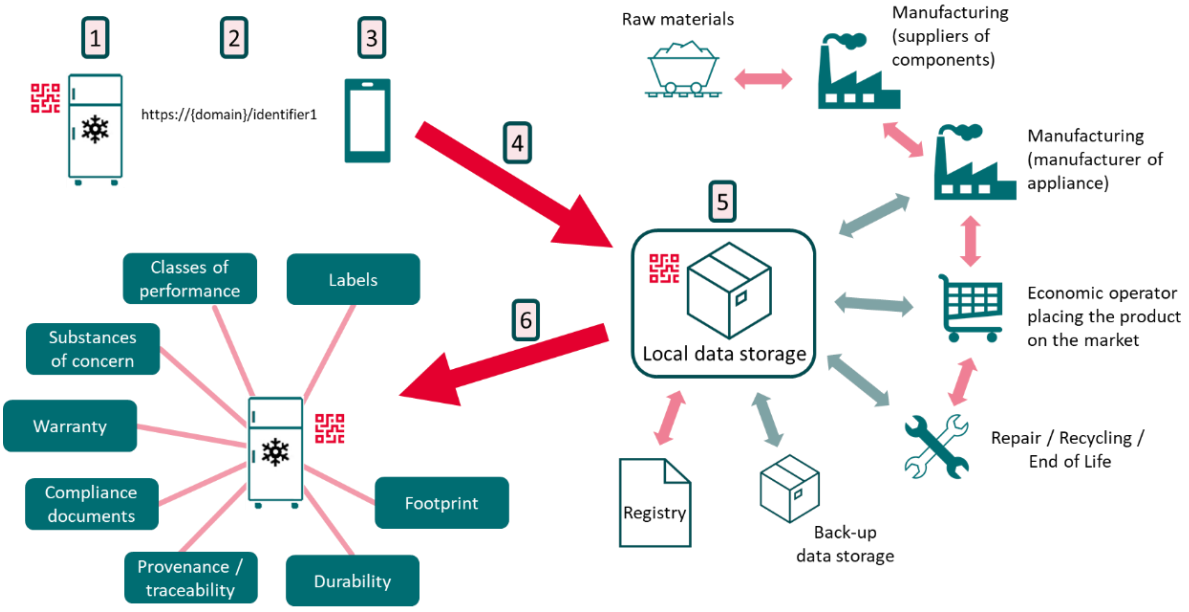

Figure 2. Working principles of a DPP. *Source: Own illustration by Wuppertal Institute, based on (Galatola 2022).*

Even though the collection and publication of product-specific data by means of IT-based systems have been analysed, demanded and partly implemented in different contexts for many years, the concrete discussion about the so-called 'electronic' or 'digital' PP is still relatively young and many aspects and details are not yet exactly defined or resolved.

It must be considered that the general idea of PPs is traditionally discussed using also different terms and approaches, such as 'digital twins', resource or material passports, environmental product declarations, life cycle files, cycle/recycling passports, etc. The concepts behind these terms often have not yet been detailed in directly comparable standards. Therefore, although the basic concepts behind these terms often may have a similar core approach, they may differ in part in their concrete goals and their execution. Thus, it still has to be decided which of the existing information tools might be replaced by a harmonized EU-wide DPP or potentially form the basis for further DPP developments.

Independent of the exact design of the future PPs, data must be systematically collected, updated and made accessible to the corresponding user groups in a suitable way, if necessary and applicable also on a product-specific level, i.e., for an individual product (for high value products). While the collection of some information can be generally product-group or model-specific (e.g., generic repair information), product-specific information that needs to be detailed even more precisely would require to integrate all relevant stakeholders throughout the entire product life cycle. If, for example, the properties or components of an individual product change as a result of a repair measure, product-specific information would have to be updated so that, for example, waste management companies can optimally dispose of the product. In the case of increasingly customised mass production, whereby design requests are incorporated, product-specific information would also be increasingly required. At this point, there is still insufficient clarity about the actual requirements of the future DPP, but some aspects must definitively be carefully weighed against each other in terms of their advantages and disadvantages as part of upcoming further stakeholder discussions. For example, with regard to transparency, verifiability, data disclosure or the guarantee of long-term availability and safety requirements, responsibilities and applicable standards for different target groups need to be clearly defined. Depending on the outcome, it must be decided where, by whom and for how long the data should be collected and stored, e.g., at the manufacturers, importers or other "distributors" (see Figure 2).

