Materials for SDGs: A Synergy Towards Sustainable Development

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Abstract
The 17 Sustainable Development Goals (SDGs) represent a tangible and holistic vision of sustainable development, embodying a systemic vision that integrates environmental, social, and economic aspects. By adopting such a systemic vision, designers can drastically reduce the negative impact of their products. Materials represent a design element capable of influencing the entire life cycle of a product. Indeed, in the last decade there has been a frenetic race towards greener materials, focusing mostly on the environmental aspects of sustainability and neglecting economic and social dimensions. This paper aims to investigate a new thread of thought regarding sustainability within the design process, analysing the connections between SDGs and materials. The result is a taxonomy of materials that meet the SDGs and enhance their relationships by offering designers a new approach to sustainable material selection and development.

Keywords
Materials4SDGs
Sustainable development
Sustainability
Systemic approach
Taxonomy

An Inclusive View of Sustainable Materials

The term sustainability has acquired a primarily green meaning in the last century. The English verb from which it derives, "to sustain", has an apparently banal meaning: to maintain a condition, to preserve a state. Like the sustain pedal on the piano, which, once pressed, sustains the notes, making them play for longer even when released. Similarly, sustainability in modern society aims to preserve, maintain, and improve the ecosystem and the species within it. The most widely used definition was formulated by the Brundtland Commission defining sustainable development as a "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987). This opened the dialogue around the preservation of the ecosystem and the improvement of the human condition (Vezzoli, 2018).

These concepts have subsequently influenced the agendas of associations and governments worldwide, and have become goals to be achieved. Over time, they have been interpreted and evolved until they were formalised and translated into tangible objectives by the United Nations in the 2030 Agenda for Sustainable Development (UN, 2015). The Agenda proposes 17 Sustainable Development Goals (SDGs) with a systemic vision of sustainability that integrates environmental sustainability with economic and social issues (Barbier & Burgess, 2017). SDGs aim to "stimulate action over the next 15 years (only 8 left) in areas of critical importance for humanity and the planet" (UN, 2015).

Though simplified and pragmatised, the 17 objectives can only be achieved if there is a widespread effort and a radical change in everyone's behaviour, in the way society organises and relates to itself and the environment, in the way we produce and even in the objects we use and how we use them. The latter in particular, which are part of the world that we experience every day, have triggered a virtuous cycle that actively involves both consumers and designers (Sanders, 2006). Thanks to digitalisation and globalisation, there is a growing awareness in society, which is now constantly searching for products that meet the new needs of sustainability (Manzini & Menichinelli, 2021). The designer is therefore called upon to respond to these new challenges (van der Bijl-Brouwer & Malcolm, 2020). The greatest possibility of reducing the environmental impact of a product is through its design, giving the designer increased responsibility and greater impact on the product's entire lifecycle (Bevilacqua et al., 2012; Ceschin & Gaziulusoy, 2016; Vezzoli, 2018).

Materials play a fundamental role in this context, as an element that can condition the entire life cycle of the product, and consequently the various systemic impacts. Many companies and practitioners have realised the primary importance of materials, and search for increasingly sustainable choices. Over the past decade, this necessity has led to a frantic race for green materials, linked to terms such as bio-based, biodegradable, compostable, recycled, and recyclable, sometimes generating confusion and some superficiality among young designers and consumers. As a result, the general thinking with regards to sustainable materials focuses on the environmental aspects of sustainability, neglecting the social and economic aspects. There is an urgent need for increased awareness and

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research to realign the selection and development of materials with a holistic, systemic, and strategic perspective on SDGs.

The aim of this paper is to investigate new threads of thinking regarding the topic of sustainability in the design process, offering an open-minded overview of the meanings and implications of "sustain-ability". This has been done by analysing the interconnection between the deep concepts of SDGs and materials. The core of the research proposes a taxonomy of materials that meet the SDGs, highlighting insightful connections from their collision. This synergy can provide designers with new approaches to the selection and development of sustainable materials. Finally, an extensive analysis of case studies may serve to open new horizons for further debates that focus on developing materials-based approaches to achieving SDGs.

