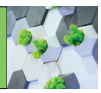
# Bio-inspired technologies and smart materials



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**INTRO**

•The material world build by humans is evolving with advances in synthetic biology and material sciences. Sustainability can be a driving force in developing new materials, but new materials do not come without risks as well.

**Potentials:**

• Taking inspiration for innovation from natural ecosystems we can harness human resources for the good of the planet while simultaneously gaining better technologies for us.
• New materials with active (sensing, responding) and passive (antibacterial) functionalities can enhance the quality of life for many.
• With new materials, new solutions to persistent issues can be found, such as buildings functioning as batteries.
• New, emerging materials can play a role in replacing crude oil and moving towards use of recycled and reusable items.
• New materials and bio-sensing provide possibilities for health care.
• Utilising materials that are currently treated as waste or pollution might offer interesting business opportunities.

**Risks:**

• New materials require substantial investments to mature to usable solutions and to mitigate unintended consequences.
• Excessive use of raw materials needs to stop, and thus even new materials should not be excessively produced or used carelessly.
• New innovations lead to the surplus of the old, and old materials or technologies might end up as waste

## 1: Research

•This phase includes scientific explorations with different raw material possibilities, material structures and properties. Research does stretch the limits of possibility, even if the usability might not be tested outside of lab environments yet.

**Ecological considerations**

•Combining different materials: Often, to make new materials last and enhance their properties, artificial components are added. This can be a good solution, but the implications for e.g. recyclability or compostability should be carefully considered and communicated.
•Finding starting points from nature: Traditionally, research processes start from the needs of humans. When aiming for a better balance with natural ecosystems, starting points for research should also be found in the needs of nature. Waste materials or invasive species, for example, might offer interesting opportunities for material sciences.

**Societal considerations**

• Research funding: As researching new materials is often based on trial-and-error type of testing, it requires grand amount of funding and the results of any one experimental branch can not be guaranteed. To move forward with material sciences, adequate funding is necessary, but prioritization of different research areas might be necessary.
• Ecological costs: when considering the costs of new materials, not only their current monetary value should be given priority, but emphasis should always be put to their whole costs to ecosystems and the society.

## 2: Development of concepts and products

•As new materials emerge from the scientific field, their application areas and use properties still need to be refined. As they are turned into products, they at the same time become parts of whole products and production chains, and their recycling properties, among many other factors, need to be refined.

**Ecological considerations**

•Recycling and promoting circular economy: As new materials and production methods are developed, it is good to always consider adding elements that promote circular economy, such as using recycled raw materials or ensuring the recyclability of the materials or changeability of product parts.

**Societal considerations**

• Licensing and growth: With new solutions, the pros and cons of licensing should be carefully considered. Licensing might enable attaining funding or selling the idea to bigger companies and thus scaling the solution. On the other hand, it might limit the use of the new solution as grass-roots hobbyists, for example, might not be able to experiment with the new material anymore.
• Considering wider impact: At this stage, new innovations are still in very small scales and not widely used. However, it is necessary to already consider the consequences of the innovation scaling up: how could it change every-day practices, for better or for worse?

## 3: Introduction and early implementation

•As the new materials mature, they will eventually reach the consumers. As the consumers encounter the new materials, their safety and rights need to be considered in a new way.

**Ecological considerations**

•Multi-criteria evaluation: Materials that make it to user testing phase usually have positive effects to at least some sustainability values. When considering taking up new technologies, their sustainability should be assessed from multiple perspectives, considering many different environmental values, such as climate change, biodiversity and toxicity.
• Benefits of new materials or solutions: Changing for more sustainable materials is usually a good decision from environmental perspective. However, even more sustainable materials have their environmental footprint, and if the use can be avoided altogether, it can be an even better alternative.

**Societal considerations**

•User rights and knowledge sharing: when testing with smart materials that have functionalities affecting the users or their direct environment, the user rights and privacy should be carefully ensured. Users should also have enough knowledge available for them about the products they are using in simple enough language.
• Considering time scales of use: If a solution is perfect for 5 minutes of use but harmful for long periods of time before and after, the actual benefit of the product might be questioned. In such situations, careful consideration of whether to introduce the new product or not is needed.

## 4: Scaling-up and fine-tuning established technologies

•If a new material or solution proves to be useful, it might enter the scaling phase. In this phase, the solution gains popularity and becomes more common. With larger production amounts and wider user base, new responsibility considerations also become relevant.

**Ecological considerations**

•Resource use: As new solutions are scaled up more resources are used. Thus, it is important to ensure that the raw materials of solutions that will be taken up in large scale can truly be produced sustainably even at scale.
•Limiting overall consumption: Even as new materials might be less ecologically harmful than traditional materials, their use still consumes limited natural resources. Thus, even with new materials, the overall consumption of virgin raw materials should be decreasing to achieve true sustainability.

**Societal considerations**

•Inclusion and fairness: New materials can sometimes offer life-enhancing opportunities for people with disabilities, the elderly, or other special groups. From social fairness viewpoint, equally distributing the opportunity to benefit from these scientific advancements regardless of e.g. financial situation is important, especially in context of health care system.


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