GRANTA TEACHING RESOURCES

ADVANCED INDUSTRIAL CASE STUDIES

Materials for a Tablet Device

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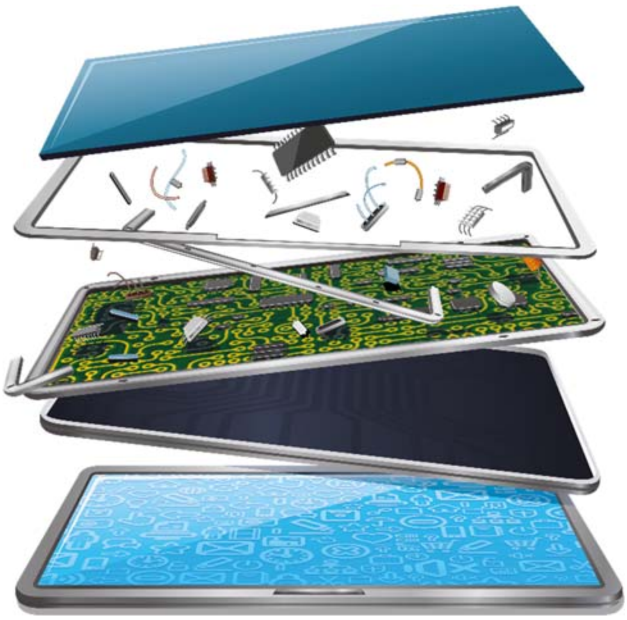

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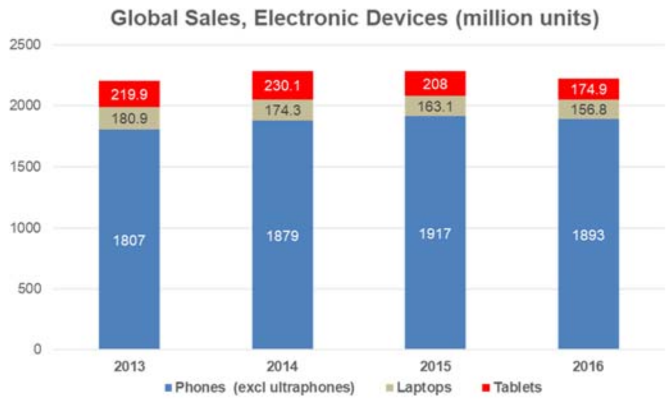
Summary

CES EduPack provides, not only, a rational and systematic approach to materials selection, but also has useful eco/sustainability data and tools for green engineering and eco design. These will be essential for the purposes of teaching and training the work force of the future. The available databases enable informed materials-related decisions in many specialized areas. In this advanced case study, we focus on materials decisions for a tablet device, in order to explore its performance.

1. What is the Scope?

Consumer electronics has a huge impact on the global economy, the environment and people's daily lives. Around 2 billion mobile phones are sold yearly [1] and devices such as laptops or tablets sell several hundred million units each per year. Although there are signs that the growth is slowing down, 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.



As mobile phones have become larger with improved screen technology and increased demands due to, *e.g.*, gaming and streaming of films, the mechanical integrity of the chassis has gained in importance. Indeed, some models have had issues with flexural (bending) strength and stiffness. Touch screens on smartphones and tablets also need to resist scratches when they are used or transported. While the circuit boards in the interior of the devices normally have sufficient fracture toughness and strength, the mechanical properties of the back plate of the casing and the glass screens are more critical and therefore need consideration.

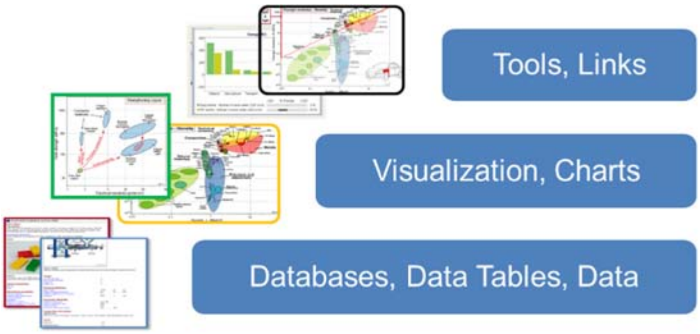
Moreover, there are a number of hazardous, restricted and critical materials in consumer electronics that should be investigated. From the flame-retardants in polymer casings and lead in the solder, to Lithium in the rechargeable batteries of the devices. These will affect the recyclability of the components and will also be subject to legislation and regulations by, for example, USA and the European Union. All of these aspects are important in a sustainability and circular economy context; in particular, to future engineers and designers.

