

Executive Summary

The challenge of climate protection

Photonics—the technical application of light—allows us to make the use of raw materials, materials and processes much more ecological.

Thanks to photonics research, sunlight is very efficiently converted into electrical energy. And also the reversal, i.e. the generation of light from electric current, is much more efficient today than it was just a few years ago, thanks to the great progress made in the development of photonics. In global communication, photonics with fiber-optic networks provides the basis for low-loss transmission of huge amounts of data across national and continental borders. Photonics also helps obtaining data by means of image systems and optical sensors. All these optical technologies are emission free and extremely energy efficient and thus make a decisive contribution to achieving the goals of climate protection and sustainability. Photonics solutions have already been awarded as many as three times with the most generously endowed environmental prize in Europe—the German Environmental Award.

INNOVATIONS IN MANY AREAS

The potential of photonics technologies is promising in many fields of application. In the field of climate protection, current developments include satellite-based lasers that measure the global distribution, formation and adsorption of greenhouse gases online. This also opens up perspectives for promptly recording local climate change events. Land-based optical systems for early detection of forest fires are increasingly being used, pseudosatellite-based systems are about to be launched.

The proportion of secondary production (recycling) of metals and other materials, for example from cars or mobile phones, can increase significantly thanks to non-contact, extremely fast and precise photonic processes. One example: processes for cutting and sorting materials from mobile phones using laser-induced breakdown spectroscopy (LIBS) are currently being developed; systems for recycling identical metals are already in use.

In agriculture, locally and temporally resolved analysis of growth conditions by photons is used for the exact local dosage of fertilizers and herbicides. Research is being conducted into using laser to eliminate unwanted weeds.

Photonics technologies also make a decisive contribution to efficient production in energy generation, in increasing the efficiency of solar cells, in energy storage and conversion, in reliable and safe battery cells and in compact electric drives for electromobility. Also already in use: optical processes for protection against wear and corrosion with environmentally friendly materials. The production of compact high-performance electronics becomes highly reproducible through material-adapted joining processes.

In the field of thin-film technology, lasers are better suited than any other tool for the economical and environmentally friendly production and modification of extremely thin, functional layers—for example for photovoltaics or electronics. In the production of renewable energy such as wind energy, photonic processes enable higher efficiencies and longer service lives.

Both the optimization of combustion processes of classical fossil fuels and the development of corresponding turbines for renewable energy sources are made possible in particular by laser application techniques of materials resistant to highest temperatures and precision bore holes for optimized cooling flows. The CO₂ emissions can be systematically reduced.

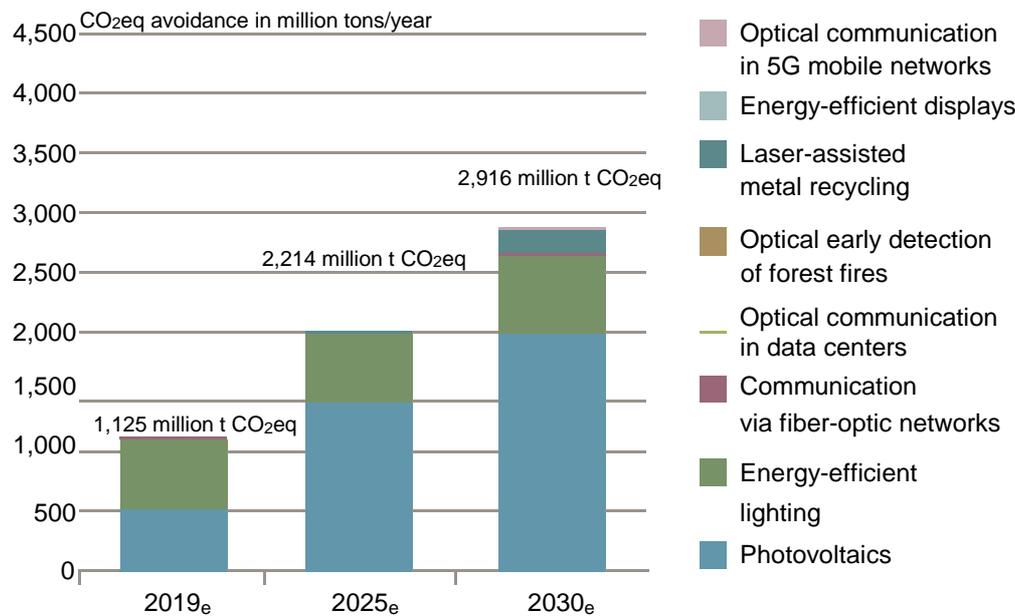
“3-D printing” enables completely new design freedom in the entire production technology. Lightweight construction and crash behavior, stability, recyclability, integration of sensors are no longer conflicting goals. Additionally, high-precision process control allows us to use measurement results that are available in real time to adjust current production and minimize reject rates.

