Teaching Resources on the Sustainable Management of Critical Raw Materials

Trainer's Manual for
Sustainable Materials Usage

March 2020

This activity has received funding from the European Institute of Innovation and Technology (EIT), a body of the European Union, under the Horizon 2020, the EU Framework Programme for Research and Innovation

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SusCritMat

1 Context and Introduction to Training

This booklet is supplementing the teaching materials and the set of further supporting booklets that have been developed to support teachers in conducting training courses related to the sustainable management of critical raw materials.

SusCritMat aims to educate people from Master's student level up, both in industry and academia about important aspects of sustainable critical raw materials. In a novel concept, it introduces courses on these complex and interdisciplinary topics in a modular structure, adaptable to a variety of different formats and accessible to both students and managers in industry. These courses will develop new skills, which will help participants to better understand the impact and role of critical raw materials in the whole value chain; enabling them to identify and mitigate risks. Understanding the bigger picture and the interconnected nature of global business and society is increasingly necessary to and valued by industry.

SusCritMat is an EU-funded project that brings together the technical and pedagogical expertise of leading educational institutions and business partners. It uses and creates teaching materials which can be combined into different course formats.

The collection of training manuals presents the key messages related with the sustainable management of critical raw materials in three major sections:

- Introduction to criticality
- Analysis of criticality
- Solutions for sustainable management

In particular, the solutions part will be in the focus. The intention is to underline the possibilities that are available to approach and implement a circular economy for critical raw materials and the products bearing these. Doing so the concrete actions, i.e. the things that can be done, are highlighted, instead of only mentioning all sorts of associated problems or barriers in the context of CRMs.

The overall goal of the SusCritMat project is to qualify lecturers to teach the topics themselves. Therefore, the teaching resources do not only provide an introduction and improved insight into selected thematic issues, but also deliver a set of teaching materials "ready-to-use".

- Learning targets that will be reached after having taught the courses
- Presentations on the specific topics including also notes on how to present the slides and key messages.
- Group work exercises including the task or question to work on, if applicable further reading on the methodology and the solutions in case of tasks requiring calculations.
- Assessment questions and the correct answers for each specific topic.
- Additional reading for each topic.

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1.1 Training Materials List

The *SusCritMat project* developed the following teaching materials:

Basics
Critical Resources for Emerging Technologies
Criticality
Supply Chain Resilience
Supply Risk Factors
Circularity
Circular Economy
Characterizing the Urban Mine
Circular Business Models
Waste Management and Recycling Potential
Closing Loops on Product Level
Governance
Geopolitical Aspects
Metals & CRM Scenarios
Restricted Substances Legislation
Impact on Society and the Environment
Sustainability Assessment
Responsible Mining
Responsible Sourcing / Certification
Environmental Aspects
Sustainable Materials Usage
CRM and Sustainable Development
Tools
MFA - Material Flow Management
Simulation-based Design for Recycling (DfR)
Good Use of Data
LCA – Life Cycle Assessment
Process Models based on LCA

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1.2 Suggested timetable

The agenda contains a recommended timing for the lecture and exercises. However, depending on the pre-existing knowledge or group size the time can be extended.

- Lecture: 45 minutes
- Exercise: 45 minutes

1.3 Key Messages

There are databases you can use for teaching materials decisions, containing information about their properties and performance. They also provide information about legislation and regulations. The example of backpanel casings of tablet devices is used to show how to find out what materials a certain product is made of. Knowing this, it is possible to use performance indices to make comparison between materials. The relevant database can also be used to look at the risks related to the life cycle of a tablet device and to assess the effects of a possible substitution on the environment.

1.4 Learning Objectives

The learners should be able to name databases such as CES EduPack to find information about certain materials, assess their performance for certain tasks, find out about their criticality and the effects of their substitution.