Previous studies have found an approximately linear relationship between mass and embodied emissions for these kinds of products [2]. However, a more sophisticated linear model including display, battery, and circuit board mass, *etc.,* is slightly more accurate. Improved design and reduced material usage has already resulted in up to 50−60% lower embodied greenhouse gas emissions for newer products than older products with similar functionality, especially reductions in integrated circuit content. In this paper we have adapted/simplified the Bill-of-Materials (BOMs) for a couple of generic tablet devices. The main purpose is to compare scenarios for material decisions and show the possibilities of the software, rather than to provide accurate absolute values. The numbers are, however, realistic.

2. What Can You Do with CES EduPack?

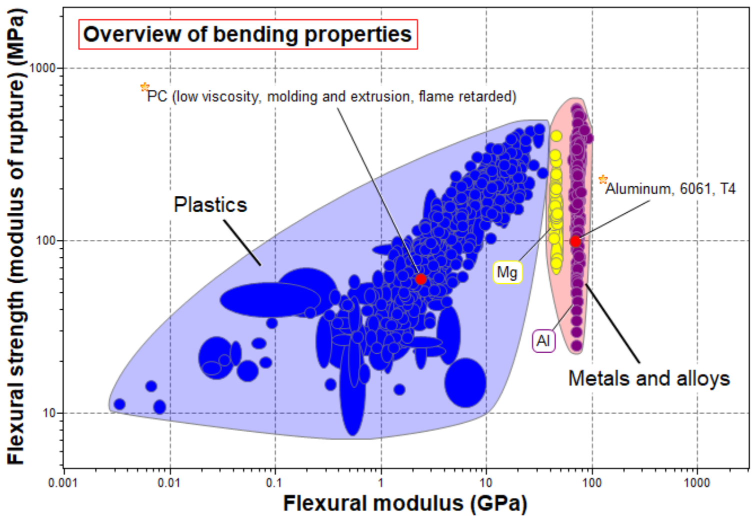
CES EduPack makes a systematic and comprehensive approach to material selection possible. This is based on the work of Professor Mike Ashby [3] and co-workers. The data and the tools that come with the software enables lightweighting and other enhancements to mechanical performance. It is also useful for benchmarking of options, for example when re-engineering products. Benchmarking can be done visually, using *property charts* that are prepared quickly with the plotting tools.

The advanced Level 3 databases provide comparable data on thousands of materials. Here, we will use *the Sustainability database*, as it contains the enhanced Eco Audit tool for assessment of life-cycle performance as well as easy access to criticality and resource data on Elements, with direct links to this data-table. There are also data-tables for energy storage as well as regulation and legislation that is helpful for the kind of study we are conducting here.



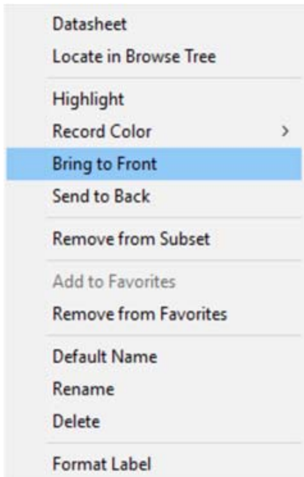
The hierarchy of features used in this tablet case study

3. Using CES EduPack to Compare and Benchmark Materials



Starting with mechanical properties, we quickly identify that for a tablet device, the relevant load case for the structural integrity will be *panel in bending*. CES EduPack can be used to compare and benchmark different material options visually in a property chart. For *the backplate casing*, two realistic and relevant design alternatives can be used as an illustrative example [2]. One *polycarbonate (PC)*, typically used for low-cost specialized reading tablets that has to be lightweight to compete with books, and one *aluminum (Al)*, which is more durable and resilient, yet relatively light.