When implementing a DPP, it is therefore important to consider not only where the data will be stored, but also by which bodies the data will be entered into the system. This can be done, for example, by the manufacturers, suppliers or importers, whereby company and business secrets must be protected. Since also the possibility of updating product data over the life cycle must be addressed, it has to be taken into account that the corresponding system must not only guarantee data input (write access) from distributors in the long term, but also other actors such as repair companies. Furthermore, not all data and information collected are equally relevant for all groups of persons in order to fulfil their market role. The system that collects this data and information must therefore ensure that certain target groups have access to selected relevant content in the sense of target-oriented data management (“need to know” principle). This also applies in particular to the protection of sensitive company data (European Policy Centre 2020). If, for example, it becomes necessary to show where raw materials for products or components come from, the question arises as to what extent such information may be read out, e.g., exclusively for the purposes of market surveillance, or also by other bodies in the sense of fair global supply and value chains.

The DPP in the new Batteries Regulation - A blueprint for other policy areas

One example that illustrates the increasing complexity of product assessment and policy-making and the high potential a DPP can offer is provided by the product group "battery", in this case portable, industrial, automotive and light means of transport batteries. In the EU, the production and disposal of batteries have been regulated by the EU Batteries Directive (2006/66/EC) since 2008. The aim of the directive at that time was mainly to limit the use of cadmium and mercury and to standardise and regulate the waste management of spent batteries (European Commission 2020d).

As a core component of e-mobility and due to the progressive electrification of power tools, the demand for batteries has gained substantial importance in recent years. Not only the number of batteries but also their size, composition and intended use have changed to such an extent that the Batteries Directive 2006/66/EC could no longer do justice to them. At the same time, the battery has also become increasingly important in terms of its added value and environmental impact. In October 2017, the European Commission therefore founded the European Battery Alliance to strengthen further research and industrialisation of batteries in the EU, and one year later set the framework for a sustainable and competitive battery value chain in Europe with the "Strategic Action Plan for Batteries" (European Commission 2018).

Under these conditions and as part of the European Green Deal, a draft for a new Batteries Regulation was therefore presented by the Commission in December 2020 and adopted by the EU parliament in March 2022

(European Commission 2022). The proposal for a new Batteries Regulation contains ambitious requirements to increase sustainability, traceability and social standards over the whole battery product life cycle. It includes requirements regarding the performance and durability of batteries and their carbon footprint, the use of recycled materials as well as the collection and recycling rate. Furthermore, the socially responsible sourcing of materials is also part of the regulation as well as a label indicating the carbon footprint performance class of the batteries. The labelling of batteries e.g., via QR-codes is relevant for different groups of actors: for the end customer, it serves as a decision-making aid when purchasing or disposing the product, while service stations, intermediaries or recyclers can obtain detailed information about the condition and composition of individual batteries (European Commission 2020c).

Within the framework of the Batteries Regulation, an electronic battery information exchange system will be set up from 2026, in which information on each battery model placed on the EU market will be registered and made available to the public. Also in 2026, each regulated battery placed on the market (or changing its status, e.g., repair, 2nd life...) will also have an electronic record: the "battery passport", which is a DPP for batteries. The electronic exchange system can be linked to the individual digital "battery passport" via a QR code and in this combination offers the possibility for traceability and monitoring of the batteries (same principles as in Figure 2). The labelling and in particular the use of a DPP thus facilitate the necessary monitoring of compliance with the requirements as well as market observation or the evaluation of measures taken (European Commission 2020c). The information available on the battery passport is divided into two areas: information that is collected according to the model series and information that is collected specifically for each individual battery. Table 1 shows the main information related to CE aspects.

