Laserlab-Europe for Clean Energy

Global energy consumption has increased dramatically in recent years due to economic development, rising population and technological developments and is projected to continue to grow in the coming years[1]. Moreover, the electrification of large and emerging sectors of the economy, the decentralisation of the distribution grid and the digitalisation are likely to disrupt the whole energy scenario[2]. Yet, in the fight against climate change, many countries have announced ambitious targets for reaching net-zero emissions by 2050 and are seeking to accelerate their clean energy transitions. In Europe all 27 Member States committed to turning the EU into the first climate neutral continent by 2050.

To achieve these objectives, Europe has to massively step up investments in clean energy technologies for new solutions that tackle the entire energy value chain with a view to:

- Increasing the efficiency of light harvesting and energy conversion technology
- Enhancing the performance of energy storage, i.e. hydrogen cells, batteries, optimising the energy distribution
- Improving efficiency and reducing waste.

Laserlab-Europe can play an essential role in supporting clean energy transition research and innovation in Europe through multifaceted innovative approaches, by offering cutting-edge laser based technologies in the four competence pillars of Materials, Processing, Diagnostics and Devices, covering the entire value chain of technology development, as well as performing curiosity-driven research and satisfying technology inquiries from universities, research institutions and industry.

- **Laser-driven methods for material treatment** are used for growing and optimizing energy relevant materials with new physical and energy engineering properties for covering applications such as photovoltaics, displays, cathodes for batteries and fuel cells, as well as bio-inspired materials.

  - Optical 3D printing of renewable plant-derived resins for rapid prototyping and additive manufacturing.
  - Laser based photochemical fabrication of graphene-based electrode materials and interlayers for energy –related applications.
  - Additive manufacturing of 3D battery electrodes.

- Ultra-fast lasers can be employed for **nano**-**processing** of e.g. energy-collecting and converting surfaces, improving their functionality and conversion efficiency as well as for micro/nanofabrication of 3D nanostructures and photonic circuits in transparent materials.[3,4]

  - Ultrafast lasers for Nano structuring cathodes for enhanced H_2 Production.
  - Improved performance of fuel cells through Ultrafast Nano structuring.
  - Bioinspired laser nanofabrication of antireflective materials for photovoltaic and solar fuel cells applications.
  - Laser 3D nanolithography of inorganic glass-ceramic and crystalline materials for high performance and resilience devices in microoptics and nanophotonics.

[1] Final energy consumption is expected to increase by about 39% by 2050, at an average annual rate of approximately 1%. (IEA, 2019b, Stated Policies Scenario).
[2] World Economic Forum, "The Future of Electricity New Technologies Transforming the Grid Edge - EU Agenda." (2017).
[3] Pimenidis et al. https://doi.org/10.1016/j.ijhydene.2021.09.010)
[4] Papadopoulos et al., Adv.Mater. (2019), 31, 1901123

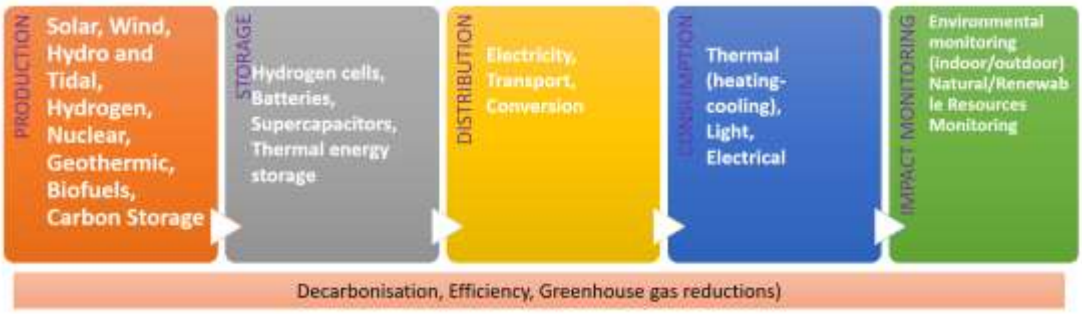
- Looking into **diagnostics**, lasers can be uniquely used for interrogating the transport dynamics of photo-generated carriers in real time, progressing the development of high efficiency light-harvesting and energy conversion technology.

> - Integrated microoptical components for enhanced imaging and photon energy delivery.
> - Ultrafast lasers for monitoring charge injection dynamics in photoanodes.
> - Ultrafast lasers for assessing competitive deactivation channels limiting emission efficiency of solar concentrators.
> - Optical microscopies for *in situ* and *operando* monitoring of the physico-chemical processes occurring in battery materials during multiple charging-discharging cycles.

- photons can be employed in optical sensing **devices** for monitoring battery capacity or leakage in hydrogen fuel cells, or for monitoring the structural integrity of energy production/conversion equipment, while advanced laser processing can be used for the development of hydrogen storage materials and devices.

> - Optical fiber sensors for structural health monitoring of energy conversion structures.
> - Laser Shock peening as a processing technology to increase resistance to hydrogen embrittlement of materials used for hydrogen storage, transport and usage.
> - Surface Enhanced Raman Spectroscopy can be used to monitor the increased presence of reactant gas molecules (CO_2 and O_2) on the surface of ionomer-coated catalysts.
> - Embedded evanescent wave fiber optical sensors for studying degradation mechanisms in batteries during operation.

Laserlab-Europe's ambition is to accelerate the progression of the clean energy objectives by bringing solutions targeting all areas of the energy value chain: Energy Production and Conversion, Storage, Distribution, Consumption and Impact Monitoring.



Laserlab-Europe provides fast-track access to laser facilities and novel photonic diagnostic tools and processes, simultaneously offering performance assessment and standardization services, for speeding up photon-driven Clean Energy research and innovation.

Laserlab-Europe simultaneously supports demand-driven research responding to the current needs of society and the economy of today, as well as curiosity-driven research addressing the needs of tomorrow and transforming the economy.

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