An overview plot, including these 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. The polycarbonate is represented by the *Unfilled, low viscosity, molding and extrusion, flame retarded* grade while the aluminium is represented by the *Al 6061* alloy in the MaterialUniverse of CES EduPack, which is realistic [4]. 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. The candidates have different densities and would have different thicknesses in this application.



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 below.

If two objectives are shown together in the same chart, it is customary to plot the indices for *minimization* on the axes. The expressions for the performance indices (material indices) can be found via the *Help* function in the menu. They are inserted into the Chart stage using the *advanced* button, so the equation editor appears. We used:

σ/ ρ_f ^ (1/2)

for the Y-Axis (flexural strength) and:

ρ / E_f ^ (1/3)

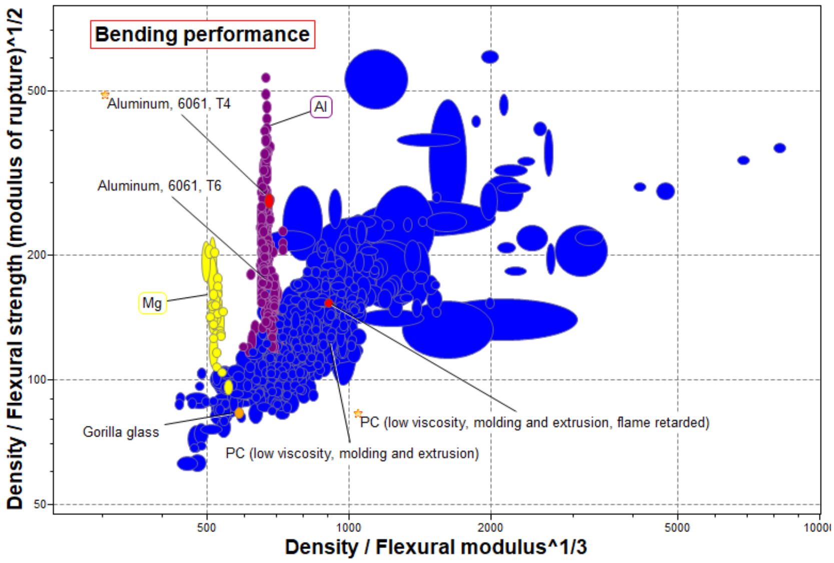
for the X-Axis (flexural modulus).

Stiffness-limited design at minimum mass

FUNCTION AND CONSTRAINTS[1]			MAXIMIZE[2]	MINIMIZE[2]
Panel in bending		length, width fixed; thickness free	$E_f^{1/3}/\rho$	$\rho/E_f^{1/3}$

Strength-limited design at minimum mass

FUNCTION AND CONSTRAINTS[1,3]			MAXIMIZE[2]	MINIMIZE[2]
Panel in bending		length, width fixed; thickness free	$\sigma_f^{1/2}/\rho$	$\rho/\sigma_f^{1/2}$



In this chart, the actual situation is clearer. Since we are minimizing the two indices, the "best" materials are those closest to the lower left corner. The Al has better performance in stiffness but PC better in strength. The situation thus represents a trade-off decision. Since we are benchmarking materials already in use, we know that both options are "good enough", in some sense. If properties need to be improved, better alternatives can be explored using this type of chart. The Al T6 and non-flame-retarded PC are examples of that.

The display glass is an interesting component both from a materials perspective and for its mechanical integrity. It was developed already in the 1960s by Corning but gained its current popularity for the specific application in smart phones and tablets. By adding a record (right-clicking) of the estimated properties of Gorilla glass into the benchmarking chart, we see that its bending performance is better than the casing materials. We have used assumed but realistic values: Density: 2420-2430 kg/m3, E_f: 75-77 GPa and σ_f: 800-895 MPa.

4. Using CES EduPack to Investigate Critical Materials and Elements

In CES EduPack, there is a compositional summary and composition detail for all materials at Level 3. In the Sustainability database, there are also direct links to the main elements that make up the material in the Elements data-table, where further information is given for each component. Critical elements are not universally defined, but the concept represents an assessment of the future supply risk of an element and the difficulty of substituting the function they are providing. That is dependent on the availability of natural resources in the country of manufacture and the specific technological application. This may vary as new reserves are found, or as political and regulatory circumstances change.

