A standards-based knowledge system for the circular economy

The business case and the challenge for the circular economy

All products are designed, manufactured and sold under market constraints that evolve over time. Today, consumers are increasingly mindful of ethical considerations and the use of recycled materials and a low environmental impact are now selling points.

Providing data to business partners and consumers about these aspects of a product is both essential and challenging. Information systems are needed, for example, to support decision-making in low energy production techniques and efficient transport options, balanced by the resilience of the product and the ease and recoverable percentage of the materials at the end of its life.

It's clear that data is necessary to realize the circular economy. But data is not sufficient. We are drowning in data but starved for knowledge. We need a system that can give us *usable knowledge* during the entire lifecycle of a product.

A standards-based solution

Two communities are willing to join forces. The business and supply chain community on the one hand, and the data exchange and engineering community on the other. These communities choose to create industry standards at GS1 and W3C respectively. Both organizations welcome the opportunity to share their ideas regarding how to meet the EU Data Strategy and Circular Economy Plan.

W3C's standards underpin the World Wide Web - the basis of all data exchange today. GS1's identifiers, the best known of which is the ubiquitous barcode that causes beeps at the checkout, underpin a suite of standards used by industries around the world. Sectors include retail & supply chains, transport & logistics, healthcare and more.

The ultimate vision is simply stated: a product carries a barcode or a QR code that is an entry point for information that is usable by business partners, consumers and regulators.

The details are more complex. Data will come from multiple sources at different stages in the manufacturing process and be subject to differing access control regimes. Integrating that data into useful information can only be achieved if it is linked together and provided using standardized terms.

The goal of this effort is to provide interoperability for an information system accompanying the flow of goods and materials in the circular economy. This information system will create usable information about products and their instances, and will help to store information about it. This will enable information exchange needed from product design through to the last step of dismantling the item and the reuse of its components.

This suggestion integrates well with current cutting edge systems and also aligns well with other Commission policies and initiatives like the Core Vocabularies[1]. But it is far from being a done deal. Many of the existing systems can be reused, but must be considerably enhanced to serve the circular economy. Implementation guidelines, the development of vocabularies, taxonomies and ontologies is the necessary first step.

Working with their respective communities, W3C and GS1 foresee tangible business benefits and important steps towards a truly circular economy, Such efforts are likely to reveal new obstacles and research topics on the road to meeting the challenges.

Full lifecycle usage scenario

Let's imagine Mary visiting her hardware store to buy an electric screwdriver. She points her mobile to the QR codes of several screwdrivers. An App automatically retrieves the machine readable information behind the URI encoded in the QR code and compares the scanned screwdrivers. Energy consumption, ratings of other consumers, how much of it can be recycled and also whether there are toxic materials inside. Mary is now able to make her choice based on the information she needed.

For the chosen model, the engineering is done in Germany, the design in Italy and the manufacturing plant is in Spain. The engineers needed to select materials to build the screwdriver. The choices for the housing were aluminium or acrylonitrile. For the insulation of the electrical engine, the Italian designer had an audacious idea about a new hand-friendly form. But could the

[1] https://joinup.ec.europa.eu/solution/e-government-core-vocabularies

materials suggested provide that form without breaking? A lot of communication was needed to balance benefits and tradeoffs. Finally, engineers went to Spain with their compromise to hear that this is incredibly difficult and energy consuming to produce. But they manage with solar energy.

Mary leaves the shop with her electric screwdriver.

