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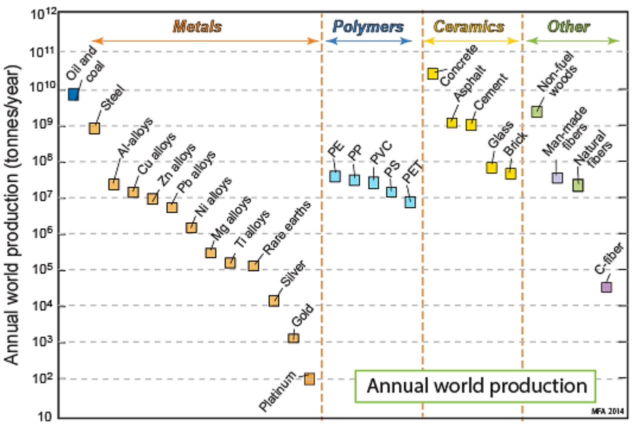
1. Materials in the built environment

The concept *Built Environment* is used when referring to surroundings created by humans, for humans, to be used for human activity. This would include, for example, houses and other buildings, roads, parks, etc.

It is obvious that this is of huge direct importance to everybody's daily life, but it is also contributing some of our most urgent long-term challenges. With a world population of many billions, the impact from construction and maintenance is monumental. Resource extraction and material production as well as heating and other energy use, including transport systems, all have global-scale consequences. This can be seen in the annual production levels of materials (oil and coal as reference):



The built environment is considered in one of the 17 UN Sustainability Goals, formulated in 2015. Goal 11 concerns many aspects of Urban planning, which shows that the built environment is also qualitatively important.

In this case study, we will explore aspects of materials in buildings that can be investigated using the Architecture database of CES EduPack. This contains some 127 materials, over a quarter more than the regular Level 2 database. These materials are linked to four building systems. The additional materials datasheets include:

- *More classes of concrete*
- *More classes of brick and tile*
- *More fibers, particle and plywoods*
- *More materials for insulation*

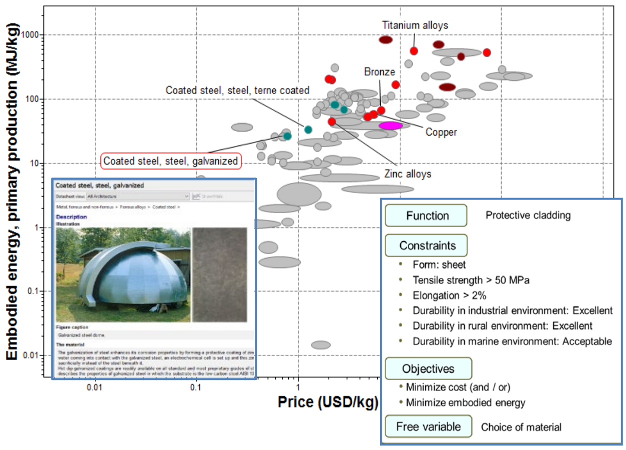
Building design can also benefit from the unique material properties supplementing the Level 2 datasheets:

- *Mechanical properties in bending*
- *Hygro-thermal properties*
- *Acoustic properties*
- *Durability in various atmospheres*

The study of the built environment is interdisciplinary in nature and includes disciplines such as architecture and many types of engineering. We will focus on buildings.

2. Material selection for buildings

The extended range of materials can be used for selection, for instance, minimizing cost and embodied energy for a resillient house cladding.

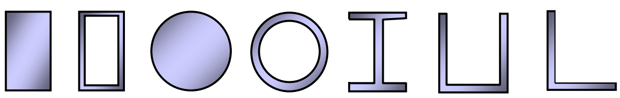


In this case, there is no mechanical performance to consider. The best materials can simply be identified in the chart after applying suitable constraints (see insert).

3. Structural sections

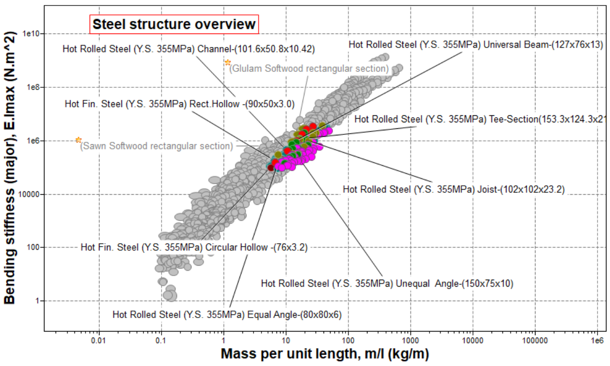
Although Goal number 11 refers to resilient and safe cities in a broader sense, the mechanical safety and integrity of buildings is certainly an important component.

The Architecture database is extended with a data-table of structural sections in standard dimensions. This makes it possible to discuss the importance of shape.