Materials That Meet SDGs

There is no hierarchical classification of the SDGs consistent with the principles contained therein, but to deal with them within thematic areas, we will apply the diversification published by Johan Rockström and Pavan Sukhdev in 2016 (EAT, 2016). Their systematisation of Sustainable Development Goals is based on the tripartite model of the economic, social, and environmental implications of sustainability. Taking this reference, the SDGs and materials cases will be clustered within three main thematic areas: Biosphere, Society, Economy.

Biosphere

The preservation of the biosphere is a necessary condition for the survival of animal and plant species. The focus of this discussion will therefore be on materials that support the biosphere, operate cohesively with it, without hindering it.

- SDG 6 aims to ensure the availability and sustainable management of water and sanitation for all. Water-filtering materials can support this goal. *Indus,* a project by The Bio-Integrated Design Lab at the Bartlett School of Architecture is a modular system of bioinspired tiles that, thanks to algae and an algae-based hydrogel, allows small rural communities to obtain clean water. A second example is *Acquaporin,* which purifies the water through its *Drinking water membranes* project. It relies on a semi-permeable TFC biomimetic membrane that exploits the operating principle of the aquaporin proteins inside it.
- SDG 13 calls for urgent action to fight climate change and its impacts. Materials that support this goal are carbon neutral or carbon negative. One such material is *Made of Air*: a carbon-negative bioplastic made from a binder with biochar, a carbon-rich material produced by burning biomass without oxygen, which prevents carbon from escaping as CO2. Another example is olivine: an abundant mineral that can absorb its own mass of carbon dioxide when finely pulver-

ised. Another way in which climate action can be taken is to raise community awareness: the smart fabric *Aerochromics* by Nikolas Bentel operates by reactivating and transforming its patterns as the levels of harmful particles in the air increases.

- SDG 14 aims to preserve the oceans, seas, and marine resources and ensure they are used sustainably. In this sense, *ECOncrete*® is a bioinspired material on a micro and macro level, that fosters the growth of marine life on under-water concrete infrastructure. Other projects share the same goal, such as the *3D-printed Coral Carbonate* by Danielle Dixson and Emily Ruhl, designed to constitute natural coral skeletons to be inserted into the marine environment. In addition, numerous projects aim at de-plastifying the seas, hence the collaborative project between Parley® and adidas® for the design of a shoe made of reclaimed marine plastic waste: the *Ultra Boost prototype* shown in Fig. 1.

Fig. 1
Parley and Adidas collaboration for the *Ultra Boost prototype* shoe. © Filipe Alves on Unsplash.

- SDG 15 aims to protect, restore, and promote the sustainable use of terrestrial ecosystems. In this perspective, materials with FSC and PEFC certifications, international standards in the field of wood and its derivatives, are developed with the aim of spreading the principles of good forest management in civil and industrial society. An international group of researchers has been working on a biomimetic material to combat desertification through a micro and meso structure that facilitates condensation, drawing inspiration from cacti and beetles (Park et al., 2016).

Society

The social dimension of sustainability determines if a product promotes people's welfare, health, and safety (Ljungberg, 2007). In literature, it is challenging to find correspondences with socially

diid No. 76 — 2022
Doi: 10.30682/diid7622i

sustainable materials. One of the possible approaches is to shorten the supply networks of raw materials and facilitate local small and medium businesses as a measurable parameter that can be referred to the procurement of natural resources, renewable and non-renewable energies (Allione et al., 2012). This research, however, explored other approaches to determine materials that are sustainable in a social sense, following the SDGs.