Composition overview (excerpt from *Al 6061*)

Compositional summary

Al96-99 / Mg0.8-1.2 / Si0.4-0.8 / Cu0.15-0.4 / Cr0.04-0.35 (impurities: Fe<0.7, Zn<0.25, Mn<0.15, Ti<0.15, Other<0.15)

Material family	Metal (non-ferrous)
Base material	Al (Aluminum)

Composition detail (metals, ceramics and glasses)

Al (aluminum)	* 95.8	-	98.6	%
Cr (chromium)	0.04	-	0.35	%
Cu (copper)	0.15	-	0.4	%
Fe (iron)	0	-	0.7	%
Mg (magnesium)	0.8	-	1.2	%
Mn (manganese)	0	-	0.15	%
Si (silicon)	0.4	-	0.8	%
Ti (titanium)	0	-	0.15	%
Zn (zinc)	0	-	0.25	%
Other	0	-	0.15	%

The EU and USA have both published lists of critical elements which are included in CES EduPack. The 2017 lists are shown to the right. These elements are critical with respect to technological/economic importance, difficulty to substitute and exposure to supply chain risk such as, monopoly, supply shortage, price volatility and local conflicts.

If we consider the two candidate tablet materials in our comparison, neither of them contains more than 5 wt% critical elements, as indicated in their datasheets, see the flame-retarded unfilled PC record, below.

Antimony *+	Gadolinium *	Molybdenum *	Silicon *
Arsenic *	Gallium *+	Neodymium *+	Strontium *
Barium *	Germanium *+	Niobium *	Tantalum +
Beryllium *+	Holmium *	Osmium *+	Tellurium +
Bismuth *+	Indium *+	Palladium *+	Terbium *+
Carbon, graphite *	Iridium *+	Platinum *+	Thorium *
Cerium *+	Lanthanum*+	Praseodymium *	Thulium *+
Chromium *+	Lithium +	Promethium *	Tin +
Cobalt *+	Lutetium *	Rhodium *+	Tungsten *+
Dysprosium *+	Magnesium *	Ruthenium *+	Ytterbium *
Erbium *+	Manganese +	Samarium *+	Yttrium *+
Europium *+	Mercury *	Scandium *+	

** = EU Critical Materials list, + = US Critical Materials list*

Restricted substances risk indicators		
RoHS (EU) compliant grades?	ⓘ	✓
REACH Candidate List indicator (0-1, 1 = high risk)	ⓘ	0.18
Notes May contain restricted (wt%): Flame-retardant up to 15%, Stabilizer / Pigment up to 0.7%, UV-stabilizer up to 1.9%		
SIN List indicator (0-1, 1 = high risk)	ⓘ	0.18
Notes May contain restricted (wt%): Flame-retardant up to 15%, Stabilizer / Pigment up to 0.7%, UV-stabilizer up to 1.9%		
Critical materials risk		
Contains >5wt% critical elements?	ⓘ	No

Both *Critical materials risk* and *Restricted substances risk indicators* are listed in the level 3 material datasheets, as shown to the left. Further information on the EU Restriction on Hazardous Substances (RoHS) and REACH legislation as well as the SIN list can be found by clicking the information icons ⓘ.

In the sustainability database, there is also 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. The compliance of the materials depends on the specific substances used in the materials. For example, a flame-retarded polymer could contain polybrominated flame-retardants (*e.g.*, polybrominated biphenyls, PBB), some of which are restricted ("banned") in particular applications such as electronic devices, but permitted in others. 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, or to substitute the material to achieve low flammability and UV stability without the need for potentially restricted chemical additives.