1.5 Additional Reading

Materials and Sustainable Development, M.F. Ashby, 2016, Elsivier, ISBN: 978-0-08-100176-9

Teaching Package: Active-learning ToolKit - Sustainable Development, M.F.Ashby and T.Vakhitova, 2017, available on-line: https://grantadesign.com/education/teachingresources/package/

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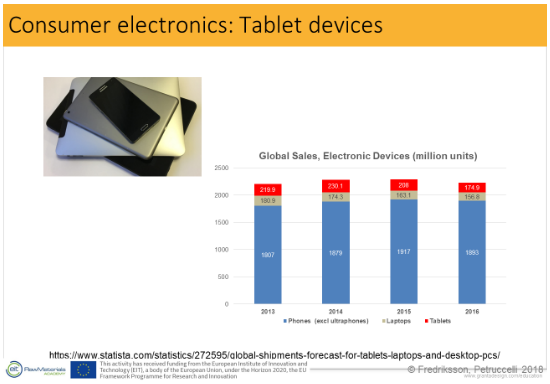
2 Slides and Notes

	
	• Around 2 billion mobile phones are sold yearly and devices such as laptops or tablets sell several hundred million units each per year so the impact of existing and future products of this kind is enormous. • There are important questions as to the sustainability of materials used in these electronic devices, such as recyclability, energy use, hazardous, restricted or critical status and resource issues. • Also, as the screens have become larger, the mechanical properties of the casing and the display glass have increased in importance

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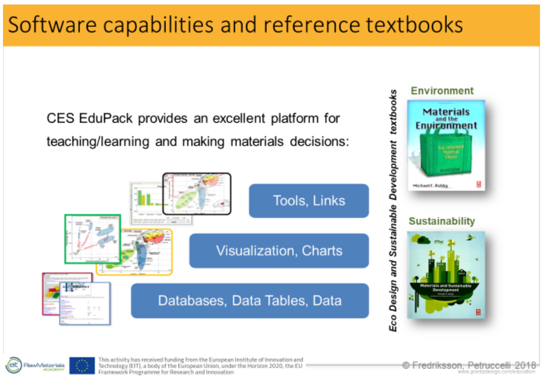

- This Case Study will be using the concepts developed by Prof Mike Ashby and co-workers here in Cambridge
- CES EduPack provides an excellent platform for teaching and discussing materials decisions
- We will show a range of features that you can use in your teaching with CES EduPack.
- There will be discussions of data on mechanical properties, criticality and eco properties
- We will benchmark material options visually using charts of their performance and assess them using the extended Eco Audit tool
- The methodologies are described in greater detail in the books of Mike Ashby, particularly the ones that you can see to the right

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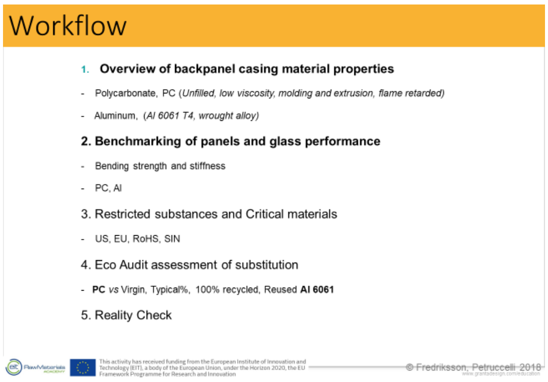
- We will be using the Sustainability database at Level 3 for this Case, which contains all the 4000 standard engineering materials of the MaterialUniverse
- This has the Enhanced Eco Audit (for life-cycle cost estimation) and data on Legislation and regulations as well as energy storage, which we will use today
- It also has convenient direct links to the Elements data-table, where you find further data on resources and criticality of the constituents



- We will now use EduPack to make an overview plot of current backpanel casing materials and show exactly how this is done
- I will benchmark the polycarbonate and the aluminium backpanels with other materials .
- When we return, Luca will discuss Restricted substances and Critical materials
- We will also compare alternatives from a life-cycle perspective using Eco Audit

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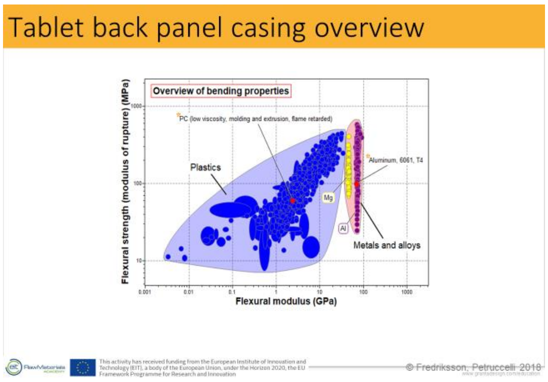

- An overview plot, including the 2 main material candidates, is shown in the chart above.
- Flexural stiffness is important in order to protect the LCD and circuit board inside the tablet, and flexural strength is needed to prevent plastic deformation.
- In the chart, thermoplastics and the light metal alloys Al and Mg are included for comparison using the custom subset feature.
- By right-clicking on the material names, the candidates can be labelled, made into favorites, their bubbles brought to front and their color can be changed to red for greater visibility.
- The chart shows that these candidates represent intermediate strength and stiffness. The Al appear stronger and stiffer than the polycarbonate. However, this is not a just way to compare materials for a lightweight tablet backplate.