- SDG 1 aims to end poverty, in all its forms and everywhere. This goal dialogues perfectly with green building materials applied in disadvantaged communities: materials of natural and local origin, such as wood, mud, coconut palm leaves and above all bamboo, are used by local labour for the construction of buildings for social purposes. On the opposite side of the coin, the plastic materials that invade communities without structured recycling networks can be seen as a precious resource for them. In Kenya, *FlipFlopi*, a *dhow*, the small traditional East African boat, was made entirely of recycled plastic from materials recovered by collecting flip-flops, since they are made of flexible expanded lightweight plastics.
- SDG 2 aims to end hunger, achieve food security, better nutrition, and promote sustainable agriculture. Not only materials, but technologies as well can be used at this juncture. The Food and Agriculture Organization (FAO) has offered open-source 3D designs of innovative equipment for post-harvest handling and food processing that can be downloaded and used freely. Reducing food loss and waste could be an approach in support of Zero-hunger materials. *Apeel* is a protective extra peel that seals moisture in and keeps oxygen out, based on substances that exist in the peels, seeds, and pulp of all fruits and vegetables.
- SDG 3 aims at ensuring healthy lives and promoting well-being for all people of any age. Latex, a widespread and not particularly new material, has nevertheless enabled the introduction of disease prevention and protection products. More innovative materials were also used to fight for the cause such as, for example, antibacterial coatings based on silver dioxide, which during the Covid-19 pandemic were applied by Industrie Grafiche Pacini on paper products (books, magazines, menus), as well as packaging and children's toys. Another example is *d3o*, a company that develops a series of polymer blends formulated to achieve specific properties for protective or shock-absorbing products for sports, motorbikes, and industrial safety.
- SDG 4 aims to ensure inclusive and equitable quality education and promote lifelong learning opportunities for all. Innovation was pursued towards this end in educational support materials. The first example is the *ETHERGRAF*® pen: its metallic tip microscopically "scratches" the paper, oxidising it without tip wear or waste, making it a "forever pen". Paper is another critical focus and, thus, Favini's *Crush* paper line is made from by-products of agro-industrial processing. These innovations do not represent an inclusive and equitable educational phenomenon to date, but they hold great potential for products that can provide lasting tools and raw materials

supply for education to disadvantaged communities.

- SDG 5 aims at gender equality, eliminating disparities and ensuring equal opportunities. The material that first provided great inspiration was an equal-opportunities fabric: jeans denim. A fabric which has fostered equal opportunity for women giving them the freedom to dress in defiance of stereotypes since the 1960s, in parallel with the feminist movement. Starting from the concept of gender neutrality, the trend in "gender-neutral design" works on the CMF (Colour, Material, Finishes) aspects of materials. A groundbreaking example is in the sector of children's toys: in 2012, *Harrods* unveiled the first gender-neutral toys department to prevent the formation of gender stereotypes from an early age.
- SDG 7 aims at ensuring access to affordable, reliable, and sustainable energy for all. In this context, high-performance composite materials for wind turbine blades carry with them a major problem regarding their disposal, but the *FiberEUse* project envisages new circular economy solutions for the reuse of end-of-life fibre-reinforced composites Fig. 2. In the category of materials that support clean energy, there is an impressive project developed by dyaqua: *Invisible Solar* is a new photovoltaic material that can take the appearance of terracotta, stone, cement, or wood, to integrate and maintain the aesthetic continuity of buildings and landscapes.
- SDG 11 makes cities and human settlements inclusive, safe,

Fig. 2
***FiberEUse* project displayed at FuoriSalone 2021, a close-up of the recycled composites on a chair prototype. Ph. by the Author.**

resilient, and sustainable. The *i.active BIODYNAMIC* cement by Italcementi featured in the Italian pavilion at Expo 2015, when irradiated by sunlight, "captures" certain pollutants in the air, transforming them into inert salts and thus helping to rid the atmosphere of smog. A similar example is *theBreath*® by Anemotech S.r.l., a fabric with multi-capacity applications,

diid No. 76 — 2022
Doi: 10.30682/diid7622i

that, through the natural flow of air, coupled with perforated metal panels or expanded metal sheets, absorbs and purifies the air without the use of additional energy sources.