Table: Legislation and Regulations
Subset: Legislation and Regulations

- Legislation and Regulations
  - Advisory organizations
  - Asian Directives
  - Environmental taxes
  - EU Directives and Regulations
    - Battery directive
    - Control of Substances Hazardous to Health (COSHH)
    - Ecodesign Directive
    - End-of-Life Vehicles Directive (ELV)
    - Energy Efficient Buildings Directive
    - EU Automotive Fuel Economy Policy on carbon emissions
    - Hazardous Substances Directive (RoHS2)
    - Landfill Directive
    - Product Liability Directive
    - Registration, Evaluation, Authorization and Restriction of Chemical Substances Directive (REACH)
    - SAVE Directive
    - Supply-Chain Due Diligence (2014)
    - The EU FLEGT Action Plan (2003)
    - The EU Packaging Directive
    - The EU Plant Health Directive (2000)
    - The Reusing, Recycling and Recovering of Motor Vehicles
    - UK Packaging Regulations (2003)
    - Volatile Organic Compounds Directive (VOCs)
    - Waste Electrical and Electronic Equipment Directive (WEEE)
    - Waste Framework Directive (WFD)
    - Water Framework Directive
  - Health and Safety
  - International Agreements and Protocols
  - Standards
  - Trading schemes and Subsidies
  - US Environmental legislation

Recycling and end of life						
Recycle	ⓘ	✓				
Embodied energy, recycling	ⓘ	* 32.4	-	35.8	MJ/kg
CO2 footprint, recycling	ⓘ	* 2.54	-	2.81	kg/kg
Recycle fraction in current supply	ⓘ	40.5	-	44.7	%
Downcycle	ⓘ	✓			
Combust for energy recovery	ⓘ	✗			
Landfill	ⓘ	✓			
Biodegrade	ⓘ	✗			

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. This reduces the value of the polymer, making recycling an unattractive option.

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.

Grades in excess of listed weight % are not compliant:

- 0.1% Lead
- 0.1% Mercury
- 0.01% Cadmium
- 0.1% Hexavalent chromium (VI or Cr6+)
- 0.1% Polybrominated biphenyls (PBB)
- 0.1% Polybrominated diphenyl ether (PBDE)

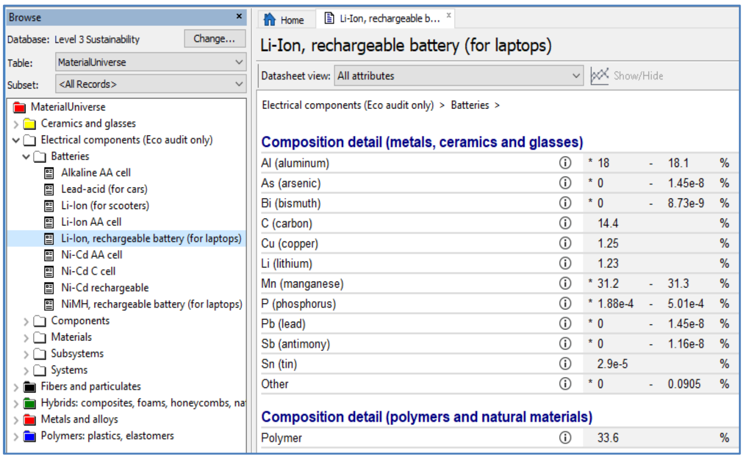
Restricted substances risk indicators	
RoHS (EU) compliant grades?	✓
REACH Candidate List indicator (0-1, 1 = high risk)	0
SIN List indicator (0-1, 1 = high risk)	0
Critical materials risk	
Contains >5wt% critical elements?	No
Abundance risk level Highest risk elements Copper	Medium
Sourcing and geopolitical risk level Highest risk elements Silicon	High
Environmental country risk level Highest risk elements Silicon	Medium
Price volatility risk level Highest risk elements Copper	Very low
Conflict material risk level Highest risk elements Copper	Caution

5. Eco Audits and Critical Material Investigation of Lightweight Tablets

By replacing one of the main structural components, going from flame-retarded PC to Al 6061 in the backplate of the casing, we remove the risk of restricted substances in the material by design and improve the recyclability. Below, we have used the Enhanced Eco Audit tool to investigate the life-cycle consequences of this product modification. A simplified generic BOM for a tablet with PC casing is given below. Secondary processes and material removal are neglected. Note that warning indicators for critical, restricted and hazardous materials appear to raise design awareness.

Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	Secondary process	% removed	End of life	% recovered
1	Casing\Backplate	PC (low viscosity, molding and extrusion, flame retarded)	Virgin (0%)	0.07	Polymer molding		0	Landfill	100
4	Casing\Metal screws	Stainless steel, austenitic, AISI 316LVM, annealed	Typical %	0.0005	Forging		0	Landfill	100
6	Casing\Metal tabs	Stainless steel, austenitic, AISI 316LVM, annealed	Typical %	1e-05	Forging		0	Landfill	100
4	Casing\Plastic tabs	ABS (rubber modified, injection molding and extrusion)	Virgin (0%)	0.0025	Polymer molding		0	Landfill	100
1	Casing\Bottom plate	ABS (medium-impact, injection molding)	Virgin (0%)	0.011	Polymer extrusion		0	Landfill	100
1	Display\LCD panel	LCD panel (liquid crystal display)	Virgin (0%)	0.16	Incl. in material value		0	Downcycle	100
1	Display\Glass	Alumino silicate - 1720	Virgin (0%)	0.18	Glass molding		0	Landfill	100
1	Display\Plastic frame	ABS (high-impact, injection molding)	Virgin (0%)	0.008	Polymer molding		0	Landfill	100
1	Mainboard\PCB	Printed wiring board (for laptop)	Virgin (0%)	0.047	Incl. in material value		0	Downcycle	100
1	Interior parts\Antenna	Brass, CuZn36, C26800, hard (basis brass)	Typical %	0.0011			0	Landfill	100
1	Interior parts\Connector	Silicone (VMQ, heat cured, 10-30% fumed silica)	Virgin (0%)	0.0015	Polymer molding		0	Landfill	100
1	Interior parts\Rubber strip	Silicone (VMQ, heat cured, 10-30% fumed silica)	Virgin (0%)	0.0044	Polymer molding		0	Landfill	100
1	Interior parts\Battery housing	ABS (high-impact, injection molding)	Virgin (0%)	0.02	Polymer molding		0	Landfill	100
2	Interior parts\Speakers\ABS	ABS (high-impact, injection molding)	Virgin (0%)	0.001	Polymer molding		0	Landfill	100
2	Interior parts\Speakers\Aluminum	Aluminum, 5005, H14	Typical %	0.0005	Rough rolling		0	Landfill	100
1	Battery	Li-Ion, rechargeable battery (for laptops)	Virgin (0%)	0.127	Incl. in material value		0	Downcycle	100

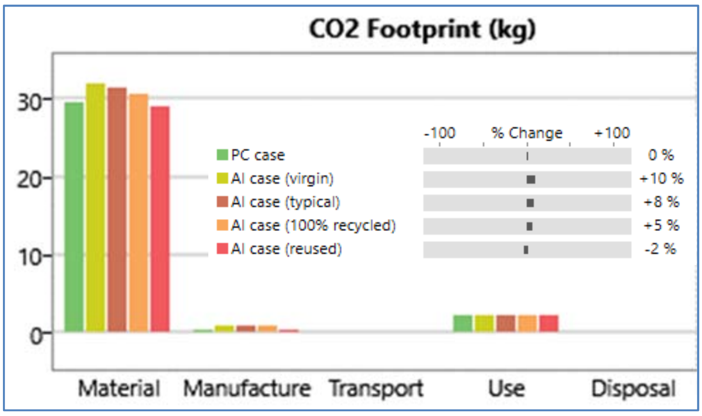
As can be seen in the BOM above, there are a number of electrical components, such as LCD display, circuit board and batteries, added in the database to represent generic parts. These records are visible in the Browse mode if the <All Records> subset is chosen, as shown to the right. The records give further detail on typical compositions for a number of electrical components that we have used for the tablet device. The result of the Eco Audit for the flame-retarded PC option and several scenarios for Al 6061 is shown in the summary chart below.



The BOM entries for 4 alternative Al scenarios are given below, each replacing PC, above. They represent various degree of circularity, from an open-loop virgin Al with Landfill to a fully closed-loop, reusing the casing.