Table 1. CE related information captured by the DPP

Information about the battery model	Information about the individual battery
▪ Material composition of the battery, including its chemistry, hazardous substances contained in the battery other than mercury, cadmium or lead, and critical raw materials contained in the battery ▪ Carbon footprint information ▪ Information on responsible sourcing as indicated in the report on its supply chain due diligence policies ▪ Recycled content information ▪ Expected battery lifetime expressed in cycles, and reference test used; Capacity threshold for exhaustion (only for electric vehicle batteries); ▪ Period for which the commercial warranty for the calendar life applies; ▪ Initial round trip energy efficiency and at 50% of cycle-life; ▪ Internal battery cell and pack resistance; ▪ C-rate of relevant cycle-life test.; ▪ The labelling requirements ▪ The EU declaration of conformity ▪ The information regarding the prevention and management of waste batteries	▪ Information about the values for performance and durability parameters, when the battery is placed on the market and when it is subject to changes in its status; ▪ Parameters related to the electrochemical performance and durability ▪ Rated capacity (in Ah), capacity fade (in %). ▪ Power (in W) and power fade (in %). ▪ Internal resistance (in Ω) and internal resistance increase (in %). ▪ Energy round trip efficiency and fade (in %). ▪ An indication of their expected life-time under the conditions for which they have been designed. ▪ Information on the status of the battery, defined as [‘original’, ‘repurposed’, ‘reused’], or ‘waste’; ▪ Information and data as a result of its use, including the number of charging and discharging cycles and negative events, such as accidents, as well as periodically recorded information on the operating environmental conditions, including temperature, and on the state of charge;

Source: based on (Council of the European Union 2022).

The introduction of the DPP is thus an important contribution to the successful implementation and monitoring of the measures of the Batteries Regulation. As the Batteries Regulation with its new sustainability approaches for batteries also serves as a blueprint for further initiatives within the framework of its policy for sustainable products, the DPP can also make a relevant contribution to increasing transparency and traceability in these new areas.

A possible DPP-based evaluation approach

As described previously and showed in Figure 2, the DPP offers the possibility to make a product more transparent and traceable along the whole value chain, to give actors along the value chain, such as service providers or recyclers, access to the information relevant to them and, ultimately, to provide consumers with all the information they need to make a purchasing decision. In addition, the DPP offers further benefits to European and national authorities with regard to the monitoring and enforcement of the product regulation as well as the ex-post evaluation of policy measures.

The ex-ante or ex-post evaluation of proposed or implemented policy measures is a common means of assessing their efficiency and effectiveness. While this is done ex-ante in the case of working plans, preparatory studies and impact assessment studies, the review of measures on product-group level is done ex-post after several years. With regard to the framework of the ESPR itself, about 8 years are foreseen for the evaluation of the framework regulation. For the implementation and reliability of an evaluation, the underlying data plays an elementary role, which, however, is sometimes difficult to obtain, incomplete or not available in the required granularity. Here, a DPP and the associated exhaustive set of product data can make a decisive contribution to improving the quality of monitoring and ex-post evaluation and, based on this experience, also ex-ante evaluation in the long term. It is assumed here, that data will be stored and accessible for a long time.

To provide usable information in this regard, it must be available in the necessary scope and level of detail for the respective purpose of the analysis. In addition, there is the need to avoid a disproportionately high administrative burden for the economic operators. For this reason, in the ESPR framework, the ecodesign requirements as well as the data to be recorded in the DPP will depend on the product group to be regulated. Furthermore, the DPP should be specific to either the item, batch or product model, depending on the complexity of the value chain, size, type or impact of the products under consideration.

The type of information collected in the DPP will also be actor specific. For example, while it is sufficient for the end customer to obtain information on energy consumption or service life, additional information is relevant for the ex-post evaluation of a regulation. An overview of all core indicators particularly relevant for the monitoring and evaluation of ESPR regulation can be found in Annex I of this paper. To check the achievement of the regulation with regard to the above-mentioned core indicators, two levels of monitoring could be adopted: a micro level and a macro level. At the micro level, the DPP will make it possible to obtain specific information on each individual product and thus monitor trends for a particular product category, while at the macro level this information in aggregated form will make it possible to monitor the impact of all products regulated by the ESPR based on various indicators.

The DPP database can be used to obtain precise data on the individual product at a micro level. For example, and depending on the DPP requirements set for a specific product group, it would be possible to obtain data regarding the time of market entry, the materials contained in the product or the GHG emissions caused during its production. Furthermore, this micro level could also be used to collect information about the product's use phase up to its disposal. By reading the DPP at the end of the product's life cycle, it would be possible to tell how often a product has been repaired, how intensively it has been used, how long it has been on the market or whether it will be put to a second use. If the focus is extended from this micro level to a macro level and thus a variety of these products are considered. The success of a regulation in terms of different socio-economic and environmental impacts can be monitored and evaluated at such a macro level. On this basis, for example, indicators relevant to ESPR as mentioned above can be identified.