- SDG 16 focuses on promoting peaceful and inclusive societies for sustainable development. This theme is inevitably connected to SDG 8, but now it will be looking at two realities that produce material in collaboration with the local communities. The first is *karuun®,* which produces rattan with Indonesian communities innovating the traditional way of processing this kind of material. The second is Ananas Anam, the maker of *Pinãtex*. *Pinãtex* is a leather-like material that comes from the harvesting of pineapples, a by-product of existing agriculture. Through the recovery of this material, it has been possible to create an additional income stream for farming communities, helping the circular economy and the economic development of the Philippines.

Economy

Profit is a necessary condition of sustainability (Elkington, 1994). SDGs for sustainable economic development concentrate on ensuring a better future in terms of profit and work conditions in general.

- SDG 8 promotes inclusive, and sustainable economic growth. The most representative material is a protest against the working condition of child workers in Congo to extract cobalt and coltan. The material becomes a rich asset that exceeds the value of human life. *Fairphone 2* has set out to fight for this issue: the materials used are obtained from Congolese mines managed by non-governmental organisations outside the military conflicts in the area. Another case is the Italian company *OltreCafé,* which gives new life to coffee grounds, creating pellets for stoves and reusing a precious resource that would otherwise end up in landfills.
- SDG 9 focuses on building resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation. The design of *Plyskin,* a thesis project at the Royal Academy of Art in The Hague, Netherlands, was based on the structure of a polar bearskin, and consists in generating a three-layered module to insulate a building efficiently (Cafsia, 2017). Another case study is a collaboration between the Italian companies *Mapei* and *Iren*. They signed an agreement to use thermoplastic polymers deriving from innovative recycling processes to create durable and sustainable road surfaces.
- SDG 10 seeks to reduce inequality within and among countries. Many projects deal with minority communities: one of them is the *Quid* project. The material involved is recycled fabrics that are transformed into ethical fashion garments, offering job opportunities to vulnerable people. Broadening the concept of inequalities, in the *IMK architects* project for a *hospital façade* , the bricks were made out of earth and subsequently dried on site, uplifting the country's development and providing jobs for the people in the local

community. But looking at the SDG from another perspective, a very innovative case to ensure equal opportunities for blind people is the *Braille E-Book*, which instantly generates a slight roughness on the screen using EAP (Electroactive Polymers) technology.

- SDG 12 aims at sustainable consumption and production patterns. In this SDG, relevant companies have a more comprehensive vision of the entire concept of sustainability: the B-Corp Patagonia developed *Infinna*, a regenerated textile fibre from cotton-rich textile waste with the natural look and feel of cotton. The Italian B-Corp Davines developed a solid shampoo: a real example of responsible consumption, because it drastically reduces the packaging and the resources needed to obtain the same function. The last example is a material from GoodHout's, *a* coconut husk panel manufactured by upcycling existing agricultural by-products and waste streams, caring for customers' health by avoiding the use of toxic chemical additives, and supporting local communities.
- Most importantly, there is SDG 17, which strengthens the means of implementation and revitalises the global partnership for sustainable development. With regard to this SDG, the chosen materials are those that focus the attention on the networks and the relations between the different parties involved. The first material is *MOSO® Bamboo,* an example of a partnership between Europe (the Netherlands) and China: it establishes a production plant totally dedicated to the production of bamboo veneer. The other example of a network is *Precious Plastics*, Fig. 3 an open-source community that promotes knowledge about recycling plastics, thanks to a digital platform, with the goal of creating an alternative global recycling system.

Fig. 3
***Precious Plastics*, the community was hosted in the Ro Plastic Prize 2020 finalists' exhibition. Ph. by the Author.**

diid No. 76 — 2022
Doi: 10.30682/diid7622i

The case studies delineated in the paragraph above were the result of a collection effort, supported by a profound reasoning on the intrinsic objectives of each SDG. At the initial connection between SDG and material, however, it became clear that, while basing their concept mainly on one, they also nurtured other objectives. Above them all however is the purpose of collaboration and generation of a network to achieve the objectives (SDG 17). Fig. 4 shows how the cases intertwine objectives and form bridges for joint objectives.