More than a year later, while charging her screwdriver, a lightning strike impacts the electricity system and kills the charging station. Mary takes her mobile, scans the QR-code on the screwdriver and adds this information to the product profile. As the charging stations changed over time, there is no way to charge the screwdriver anymore. The batteries are mostly worn out. Mary decides to bring the screwdriver to the collection station. Instead of throwing it into a pallet cage, the ward at the station scans the QR code. The product sheet includes the information that the charging station is destroyed by lightning, that the batteries are worn out and that the rest of the screwdriver is quite OK. He throws the charger into a pure material recycling cage and the screwdriver into a cage to dismantle and recover components.
The recycling cage is brought to a recovery plant. At the entrance, the QR code of the screwdriver is scanned and the product information sheet is loaded. The machine readable information from the sheet allows the operator to automatically discover the correct dismantling and recovery production sheet. This contains sufficiently detailed data to instruct a robot to separate the engine from the aluminium housing. The production of that housing consumed more energy than the acrylonitrile alternative, but the wealth of solar energy in Spain compensated for that. At the same time, recycling the housing is easy. The engine and the bearings are not worn out. They are recovered and can be refurbished to serve in a new screwdriver. To test them, the current performance is compared to the performance in the machine readable product sheet.

This full lifecycle usage scenario has many points where data is created, stored, changed and exchanged by different parties. The QR code, that contains GS1 identifiers expressed as a URL following the GS1 Digital Link standard, acts as a single entry point for multiple data sources.

The more Europe deploys efforts to become a data economy, the clearer it becomes that usable data is needed to achieve many goals set in policy. This is as true for the circular economy as for other policies. The more we know about the combination of materials when designing a product, the more we will be able to use only combinations that can be recycled. In the example above, the Italian designer was able to use the detailed data about different materials to make the choice of housing.

Conscious decision making is a first step towards the circular economy. And conscious decision making needs knowledge. There is too much data for humans to process directly, so to make it usable, we need knowledge representation, and to have the right knowledge at the right time at the right place for the right people.

Our proposal with this paper is to make the information that is already available from trusted sources (like manufacturers) usable through standardized processes and open standards.

A data strategy to build usable knowledge

As we are in the launch phase of designing the information system around the circular economy, we can still make choices about architectures, choosing whether to use a centralized or decentralized system and how to make the transition towards a circular economy model.

Given the context of the large variety of products in our complex economy, we must expect a high variety in data streams. To be able to combine those, we need to use formats and agreed terminologies that allow us to merge a variety of data streams. Data flows need to be organized to add facts to a *knowledge graph* or to feed data streams into a deep learning system. We need open identifiers for objects and data about their constituents in order for IT to help us in the decision making either by machine reasoning or by the provision of pertinent and usable information.

What we suggest here is to accompany the creation of circular product life cycles with data capable of helping with the management of information and products participating in that life cycle. Real world circular workflows need to be accompanied by an information workflow that reflects the decisions taken, that is capable of demonstrating compliance with relevant procedures, and that augments our knowledge by recording relevant events. Such a system is also capable of supporting ad-hoc collaboration via smart contracts very easily. Just like any other data, legal or contractual information in machine readable form can be added as annotations and secured with techniques like blockchain. This means our suggestion may align well with the European Commission's policies beyond the circular economy, which makes it a realistic proposal for a step by step development.

IT systems often represent significant investment so it is important to maximize the reuse of existing systems and adopt a simple to implement approach that does *not* require substantial re-engineering. We need to take advantage of existing information and data flows. We need to log the context of data as it flows through our current systems. This lowers the barrier towards a more complete information twin helping to make the current systems circular. A precondition for the reuse to be affordable is the use of open and global standards for product identification, for data capture and sharing, and the use of common standards of knowledge representation to build up a smart system that will be distributed and resilient.

To do so, we need to take advantage of the advances in knowledge representation and combine it with the advanced digitization of the retail industry and the industry at large. This is the approach used in Industry 4.0 and Industrial Data Spaces.