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- The candidates have different densities and would have different thicknesses in this application.

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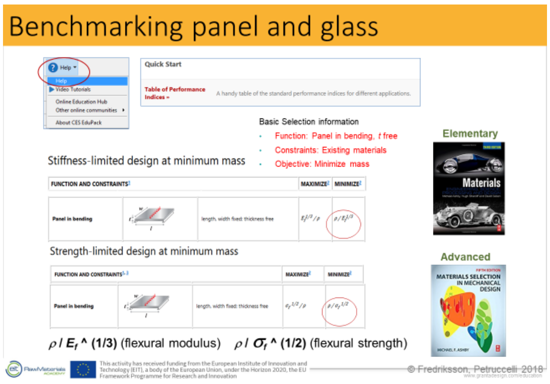

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- Although a simple chart plotting flexural strength on one axis and flexural modulus on the other will give you an overview of material properties, benchmarking needs to be done in relation to the relevant *performance index* of the specific application.
- For a panel in bending, with the objective to minimize mass, the indices will be combinations of properties, limited by strength and stiffness, respectively.
- The performance indices for both strength-limited design and stiffness-limited design of a panel in bending are shown in the next slide.

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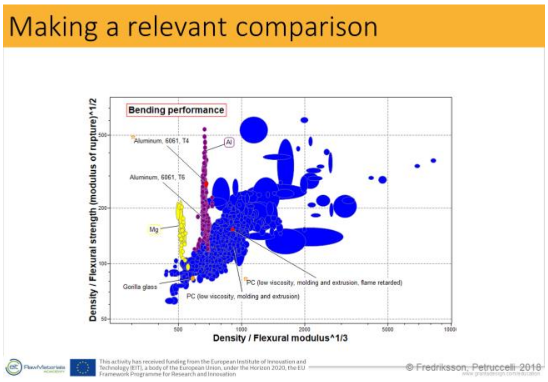
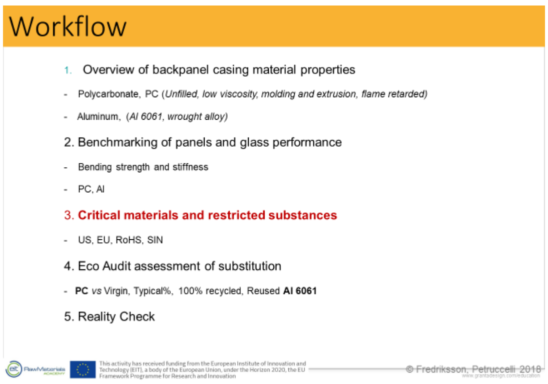


- The best way to make a fair comparison between materials is to use Performance indices
- Let's investigate mechanical performance: Flexural stiffness and Flexural strength
- This plot is at Sustainability Level 3, All bulk materials (background), Limit stage with Composition overview: Hardwoods, Composite woods (green), Then highlight plywood as a reference material
- Plywood compares relatively well with other woods and other materials



- Now, we have seen how EduPack is used to benchmark mechanical properties and performance

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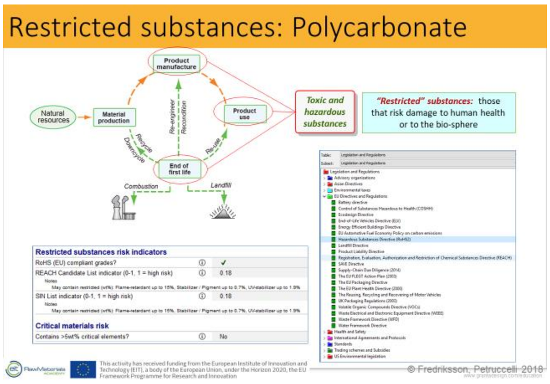

Let's have a look at the risks related to the life cycle of a product such as a tablet device. Here, we will focus on potential restricted substances related to the polycarbonate.