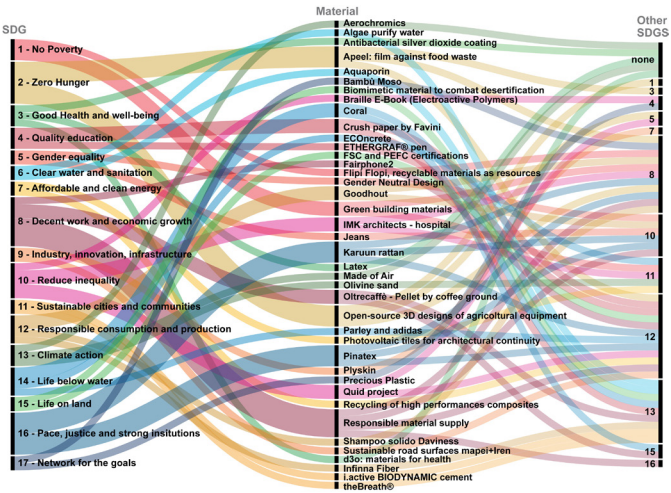

Fig. 4
Case studies analysis as a bridge between SDGs, a data visualisation obtained through https://rawgraphs.io/, by the Author.

The cases selected to represent the material side of SDGs were also classified according to material categories and application sector Fig. 5. The result is that most of the cases presented refer to natural materials, though they also cover the other families. In fact, sustainable innovation can also be achieved through more traditional materials, reaching diversified sectors of application to foster sustainable development. What changes is the systemic vision within which the material is embedded, which may or may not make it sustainable.

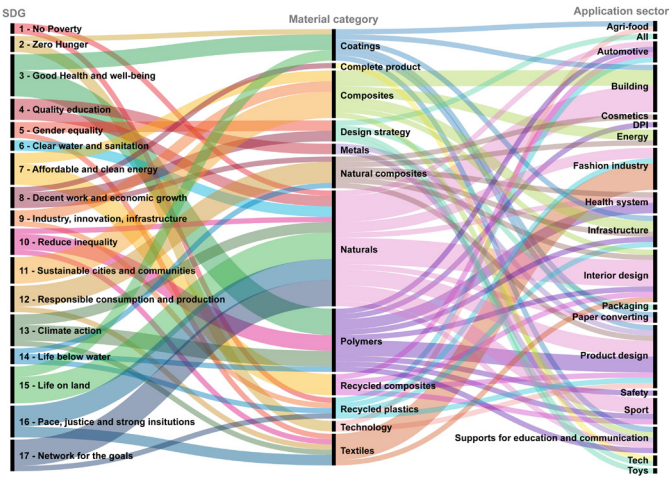

Fig. 5
Case studies analysis clustered by materials categories and application sector; a data visualisation obtained through https://rawgraphs.io/, by the Author.

From the research it was possible to draw up roadmaps for the selection and development of materials aimed at achieving SDGs. These indications, elaborated in Fig. 6, emerge from this study and from the research into case studies, but the research remains open to debate and integration. However, we wanted to emphasise how the approach we adopted made it possible to consider lines of development and a selection of materials for sustainable development that consistently integrate social and economic aspects, that are innovative, open-minded, and think out of the box. These assumptions do not claim that all the above mentioned are "sustainable materials", but rather materials for sustainable development, which integrate a systemic vision, aiming at a holistic vision of sustainability.

Fig. 6
Material-based roadmaps toward sustainable development based on the case studies analysis, by the Author.