Help Transition and Resilience with Open Standards

W3C is the standards development organization for the World Wide Web, not just a web of documents but a web of data. It has a well-developed suite of standards for knowledge representation and Linked Data that can provide central properties to an information system for the circular economy. GS1 standards have supported 25 different sectors like retail, healthcare, transport and logistics, the construction industry and more since 1974. During that time the digital revolution has had profound impacts on the way business is run and the expectations that consumers have. The GS1 Digital Link standard is part of that (r)evolution as it allows for the barcoded item to be connected not just to the individual computer to which the scanner is attached, but, via the Web to all relevant information about the item, wherever it may be[2]. And this connects the world of retail to the web of data and knowledge representation in a standard way. We believe that the combination of open standards and vocabularies are crucial building blocks for an information and knowledge system for the circular economy.

Open standards like GS1 Digital Link and those that underpin Linked Data provide industry-recognized methods to connect an item to information. It has the potential to play a significant part in the green economy as it allows the reuse of data that owners have already published about its constituent materials, its carbon footprint, its recycling options and whatever information or data the regulators, consumers or business partners need to receive. But it still allows manufacturers and retailers to remain in control of the information source, which is important for smooth implementation, minimized disruption along the chain, security and acceptance in the marketplace.

The role of GS1 open Standards

GS1 open standards have been developed by industry for industry in order to solve common challenges that involve global complex supply chains[3]. According to the EU Circular Economy Plan[4] the EU goals and the scale to be reached will involve entire sectors and the whole business model. In *Circular Data for a Circular Economy*[5] GS1 Europe introduces the potential roles of its open standards to support industry's efforts towards the circular economy transition.

GS1 supports using a common language (common semantics, ontologies, taxonomies) in order to obtain the level of efficiency and interoperability needed by the circular economy concept. Central to this is product identification and it's the GS1 GTIN[6] - the Global Trade Identification Number - that is the most commonly used product identifier in the world (beep!).

[2] https://www.gs1.org/standards/gs1-digital-link
[3] https://www.gs1.org/standards
[4] https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1583933814386&uri=COM:2020:98:FIN
[5] https://www.gs1.eu/news/circular-data-for-a-circular-economy
[6] https://www.gs1.org/standards/id-keys/gtin

Starting from the GTIN, included in the product's barcode and supported by a global data model based on data attributes agreed by industry to meet the circular economy plan, this is how the data set could be supported:

- GS1 identifiers, like the GTIN, which can be extended by batch/lot and serial numbers, can be expressed as a URL.
- Via a resolver service[7], that URL can link to any number of online resources via a 'virtual menu', just like the menu on a regular website. The links, as well as the information they point to, can be updated at any time without having to relabel the identified item.
- Multiple resolver services enable a decentralized system.
- The underlying technologies are mature and well-proven, including the GS1 identifier system, scanning technologies (including consumer scans in mobile devices), Linked Data and the Web itself. The GS1 Digital Link standard makes many normative references to standards published by W3C, IETF and ISO.

It's worth reemphasizing that there is *no requirement* to use GS1's resolver service. Indeed, there is no requirement to use any resolver service if the barcode is to link to a single destination. It's only when one URL needs to link to multiple resources that a resolver service is necessary, acting as a route map to the requested or desired information.

The role of Linked Data

The Semantic Web is a Web of Data — of dates and titles and part numbers and chemical properties and any other data one might conceive of. The collection of W3C Semantic Web technologies (RDF, OWL, SKOS, SPARQL, etc.) provides an environment where applications can query that data, draw inferences using vocabularies, etc. With Linked Data, we can create knowledge graphs and organize contextual information. The combination of this knowledge representation technology and its declarative logic work with barcodes and product registration via the GS1 Digital Link Standard which is firmly based on W3C's Linked Data principles[8].

Linked Data allows the merging of data streams even in presence of a strong variety of information. It allows us to represent knowledge about steps in a circular procedure, and attach properties of product components. In short, Linked Data allows us to annotate the information streams of the circular economy, reason over it and draw conclusions for the subsequent processing of goods and information. This in turn allows for easy compliance logging and testing. The system can be used by other machines or can feed into a dashboard serving as a user interface for control and manual intervention[9].