Component name	Material	Recycled content	Mass (kg)	Primary process	Secondary process	% removed	End of life	% recovered
Casing\Backplate	Aluminum, 6061, T4	Virgin (0%)	0.13	Extrusion, foil rolling	Fine machining	80	Landfill	100
Casing\Backplate	Aluminum, 6061, T4	Typical %	0.13	Extrusion, foil rolling	Fine machining	80	Recycle	100
Casing\Backplate	Aluminum, 6061, T4	100.0%	0.13	Extrusion, foil rolling	Fine machining	80	Recycle	100
Casing\Backplate	Aluminum, 6061, T4	Reused part	0.13	Not applicable	Not applicable	0	Reuse	100

It can be seen in the Eco Audit that, in all the scenarios investigated, the phase that dominates the energy use, and therefore the CO_2 footprint, is the *Material production* rather than the *Manufacture* or *Use* phase. 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. The aluminum 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, based on 2 years of use. The cost, however, remains the same. For more detailed information on CO_2 footprint per component, to improve environmental performance of the dominant phase, the *Detailed report* can be studied by clicking the button next to *Summary chart*. In the Al (virgin) report, it is clearly the battery and the printed circuit board that cause the most cause CO_2-emissions, around 40% each.

Component	Material	Recycled content* (%)	Part mass (kg)	Qty.	Total mass processed** (kg)	CO2 footprint (kg)	%
Casing\Backplate	Aluminum, 6061, T4	Virgin (0%)	0.13	1	0.65	3.1	9.8
Casing\Metal screws	Stainless steel, austenitic, AISI 316LVM, annealed	Typical %	0.0005	4	0.002	0.0084	0.0
Casing\Metal tabs	Stainless steel, austenitic, AISI 316LVM, annealed	Typical %	1e-05	6	6e-05	0.00025	0.0
Casing\Plastic tabs	ABS (rubber modified, injection molding and extrusion)	Virgin (0%)	0.0025	4	0.01	0.04	0.1
Casing\Bottom plate	ABS (medium-impact, injection molding)	Virgin (0%)	0.011	1	0.011	0.04	0.1
Display\LCD panel	LCD panel (liquid crystal display)	Virgin (0%)	0.16	1	0.16	2.9	9.1
Display\Glass	Alumino silicate - 1720	Virgin (0%)	0.18	1	0.18	0.17	0.5
Display\Plastic frame	ABS (high-impact, injection molding)	Virgin (0%)	0.008	1	0.008	0.029	0.1
Mainboard\PCB	Printed wiring board (for laptop)	Virgin (0%)	0.047	1	0.047	13	39.3
Interior parts\Antenna	Brass, CuZn36, C26800, hard (basis brass)	Typical %	0.0011	1	0.0011	0.0025	0.0
Interior parts\Connector	Silicone (VMQ, heat cured, 10 -30% fumed silica)	Virgin (0%)	0.0015	1	0.0015	0.0098	0.0
Interior parts\Rubber strip	Silicone (VMQ, heat cured, 10 -30% fumed silica)	Virgin (0%)	0.0044	1	0.0044	0.029	0.1
Interior parts\Battery housing	ABS (high-impact, injection molding)	Virgin (0%)	0.02	1	0.02	0.073	0.2
Interior parts\Speakers \ABS	ABS (high-impact, injection molding)	Virgin (0%)	0.001	2	0.002	0.0073	0.0
Interior parts\Speakers \Aluminum	Aluminum, 5005, H14	Typical %	0.0005	2	0.001	0.0087	0.0
Battery	Li-Ion, rechargeable battery (for laptops)	Virgin (0%)	0.13	1	0.13	13	40.5
Total				**29**	**1.2**	**32**	**100**

*Typical: Includes 'recycle fraction in current supply'

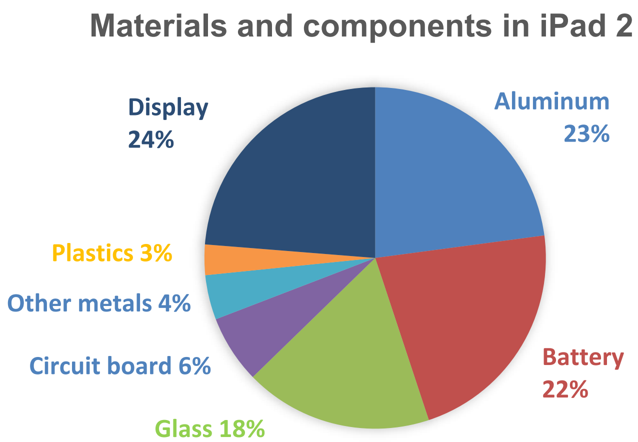
6. Analysis and Reality Check

In this Advanced Industrial Case Study, we have departed slightly from the traditional materials selection methodology, screening and ranking of a large number of materials. This systematic methodology is mainly used when selecting a material for a new product. Instead, we have benchmarked existing product materials to highlight the properties of two realistic alternatives for a tablet back panel, polycarbonate and aluminum.