Conclusions

According to the new design paradigm based on the insightful interconnections among the materials and the SDGs, a new role has been identified for the designer, who is increasingly viewed as a multidisciplinary bridge merging different disciplines and practices, such as, for instance, the design field itself, chemistry and engineering. This new design approach is a crescendo that is occurring in response to an ongoing, changing and emerging scenario related to the benefits of the planet, of society and of the economy. Inevitably, this new role implies new research and design skills that merge various methodologies and tools, to mention just a few: the ability to approach the selection of the suitable material as "a project within the project", the ability of the designer to manage and activate complexity as virtuous synergies among different actors and stakeholders while constantly considering materials not as a limit but as an opportunity.

diid No. 76 — 2022
Doi: 10.30682/diid7622i

The paper intends to open the debate on identifying material selection and development criteria in terms of social and economic sustainability in addition to the more generally considered environmental sustainability, in line with the millennial goals (SDGs), a highly unexplored field to date. The goal of this work is to look at materials from different perspectives, giving designers broadened material-based roadmaps towards sustainable development, and applying a dash of creativity, criticism of stereotypical sustainability concepts, and lateral thinking to guide their activity.

A reflection upon some limits is required. The methodology for materials selection that designers may apply as a result of this work is a selection by inspiration that relies heavily on the designer's experience and his ability to activate logical connections based on experience. For the future, a more systemic methodology could be integrated following the development in the literature of units of measure and impact assessment methods for the economic and social aspects of sustainability.

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References

Allione, C., De Giorgi, C., Lerma, B., & Petruccelli, L. (2012). From ecodesign products guidelines to materials guidelines for a sustainable product. Qualitative and quantitative multicriteria environmental profile of a material. *Energy, 39*(1), 90–99. https://doi.org/10.1016/j.energy.2011.08.055

Barbier, E. B., & Burgess, J. C. (2017). The sustainable development goals and the systems approach to sustainability. *Economics*, *11*(2017-28), 1-22. http://dx.doi.org/10.5018/economics-ejournal.ja.2017-28

Bevilacqua, M., Ciarapica, F. E., & Giacchetta, G. (2012). *Design for Environment as a Tool for the Development of a Sustainable Supply Chain*. Springer Science & Business Media.

Cafsia, L. (2017). Plyskin; insulating façade panel based on Biomimicry of the polar bear skin and fur. *IABSE Symposium Report, 108,* 58-59. https://doi.org/10.2749/222137817821232630

Ceschin, F., & Gaziulusoy, I. (2016). Evolution of design for sustainability: From product design to design for system innovations and transitions. *Design Studies, 47,* 118-163.

EAT. (2016). *How food connects all the SDGs. Stockholm Resilience Centre*. https://stockholmresilience.org/research/research-news/2016-06-14-how-food-connects-all-the-sdgs.html

Elkington, J. (1994) Towards the Sustainable Corporation: Win-Win-Win Business Strategies for Sustainable Development. *California Management Review, 36*, 90-100. http://dx.doi.org/10.2307/41165746

Ljungberg, L. Y. (2007). Materials selection and design for development of sustainable products. *Materials and Design*, *28*, 466-479. https://doi.org/10.1016/j.matdes.2005.09.006

Manzini, E., & Menichinelli, M. (2021). Platforms for re-localization. Communities and places in the post-pandemic hybrid spaces. *Strategic Design Research Journal, 14*(1), 351–360.

Park, K.-C., Kim, P., Grinthal, A., He, N., Fox, D., Weaver, J. C., & Aizenberg, J. (2016). Condensation on slippery asymmetric bumps. *Nature, 531*(7592), 78-82. https://doi.org/10.1038/nature16956

Sanders, E. B. N. (2006). Scaffolds for Building Everyday Creativity. In J. Frascara (Ed.), *Design for Effective Communications. Creating Contexts for Clarity and Meaning*. Allworth Press.

United Nation (UN). (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development. United Nations*. https://sustainabledevelopment.un.org/post2015/transformingourworld/publication

van der Bijl-Brouwer, M., & Malcolm, B. (2020). Systemic Design Principles in Social Innovation: A Study of Expert Practices and Design Rationales. *She Ji: The Journal of Design, Economics, and Innovation, 6*(3), 386–407.

Vezzoli, C. (2018). *Design for Environmental Sustainability: Life Cycle Design of Products* (2nd ed.). Springer-Verlag.

WCED. (1987). *Our Common Future*. UN.

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