[7] Anyone can run a conformant resolver service, there is no single point of failure or a requirement to use GS1's own services. The royalty-free, open standard is supported by a wealth of free, open source code.
[8] https://www.w3.org/DesignIssues/LinkedData
[9] The SPECIAL project has produced a proof of concept of this approach with industrial applications, here in the area of data protection https://specialprivacy.eu/

Standardized vocabularies are essential

For the collection station or the recovery plant to understand the product sheet mentioned in the full lifecycle example, the producer, retailer and recovery stakeholders in the circular economy need to understand the terms they use. They do not necessarily need to use a single list of terms, but they need to make those terms machine readable using standardized formats for taxonomies and ontologies. This is not a trivial process. The Linked Data vision depends on data being provided not just using the syntactic standards like HTTP URIs and RDF or XML, but on data being encoded using standard terms and code lists. Once the terms and semantics are formalized this way we can, for example, express that term A in the taxonomy of the producer is the same as the term Y in the ontology of the recovery firm. This allows for distributed development and use of such vocabularies, it allows us to be close to the ground and worry about misunderstandings later. "A battery ontology will facilitate the work of battery experts in different fields to convert real-life observations to a common digital representation", writes the BATTERY 2030+ Roadmap[10], a good example of what is at stake.

Many vocabularies already exist of varying quality, stability and adoption. It is noteworthy that, following a fully documented change-management process, GS1 publishes its own Web Vocabulary[11] that extends the massively adopted schema.org vocabulary using terms recognized by the retail and supply chain industries. It's not a perfect fit as the GS1 terms are defined to support manufacturer to retailer communications whereas schema.org, and therefore the GS1 Web Vocabulary, is designed for retailer to consumer communications. Mappings to other taxonomies are, however, usually straightforward.

GS1's internal B2B data systems include some terms relevant to the green economy and these can be added to the GS1 Web vocabulary, but it's likely that additional terms will need to be defined. For example, there is currently no widely recognized machine readable vocabulary for describing an item's carbon footprint, or environmental footprint, or recycling/safe disposal options. W3C has knowhow about bringing the community together for the development of the missing vocabularies. It is well-placed to facilitate the development of those additional terms.

Schema.org, the GS1 Web vocabulary, the W3C provenance Ontology and more already exist and are likely to be useful and important in future work. The Provenance Ontology, for example, allows the creation of machine readable assertions about the origin of an item, but it is a very generic vocabulary and would need a specific profile for the circular economy. Furthermore, no organization has widely used vocabularies for materials used in products yet. Neither do we yet have ontologies and knowledge graphs for contextualizing the combination of materials, or even a way to discover those vocabularies and ontologies automatically when we need them. This means we need to think beyond just encoding the available information, we also need to think about how to enrich it by adding new information to the existing information in interoperable ways. By using Linked Data, the standardized platform already allows to combine insights from a large

[10] https://battery2030.eu/digitalAssets/816/c_816048-l_1-k_roadmap-27-march.pdf
[11] https://www.gs1.org/voc/

variety of sources and to reason on amounts of data that go beyond the possibilities of human cognition.

A step-by-step approach would start small:

1. Finding useful vocabularies and reuse them in the context of the circular economy.
2. Make the vocabularies discoverable (CTAN[12] and LOV[13] have shown a way to do that).
3. Work with the widest possible community to develop missing vocabularies (and make them reusable by all).
4. Process the most important vocabularies through a standardisation process.
5. Make it easy for manufacturers to publish information about recycling or other environmental friendly properties and make them discoverable and available from the barcode or otherwise..
6. Encourage persistence of barcodes on products in addition to the packaging so that the data can be available for any usage also by consumers.
7. Allow producers of tangible goods to provide information in an interoperable and machine readable format

Conclusion and ask

A possible contribution of the IT standardization represented in the Multistakeholder Platform for Standardization of the European Commission is to provide interoperability for an information system accompanying the flow of goods and materials in the circular economy. This information system will create usable information about products and their instances, and will help to store information about it. This will enable information exchange needed from product design through to the last step of dismantling the item and the reuse of its components.