In order to visualize the structural element properties, we must remember that a conventional property chart consists of material performance for a given function (e.g. beam in bending) and usually a fixed cross section (e.g. square) so that shape can be eliminated from the performance index during selection within the chart. This is not the case if various structural elements are plotted.

An overview of steel structures (Angle, Channel, I-Section, Rectangular, T-Section, Tube) is shown, below. Non-steels are greyed out by a Tree stage filter.



For these structures, low mass per unit length is more important than low density. Bending stiffness is maximized. We can see that steels occupy the middle range of the chart and that some woods, added for comparison, perform surprisingly well (basically planks of softwood or laminated beams, marked with stars).

4. Eco Audit of a House

Safety and resilience are discussed above, but the environmental sustainability of a building can also be explored and discussed using our Eco Audit tool.

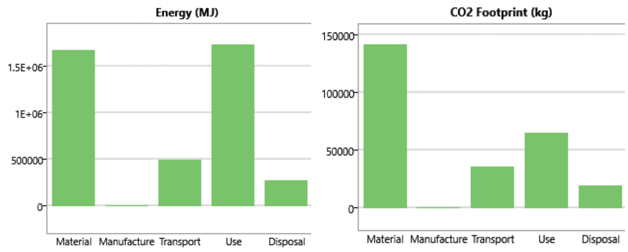
11 SUSTAINABLE CITIES AND COMMUNITIES Make cities and human settlements inclusive, safe, resilient and sustainable

Using a Bill-of-materials (BOM) for a semidetached 1-2 story house built in Colombia with 140 m^2 floor area and three bedrooms, published by Oscar Ortiz-Rodriguez *et al*. (http://www.researchgate.net/profile/Oscar_Ortiz-Rodriguez2/publications), we can perform an Eco Audit for a typical brick, concrete and steel building. Generic transports were added; 100 km for a light goods vehicle and 100 km of a 14 tonne (2 axle) truck, for the concrete.

Material, manufacture and end of life

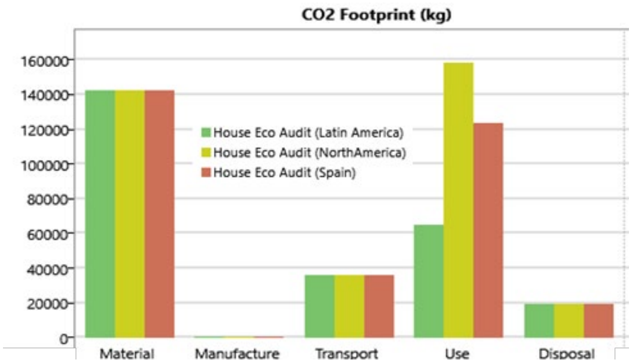
Qty.	Component name	Material	Recycled content	Mass (kg)	Primary process	End of life
1	Concrete	Dense concrete	Virgin (0%)	1.296e+06	Incl. in material value	Landfill
1	Mortar	Cement (ordinary Portland)	Virgin (0%)	3500	Incl. in material value	Landfill
1	Brick	Facing brick	Reused part	1.85e+04	Not applicable	Reuse
1	Steel	Low carbon steel	Typical %	4500		Recycle
1	Ceramic Tiles	Ceramic tile	Virgin (0%)	3580	Incl. in material value	None
1	PVC	Polyvinylchloride (tpPVC)	Virgin (0%)	284		None
1	Timber	Softwood (pine) parallel to the grain	Virgin (0%)	1691	Incl. in material value	Combust
1	Asbestos	Asbestos fiber	Reused part	780	Not applicable	None
1	Roof Tile	Ceramic tile	Virgin (0%)	257	Incl. in material value	None
1	Glass	Low-e glass	Virgin (0%)	150		Downcycle
1	Aluminium	Aluminum, pure (1200, H4)	Typical %	15		Recycle

This results in a Summary Chart of energy use and CO_2 that can now be used to explore different design options (alternative materials, recycling etc).



The scenario considers the operational energy over 50 years for a house in Latin America. It represents a typical energy consumption for a house with minimal mechanical heating or cooling, therefore, for both the energy and carbon footprint, the material phase is considerable (primarily due to concrete). This phase represents the embodied energy of the building. The average energy intensity per household in Columbia is 17 GJ/year according to the World Bank collection of development indicators, which is around 23% lower than our use phase, allowing for additional heating/cooling.

We can now explore the use-phase (operational) energy or recycling options. The Eco Audit tool includes data for the energy mixes of various countries/regions and the associated energy generation efficiencies. In the summary chart below, the CO_2 footprint for the house is shown for three countries of use: Latin America, North America and Spain, as examples of scenarios. We have used various *typical*, *reused* and *recycle* BOM options.



5. Conclusions

We have shown how CES EduPack can be used to select materials from the whole MaterialUniverse, or some of the four building-specific subsets. The structural sections data-table links architecture with engineering. The Eco Audit, finally, can be used to explore various aspects of a building when it comes to eco-properties, such as energy use and CO_2 footprint, as well as logistics, recycling and end of life options.