Restricted substances are linked to several phases of the life cycle of the product;

The compliance of the materials depends on the specific substances used in the materials. For example, a flame retarded polymer could contain Brominated flame-retardants, which are restricted.

In the sustainability database, there is a data-table on Legislation and Regulations that provides a summary of the most important materials-related legal requirements, such as the latest RoHS2 directive and REACH legislation.

In this example, Restricted substances indicators show that our polycarbonate polymer could contain a variety of restricted additives.

The significant risk value of 0.18 shows that it will be important to select a specific grade of this polymer, that is intended for electronic devices to be sold globally

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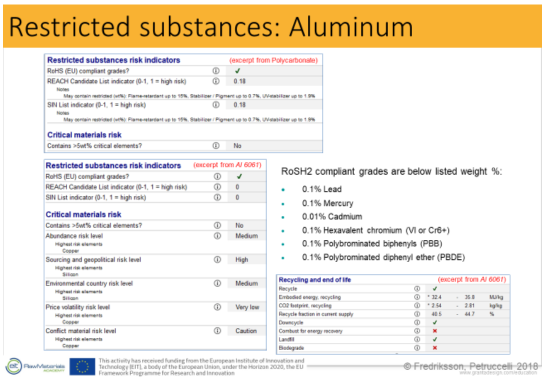

- Let's now compare with the selected grade of aluminium,
- The Al 6061 option, shown to the right, appears better from a restricted materials perspective.
- Metals and alloys that always contain restricted metals as part of their composition are not compliant, while those that *may* contain these metals as impurities (*i.e.,* not always present) are assumed to have compliant grades available. Al 6061 passes this test; risk=0
- Flame retardants are also problematic for recycling. Although flame retarded unfilled PC can theoretically be recycled, it would require a closed materials loop, since its properties are different from other grades of PC due to the additive.

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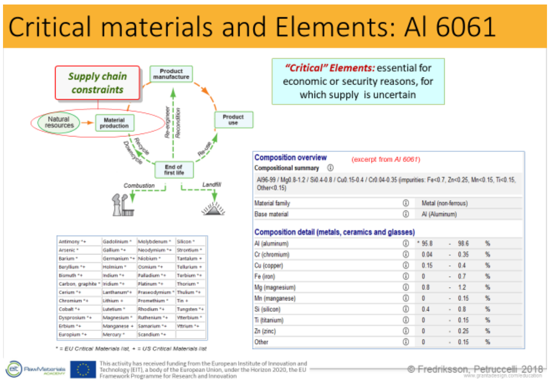

- Critical materials aspects are linked to the first phase of a product’s life-cycle
- Critical elements are not universally defined, but the concept represents an assessment of the current and future supply risk of an element and the difficulty of substituting the function they are providing;
- In CES EduPack, there is a compositional summary and composition detail for all materials at Level 3
- The EU and US have both published lists of critical elements which are included in CES EduPack. The 2017 lists is shown here (updated for 2018).
- Al 6061 does not contain significant amounts of any critical element (Cr, Si, Mn and Mg are critical, though)

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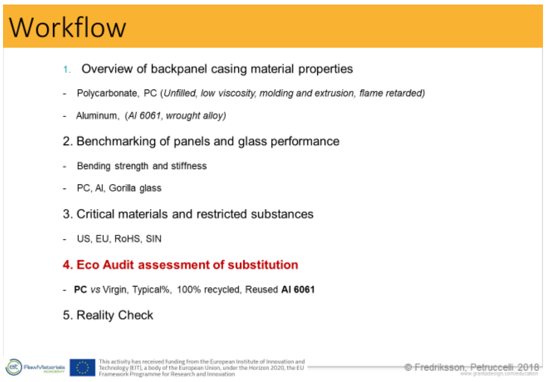
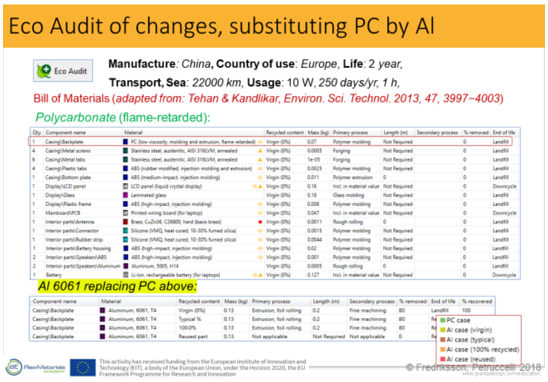