Looking at two key mechanical performance indices, bending strength and bending stiffness, flame-retarded PC and Al 6061, taken to represent generic casing material options in the benchmarking, both have intermediate performance, with possibilities to find similar materials with better index [4]. The display glass is a critical component for the structural integrity, so adding the estimated properties of Gorilla glass into the benchmarking chart confirms that it performs better than the casing materials in terms of bending strength and stiffness and will therefore not limit the tablet performance in this respect. Gorilla glass is an alkali-aluminosilicate that has extraordinary hardness and strength, due to substitution process of sodium ions near the surface into slightly larger potassium ions, creating a residual compressive stress.

When it comes to sustainability, there are real issues with the polymer casing option, since it contains flame retardants that may be restricted. For example, stricter EU legislation, introduced 2006, led Palm to stop shipping their Treo 650 smart phone to Europe, due to RoHS regulations that limit the acceptable amount of hazardous substances in electronics goods [5]. Al has been an option developed, for example, by Apple, to reduce hazardous substances and increase recyclability, which is difficult to obtain using polymer casings containing additives. In 2007, Apple CEO Steve Jobs wrote an open letter [6] highlighting changes to the company's environmental policy. Jobs specifically introduced aircraft-grade aluminum in order to improve recycling uptake [7]. Recycled aluminum requires a mere 5 percent of the energy needed to produce new aluminum, and the process produces 95 percent less greenhouse gas emissions. The CEO of aluminum company Alcoa, Klaus Kleinfeld, claims that 75 percent of all aluminum created since 1888 is still in active use today [7].

Since materials and manufacturing processes have been a key component in Apple's sustainability work, it provides an interesting example for devices, such as tablets. Aluminum was introduced not only in Laptops, but also in iPhones and iPads, as shown to the right. Furthermore, Restricted and hazardous substances, such as Beryllium, Mercury, Lead, Arsenic, PVC, Phtalates and Brominated flame retardants have been eliminated, which shows how much consideration materials decisions are given.



Another aspect touched upon by the Eco Audit in the previous section is circular economy. Al casings are more durable (wear, scratch resistance, UV degradation, *etc.*) than polymers, lasts longer and enables reuse. There are now several programs to return tablets and phones for refurbishment, which means reusing at least some parts for new products. Dedicated robots have also been developed by the manufacturer for disassembly in particular of iPhone 6. Apple's environmental responsibility report 2017 [8] reveals that precious metals recovered from old iPhones is worth plenty of money. 27.8 metric tons of raw materials were extracted out of discarded devices, including 1 tonne of gold. That gold alone was worth around $40 million. In addition, the company pulled out 1360 tonnes of copper (worth $6.4 million) and 2040 tonnes of aluminum ($3.2 million) [9].

7. What Does CES EduPack Bring to the Understanding?

CES EduPack is a very useful resource for teaching the design process, working with visual tools. The educator can easily demonstrate good material decisions and students can interactively explore ways to select and assess materials in realistic projects. Our A*dvanced Industrial Case Studies* are intended to inspire and guide product development, provide necessary knowledge and facilitate the understanding of the subject.

In this case study, CES EduPack suggests the following conclusions about tablet devices:

- The Sustainable Development database has a number of useful materials and data that promotes understanding of materials decisions during the product development process. We have successfully explored the area of *consumer electronics*.
- The *visualization tools* quickly let us have an overview of material properties to compare and benchmark different options for backplate casings, analyzing, for example, existing products. New or unique materials, such as Gorilla glass can be added,
- The Enhanced *Eco Audit* helped us to estimate the life-cycle *pros* and *cons* of aluminum compared to polycarbonate in terms of *Energy*, *CO_2 footprint* and *Cost*. One should be aware of large uncertainties of eco-properties, though.
- The results show that the suggested Al 6061 backplate casing material compares well with flame-retarded polycarbonate when it comes to mechanical properties and the reality check indicates that this move is in line with sustainability-thinking of major manufacturers over the past 10 years.

Sources of information

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