For example (Figure 3), the aggregate of individual products gives a good overview of market volume (1)[1] and taking into account their EOL, information on their average lifetime as a result of initial durability, maintenance and repairs, etc. (4). By knowing the materials used, their origin and the production of the product, it is also possible to draw conclusions about the GHG emissions caused (2) and the recycled or recyclable materials used (5 & 6). In addition, statements can be made about the efficiency of the products (3). Data gathered with the DPP will be useful to better estimate the stock volume or the way a product is used. However, some challenges will remain, meaning that many assumptions will still be necessary to elaborate the baseline for an evaluation.

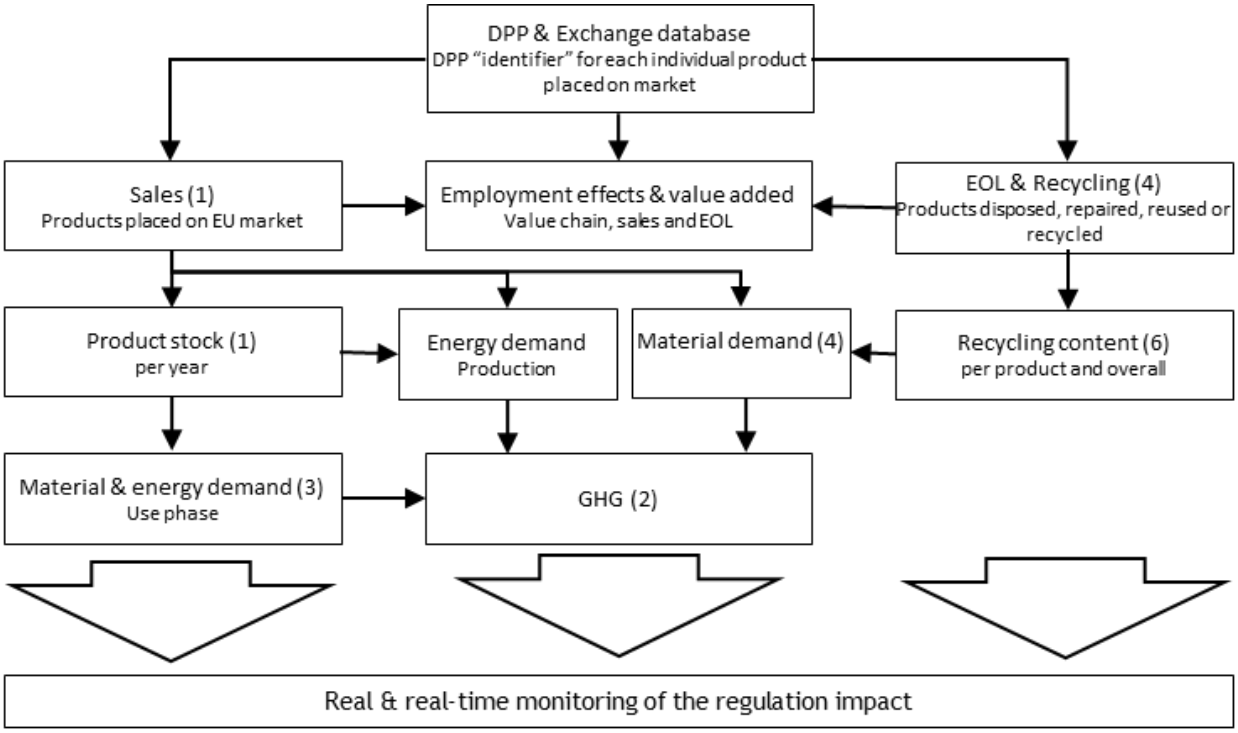

Figure 3. Structure of a possible DPP-based evaluation. *Source: Fraunhofer ISI.*

Furthermore, the information can be used to determine indicators that determine the cost effects for the end customer or possible job and value creation effects. While the former results directly from the relationship between life cycle costs and service lifetime, the determination of value added effects would presumably be of a more complex nature. For this, the origin of the materials, the place of manufacture as well as the frequency and type of maintenance and repairs would have to be determined. Nevertheless, such monitoring on the basis of the DPP would also be conceivable. To take this idea even further, it would be possible to obtain knowledge about all material flows within the EU across all product groups and about the material returns through the recycling of these products in the coming years. In this way, appropriate planning for recycling plants or primary raw material procurement can be carried out.