- We will now use EduPack to assess the effects of a possible substitution



- Substituting flame-retarded PC with Al 6061 in the backplate of the casing, we remove the risk of restricted substances in the material by design and improve the recyclability.
- A simplified generic BOM for a tablet with PC casing is given below. Secondary processes and material removal are neglected here.
- We have assumed *Transport* to be 22 000 km of sea freight (Shanghai to Rotterdam) for use (charging) in Europe, 10 W, 1 h, 250 days/year.
- We compare with 4 different scenarios of Al: (i) Virgin material; (ii) Typical reused fraction; (iii) 100% recycled; and (iv) reused.

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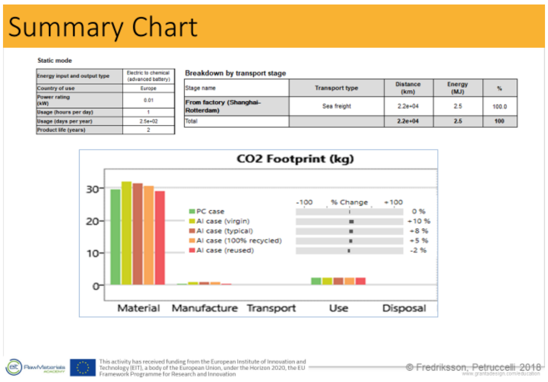
	• The color coding for the diagram is shown at the bottom
	• The Eco Audit Summary give an overview of which life phase has the largest contribution (***Material***) • We have worked with a static use phase, charging batteries 1 h every day, 250 days/year • The aluminium substitution represents a 10% increase in both energy use and CO_2 footprint, due to higher mass of the component and the machining process needed to manufacture it. Nonetheless, the higher impact of the Al casing solution can be offset by the use of recycled materials and recycling at the *End of life*. • In total, closed loop aluminium reuse results in slightly less (2%) energy use and CO_2 footprint than PC

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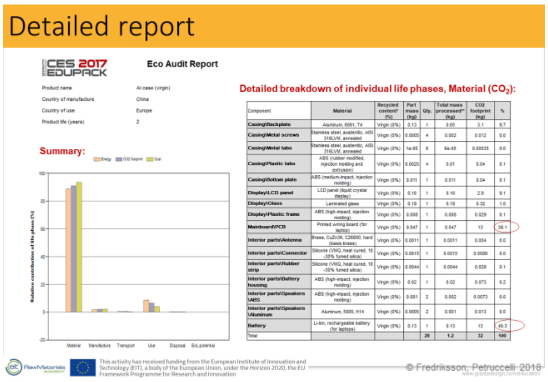
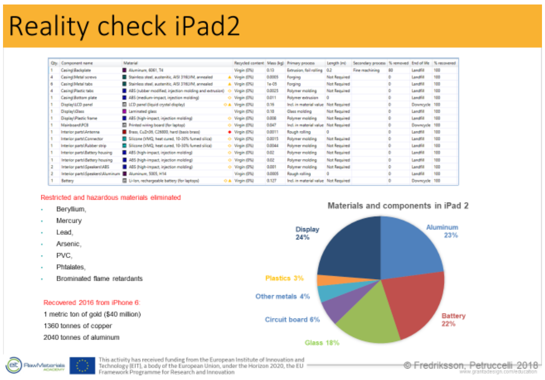


- The Eco Audits also give numerical values and additional information to work with
- We know that ***material*** is the most CO2 emitting phase of the life-cycle, so how to improve?
- The detailed Eco Audit report gives the necessary numerical data. Here the mainboard PCB and battery are both ~40%



- The Eco Audits are based on a Bill of materials for Kindles and iPad2 from the reference given before and in the Case study paper

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3 Acknowledgements and Authors

This teaching material was prepared by Benjamin Sprecher and Stefano Cucurachi, Leiden University.

The following authors have contributed to prepare the complete teaching material kit and intend to provide an overview of major topics surrounding the sustainable management of critical raw materials:

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5 Disclaimer

The teaching materials within the SusCritMat project have been prepared with great care and experienced several revisions. Nevertheless, the consortium assumes no liability for the topicality, completeness and correctness of the content provided.

In case you have suggestions or other feedback how to improve the materials, we value your opinion: Please contact us via the project webpage https://suscritmat.eu/contact/.

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