Application examples of photonics solutions for ecological sustainability

Photonics solutions	Application area	Sustainability effect
Energy-efficient lighting	Lighting	Energy conservation
Energy generation through photovoltaics	Storage and generation of energy	Reduction in greenhouse gas emissions
Laser technology in photovoltaics: sustainable power generation through efficient solar cells	Storage and generation of energy	Reduction in production costs for modules; increase in efficiency of solar cells
Laser processes for sustainable energy storage	Storage and generation of energy	Reduction in production costs for modules; increase in efficiency of solar cells
Optical communication technology in data centers	Information, communication, entertainment	Energy conservation
Optical communication technology in 5G mobile networks	Information, communication, entertainment	Energy conservation
Energy-efficient displays	Information, communication, entertainment	Energy conservation
Communication via fiber-optic networks	Information, communication, entertainment	Energy conservation
Laser against unwanted weeds	Agriculture and forestry	Avoidance of herbicides
Optical early detection of forest and wildfires	Agriculture and forestry	Reduction in greenhouse gas emissions; protection of people and the environment
Efficient turbomachinery for aircraft technology by laser-based processes	Mobility	Increase in energy efficiency; reduction in weight, fuel and emissions
Laser technology in lightweight construction	Mobility	Reduction in the energy required for mobility, especially for electromobility
Extremely lightweight construction for optical and mechanical components through additive manufacturing	Mobility	Reduction of mass in transport, also in aerospace, thus reduction in energy and fuel consumption
Laser processes for high-performance batteries in automotive engineering	Mobility	Efficiency enhancement of the manufacturing processes of high-performance batteries, thus significant reduction in cost and increase in customer acceptance of electromobility
Preservation of transport infrastructures by laser scanning for monitoring of major structures	Mobility	Sparing use of raw materials and energy for the creation and maintenance of transport infrastructures
Laser spectroscopy for exhaust gas measurement technology	Mobility	Improved engine development through new and highly accurate measurement methods, thus reduction of harmful emissions (e. g. nitrous oxide)
Manufacturing with extremely high-speed laser deposition welding	Manufacturing	Environmentally friendly and economical coating, repair or manufacture of components
Production with additive manufacturing	Manufacturing	Weight optimization for lightweight construction and resource-saving production of complex components or components in small batch sizes; resource efficiency
Laser functionalization of surfaces	Manufacturing	Energy-efficient functionalization and optimization of components; avoidance of environmentally harmful additives
Digital holography in production control	Manufacturing	Avoidance of rejects; optimization of manufacturing processes
Metal recycling of the future: laser measurement and sorting of metals and alloys	Environmental protection and recycling	Recovery of valuable materials; energy conservation
Laser cleaning	Environmental protection and recycling	Avoidance of cleaning agents and unnecessary waste; energy conservation
Recycling of mobile phones and computer electronics: urban mining with laser technology	Environmental protection and recycling	Recovery of valuable materials; energy conservation
Tailor-made laser technology for climate research in space	Environmental protection and recycling	Environmental and climate research
Earth observation satellite with optical, high-performance gratings in space	Environmental protection and recycling	Environmental and climate research

Source: Study "Light as the key to global ecological sustainability", Messe München, SPECTARIS, Fraunhofer ILT

Indirect climate protection potential of photonics, illustrated by selected examples



Source: SPECTARIS/TEMATYS

ON THE GROWTH PATH

Calculation examples for various fields of application emphasize the enormous potential of photonics. Some areas are still at the beginning of their growth path, such as optical early detection of forest fires, laser-assisted metal recycling or optical communication in 5G mobile networks. Others have already made a significant contribution to climate protection in the past and yet still have enormous potential. Just think of the light bulb that was substituted by energy-saving lamps—only a first step towards the current “LED light revolution.” Or of photovoltaics and communication via fiber-optic networks: both technologies are already widespread, but the share of photovoltaics is still increasing in the energy mix, as is the expansion of broadband networks. And even in technology fields in which photonics has already proved its sustainability and the market environment is characterized by mature products and market saturation, new, even more efficient solutions already wait in the wings. Example: LED television sets that have replaced the “energy-guzzling” tube TVs in a very short time and that are now about to be replaced by, for example, OLED or quantum dot displays with their lower energy consumption in the long run.

This study’s eight exemplary calculations alone result in an indirect contribution to climate protection of 1.13 billion tons of CO₂eq. The potential is expected to more than double by 2030 and the value of avoided CO₂eq emissions will rise to around 3 billion tons per year. Photonics is thus making a major contribution to achieving the global goals of the Paris Climate Agreement:

the greenhouse gas emissions avoided thanks to photonics correspond to at least 11 % of the defined target value of limiting the temperature rise to 1.5 °C (2.7 °F) above pre-industrial levels.

This is only a small part of the contribution that photonics solutions can make to ecological sustainability, as the many other application examples in this study show. The actual potential is much greater.

THE FUTURE OF PHOTONICS

The future of photonics has only just begun. This publication aims to highlight the potential, diversity and innovativeness of photonics as a key technology for sustainability. First, the introduction describes the development of photonics, its fields of application and its contribution to ecological sustainability. The following calculation examples for selected concrete fields of technology shall underline the reduction already achieved and the potential of a future CO₂ avoidance. In a further chapter, German high-tech solutions from industry and research are presented, showing in detail the wide range of photonics and why it is an important link between economic efficiency and environmental protection.

The study is also to be understood as a plea to support the great significance of photonics by committed research, research funding and innovation-friendly conditions.