For social aspects, the DPP and the database provide information on the type of origin of materials along the value chain. Information on working conditions is also available. Monitoring a possible change in social conditions is thus feasible in this way and shows the success of a regulation. Hence, the framework is able to allow a real-time and holistic monitoring of products and the success of a regulation. Compared to the common process, this approach is also able to cover many additional environmental and social aspects and connect them to specific core indicators. Finally, as the proposed monitoring will deliver required data to assess the average

[1] Numbers are corresponding to listed core indicators in Annex I of this paper

product put on the market and the Best Available Technology (BAT), such data could be useful to improve future ESPR requirements and/or to adjust regularly the criteria for EU Ecolabels or Green Product Procurement.

Benefits and limitations of a DPP

The concept of the DPP will theoretically provide the evaluators with an abundant data source to carry out ex-ante and ex-post assessments. However, the reality will have limitations. Practical issues especially concern the data available in the DDP and what will be collected and updated after the product has been put on the market. Data could be updated during the use phase but also afterwards until the final EOL (see Figure 2). A key issue will be the degree of specificity of the data as they can be item, production-batch, or model specific. A further potential limitation might be the access to the data of the DPP database, which will be required for policy makers but also for consultants as well as researchers supporting the policy making process. Here again, the degree of specificity of the data will be a critical point. Depending on the purpose of the evaluation, a range going from single product to product group specific data might be useful for the analysis. Data available on the item level will allow for policy makers to generate precise and comprehensive analyses reflecting the whole market. Data collected on model level will only provide useful information regarding the range of products put on the market without any link to the market volume, as already the case with EPREL.

In any case, due to the amount of data and the market volume for a product group, it is likely, that a DPP database alone will not be sufficient for the need of evaluation experts. The database will have to allow the search of specific data and to deliver processed data / aggregated figures such as average size or nominal power of the product. Considering the example of household washing machines as standard appliance: the EU-28 market volume accounted for around 15 million appliances in 2015 and is expected to increase to 16.3 million by 2030 (Boyano Larriba et al. 2017). Assuming this product group will be covered by a DPP and some of the information in the DPP database will be item specific, it becomes obvious that the data of the DPP database may not be simply processed in a standard office software environment. Accordingly, some basic functionality for data analysis for the purpose of policy analysis might be advisable to benefit of the potential offered by the DPP.

Furthermore, the DPP will be one of the main features of the proposed Ecodesign for Sustainable Products Regulation (ESPR). According to the proposal (Article 8), all regulated product groups will have a DPP so that after the Batteries Regulation, the ESPR would be the main regulation including a DPP for energy related products. In addition to this, the proposal addresses some of the aforementioned limitations of EPREL, in particular Art. 8. §2 mentions that the requirements in the delegated acts will specify the level of granularity, as the PP can correspond to the model, batch, or item level (Art. 8. §2 (d)). The range of data and actors involved in using and entering data is by far extended in the ESPR compared to the Energy Labelling Regulation, as for the DPP, "the actors that may introduce or update the information in the PP, including where needed the creation of a new PP, and what information they may introduce or update, including manufacturers, repairers, maintenance professionals, remanufacturers, recyclers, competent national authorities, and the Commission, or any organisation acting on their behalf" (Art. 8. §2 (g)). Finally, the proposal states, that "actors along the value chain, in particular consumers, economic operators and competent national authorities, can access product information relevant to them". In terms of "general requirements for the product passport", Art. 9 specifies that "all information included in the PP shall be based on open, standards, developed with an inter-operable format and shall be machine-readable, structured, and searchable" (Art. 9 (d)). This is a significant improvement compared to EPREL, for which similar requirements were limited to information to be gathered in the public part of the database. Thus, Article 9 foresees meaningful requirements but is still focussing on data related to individual products. As a result, there is no guarantee, that the data will be computable/processable to allow an analysis on the whole market and this might be the main limitation of the DPP as foreseen in the ESPR. Even if data can be technically updated along the product lifetime, it is expected that most of them will be provided before a product is placed on the market. Product specific data reflecting the use phase or the end of life will be more challenging to gather and update. In addition, the ESPR includes a very interesting and innovative feature,

which will require economic operators to remotely collect in-use data (energy consumption and other relevant performance parameters) and report it to the Commission (see Art. 4).