This suggestion integrates well with current cutting edge systems and also aligns well with other Commission policies and initiatives like the Core Vocabularies[14]. But it is far from being a done deal. Many of the existing systems can be reused, but must be considerably enhanced to serve the circular economy. Implementation guidelines, the development of vocabularies, taxonomies and ontologies is the necessary first step.

W3C and GS1 are ready to fully describe this project, open to include other partners and eager to receive comments. We are conscious that implementation guidelines, the development of vocabularies, taxonomies and ontologies can only be achieved with the contribution of many different parties and ideally under the auspices of the European Commission.

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[12] https://www.ctan.org/ctan
[13] https://lov.linkeddata.es/
[14] https://joinup.ec.europa.eu/solution/e-government-core-vocabularies

Annex 1: About W3C

The W3C mission is to lead the World Wide Web to its full potential by developing protocols and guidelines that ensure the long-term growth of the Web. Below we discuss important aspects of this mission, all of which further W3C's vision of **One Web**.

Open Standards Principles

On 29 August 2012 five leading global organizations jointly signed an agreement to affirm and adhere to a set of Principles in support of The Modern Paradigm for Standards; an open and collectively empowering model that will help radically improve the way people around the world develop new technologies and innovate for humanity. Learn more about OpenStand: the modern paradigm for standards.

Design Principles

The following design principles guide W3C's work.

Web for All

The social value of the Web is that it enables human communication, commerce, and opportunities to share knowledge. One of W3C's primary goals is to make these benefits available to all people, whatever their hardware, software, network infrastructure, native language, culture, geographical location, or physical or mental ability. Learn more about:

- Web Accessibility Initiative
- Internationalization

Web on Everything

The number of different kinds of devices that can access the Web has grown immensely. Mobile phones, smart phones, personal digital assistants, interactive television systems, voice response systems, kiosks and even certain domestic appliances can all access the Web. Learn more about:

- Web of Devices
- Mobile Web Initiative
- Browsers and Other Agents

Vision

W3C's vision for the Web involves participation, sharing knowledge, and thereby building trust on a global scale.

Web for Rich Interaction

The Web was invented as a communications tool intended to allow anyone, anywhere to share information. For many years, the Web was a "read-only" tool for many. Blogs and wikis brought more authors to the Web, and social networking emerged from the flourishing market for content and personalized Web experiences. W3C standards have supported this evolution thanks to strong architecture and design principles. Learn more about:

- Web Design and Applications
- Web Architecture

Web of Data and Services

Some people view the Web as a giant repository of linked data while others as a giant set of services that exchange messages. The two views are complementary, and which to use often depends on the application. Learn more about:

- Essential XML Technologies
- Semantic Web
- Web of Services

Web of Trust

The Web has transformed the way we communicate with each other. In doing so, it has also modified the nature of our social relationships. People now "meet on the Web" and carry out commercial and personal relationships, in some cases without ever meeting in person. W3C recognizes that trust is a social phenomenon, but technology design can foster trust and confidence. As more activity moves on-line, it will become even more important to support complex interactions among parties around the globe. Learn more about:

- Semantic Web
- XML Security, Web of Services Security
- Privacy

Annex 2: About GS1 in Europe

GS1 in Europe is a neutral, not-for-profit organisation dedicated to the implementation of global standards to improve the efficiency, visibility and sustainability of products all around the world.

We represent more than 400.000 in Europe. In a collaborative way, together with our 49 GS1 Members Organisations we bring these companies around the table and foster collaboration in order to establish common rules and common standards.

We strive to empower businesses to improve their **efficiency**, **safety**, **security** and **sustainability**.

For more information about us, our governance and our main projects, please visit **www.gs1.eu**

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