Finally, the Commission will require "manufacturers, their authorised representatives or importers to make available to the Commission information on the quantities of a product covered by those delegated acts placed on the market or put into service" (see Article 4 (b)). Through this article, basic statistics regarding the in-use phase will be available even for products, where the DPP will not be item-specific.

Discussion and recommendations

Since the concept of a DPP remains relatively recent, despite all the existing preliminary work, there are still further aspects that need to be clarified and to be addressed through additional research activities. The first challenge will be the selection of a priority list of product groups, which are particularly suitable for the introduction of a PP system. Also the question of which criteria and exact data requirements should be taken up by a DPP needs to be assessed more in detail. Even if the DPP data requirements will be product groups specific, it is recommended to define a set of common information to be gathered in order to have some harmonised impacts to be evaluable. Furthermore, the required information will depend on the information needs of various groups of stakeholders (Berger et al. 2021). Therefore, a detailed stakeholder analysis could be advisable at the beginning of further research activities to determine the respective information needs (also for later evaluations) and acceptance factors more precisely. Accordingly, as it will take time for implementing DPPs and, thus, the applicability for evaluation purpose will remain limited as long as DPPs not yet contain respective product-specific data.

To create a reliable basis for evaluations, it must be ensured that with the DPP there is a digital "single point of truth" where specific product information is digitally stored and can be accessed. The regulatory framework will have to make sure, that the access to the digital product information as well as the actuality of the data must be guaranteed until the end of the product's life and beyond until disposal. Events such as possible company sales, insolvencies, etc. must not have a negative influence on this. All groups of stakeholders with a legitimate claim to view the digital product data (e.g., manufacturers, retailers, owners, consumers, recycling/disposal companies, market surveillance authorities and evaluators) must be granted correspondingly access rights. These rights to relevant data should be based on the respective data protection requirements.

To cover all phases of a product's life cycle, a transparent value chain is essential. Companies have a substantial influence on the environmental impact of products through their purchasing decisions, among other things. However, comprehensive knowledge about the structure of the upstream supply chains and sustainability aspects is still needed. In practice, the main challenge so far is the lack of data transparency, especially beyond the directly upstream suppliers. Information on production characteristics or the origin of raw materials beyond the first or second upstream stage of the supply chain is therefore often not (yet) available to companies. Due to the lack of corresponding data, transparency gaps in the supply chain of companies often have to be closed, e.g., through simplified input-output models or through personnel-intensive direct individual enquiries with suppliers. For this reason, supply chain analyses of many companies are often based on secondary data such as industry averages (e.g., on emission factors), purchasing quantities and other supplementary estimates, which only allow realistic technology assessments or procurement decisions to a very limited extent. Regarding the carbon and environmental footprint, the elaboration of Product Environmental Footprint Category Rules (PEFCR) are a great support for all manufacturers, as they harmonize the approach (incl. data and data quality) to carry out a Life Cycle Analysis for a specific product group (European Commission 2018).

Thus, also for this application, DPPs could be highly valuable tools. In terms of product policies, the paper focused on Ecodesign and Energy Labelling implementing regulations as well as on the Batteries Regulation and the forthcoming ESPR. However, when a DPP will be mandatory for a product group, the possibilities for the evaluation of further policies instruments will be impacted as data availability will be improved. On the EU level, voluntary endorsement labelling schemes, such as the Ecolabel (European Commission 2020b) and public

procurements, such as the Green Public Procurement (European Commission 2019b) should be mentioned. Hence, not only EU policies but also national policies might benefit of the introduction of DPP for ex-post and ex-ante evaluations. Under national policies, apart from the types of instruments mentioned above, approach to promote the best products (like the German Blue Angel Label or incentive programs to invest in more sustainable technologies or to replace outdated one) could also benefit from the implementation of a DPP.

Conclusions

This paper covers the potential to improve evaluations of product-oriented energy/environmental policies by the future DPP. In the current context - especially with regard to the Ecodesign and Energy Labelling framework - the possibility for ex-ante and ex-post evaluations of products policies is rather limited. A core reason for this is the often inadequate and fragmented data basis, when elaborating and reviewing product policies, the EPREL database hasn't improved significantly the situation. At the same time, policies on the environmental performance of products become increasingly elaborated and complex: they seek to cover all stages of the life cycle of products as well as many impact categories. The EU has recognized this major informational barrier and decided to address it with an innovative solution: the DPP. The concept has now been developed and is being tested within the Batteries Regulation. This will enable a continuous monitoring of products and a reliable evaluation of the impact of product policies over the entire life cycle of batteries. Thus, the DPP makes it possible to record all relevant parameters of the life cycle for the first time and is also able to provide a reliable database for future adjustments of product policies. With the proposal of the Ecodesign for Sustainable Products Regulation, the EU aims to generalize this innovative approach, as the DPP will be the norm for any products regulated under the ESPR framework.

Although the DPP offers many advantages, it will require a certain amount of time and effort to collect the necessary data for the evaluation of several products over their entire life cycle. Nevertheless, it can also provide important initial information about the supply chain of a product. Furthermore, it should be noted that the DPP itself only acts as an information carrier enabling the collection of data necessary for an evaluation. Their operationalisation and analysis within the framework of an evaluation is therefore bound to a digital information exchange system. Such a system should therefore also allow user-friendly data exchange and access.

In summary, it can be said that the DPP in its early stages might only provide limited added value. However, with time and increasing information content, it has a very high potential and offers the possibility to bring the monitoring of products, product groups as well as the impact of regulations to a more transparent and data-based level and thus significantly increase the quality of the policy and evaluation cycle. Finally, the technical challenges to set up and implement such a complex IT system should not be underestimated. With regard to transparency, verifiability, data disclosure or the guarantee of long-term availability and safety requirements, there is a need to clarify the responsibilities and applicable standards for different target groups.

DPP might raise huge expectations for all actors, including those involved in policy evaluations as it has the potential to improve a lot the way to access to a large set of product specific data. However, the DPP will need to demonstrate in practice what it can deliver.

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Annex I

The following core indicators of performance are particularly relevant to monitor the implementation of the ESPR and its impacts (European Commission 2022):

- In terms of improved products environmental sustainability and access to sustainability information along the supply chain:
  (1) Number of product groups covered by delegated acts pursuant to Article 5
  (2) Estimated change in pollutants and Greenhouse Gas (GHG) emissions (including via removals) from the manufacturing value chains supplying regulated products to the EU Internal Market
  (3) Estimated change in energy use and efficiency and water use and efficiency of relevant regulated products placed or put in service in the EU Internal market; resource productivity (material efficiency)
  (4) Average life duration of relevant regulated products as a consequence of (a) its intrinsic durability, (b) the maintenance, repair and upgrade operations it was subject to, and (c) the number of its successive users
  (5) Contribution of post-consumer recycled materials to raw materials demand of the Internal Market - for non-precious metals, Critical Raw Materials, and plastics.
  (6) Circular material use rate - Share of material demand satisfied by secondary raw materials (% of total material use)

- In terms of incentives to more sustainable products and business models
  - Value added and its components by activity
  - Green public procurement - the share of public procurement procedures above the EU thresholds (in number and value) that include environmental elements
  - Impact on consumers due to change in cost of products and change in value from their use
  - Gross investment in tangible goods", "Number of persons employed" and "Value added at factor costs" in the recycling sector and repair and re-use sector.

- In terms of improved application of sustainable product legislative framework
  - Types of requirements set including digital product passport established
  - Rate of non-compliance with requirements set for products covered by delegated acts

Annex II

ESPR Article 5 §1 (Ecodesign requirements) (European Commission 2022):

The Commission shall, as appropriate to the relevant product groups and with due consideration for all stages of their life cycle, establish ecodesign requirements to improve the following product aspects:
(a) durability;
(b) reliability;
(c) reusability;
(d) upgradability;
(e) reparability;
(f) possibility of maintenance and refurbishment;
(g) presence of substances of concern;