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Macroarea di Ingegneria, University of Rome “Tor Vergata”

Book of Abstracts

Thermo-fluid dynamic behaviour of a small length 3D printed lattice channel in a conjugated problem

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The ever-smaller size of the electronic components and the ever-increasing thermal power to be removed, stimulate the possibility of studying the mini cooling channels with internal reticular structures, to increase the exchanged heat flow. The reduced dimensions in length imply the need to evaluate the behaviour of these lattice channels in the conjugate problem, i.e. with the development, from the inlet section, of both the thermal boundary layer and the fluid-dynamic boundary layer. The thermo-fluid dynamics characteristics of an aluminium 3D printed reticular channel are studied experimentally and numerically in this work. The lattice shape of the unit cell can be defined as a double X or a double pyramidal truss with a common vertex. The test channel (TC) is 80 mm long and has a cross-sectional area of dimensions *H*x*W*, where *H*=5mm and *W*=15mm. Pressure losses are measured and friction factors are calculated for different air volume flow rates, from 34 to 136 l/min. The flow regime varies from $\mathrm{Re}_H = 2305$ to $\mathrm{Re}_H = 9570$. Under steady state conditions, a constant heat flux is applied to the external surface of the lattice channel. Local Nusselt numbers are evaluated to understand the effect of the combined entry length problem. About the thermal performance, the main conclusion is that the tested lattice channel has average Nusselt numbers equal to 5 times the corresponding values of the smooth duct, without the truss, under the same operating conditions, i.e. conjugated problem and constant heat flux. Moreover, considering also the pressure drops in the overall evaluation of the reticular duct performance, the cooling efficiency is calculated by introducing the COP coefficient defined as the ratio between the removed thermal power by convective heat transfer and the mechanical power necessary to move the air.

Fuel Cell Hybrid Microcar sizing based on a Real-time Hardware-in-the-Loop test bench

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The urgent challenge of reducing emissions is strongly pushing for the development of cleaner transportation technologies. Among diverse promising solutions, hydrogen fuel cells (FCs) stand out as a possible key contributor to the pathway of zero-emission vehicles. This work then focuses on a microcar with a hybrid electric powertrain composed of a FC system and a battery pack. A methodological approach to the powertrain design based on a Hardware-in-the-Loop (HIL) test bench is presented, where vehicle's demands are simulated, while key powertrain components operate as real hardware in a closed-loop architecture. A linear FC scale-up approach is implemented with the aim of properly sizing the system, while ensuring the equivalence in behavior with the laboratory-scale system. Real-time tests along the WMTC homologation driving cycle show that FC oversizing compared to the baseline strongly improves the mean FC efficiency (from 46 up to 55 %), thus reducing overall energy consumption.

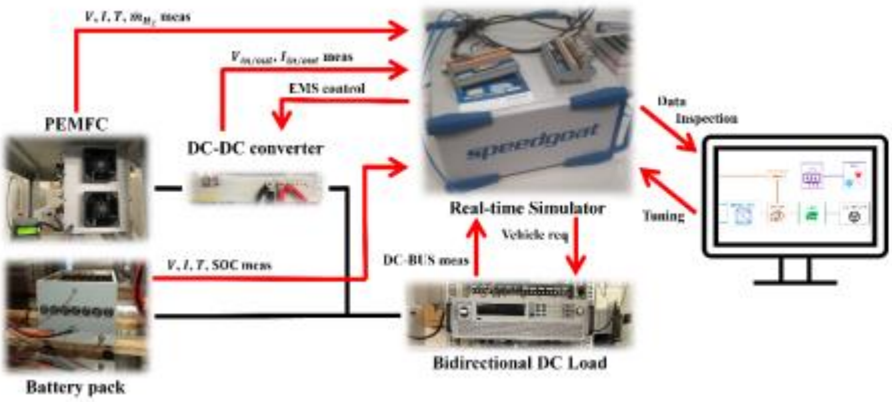

Figure 1: HIL platform, adapted from [1]

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Research, Development and Applications of Synthetic Diamond Detectors in Nuclear Fusion

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Synthetic diamond radiation detectors have proven to be highly suitable and useful for diagnostic systems in a wide range of applications, especially in nuclear fusion. Currently, two main approaches are being pursued in fusion research around the world: magnetic confinement fusion and inertial confinement fusion. In both methods, diamond detectors have played and will continue to play a significant role. They are crucial for tomographic reconstruction systems in tokamaks (first approach) and serve as time-of-flight detectors for particles generated by radiation-matter interactions (second approach).

In this presentation, I will briefly showcase the activities I carried out during my PhD in these research areas, ranging from experimental data collection to data analysis and Monte Carlo and analytical simulations.

Keywords: Solid-state Detector; Nuclear Fusion; Simulation

Synthesis and Characterization of ZnO-Sm_2O_3 Photocatalyst for the photocatalytic degradation of bentazon herbicide

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In this work, pristine zinc oxide (ZnO), samarium oxide (Sm_2O_3) and ZnO-Sm_2O_3 nanocomposite ZS were synthesized by co-precipitation technique. To investigate the physicochemical properties of prepared samples, X-ray diffraction (XRD), Fourier transform infrared spectroscopy (FTIR) and UV-vis spectroscopy (UV) were employed. XRD confirms the formation of nanocomposite consisting of ZnO (hexagonal) and Sm_2O_3 (cubic) structure. The smaller optical energy band gap of ZnO-Sm_2O_3 (2.61 eV) as compared to the individual oxides shows that it has light absorption range from UV to natural light. FTIR results confirm the formation of samples via presence of oxygen-metal bonds. ZnO-Sm_2O_3 nanocomposite shows outstanding photocatalytic performance against bentazon and achieved 90% degradation efficiency under UV light source in 140 minutes. The order of degradation efficiency against bentazon of the prepared samples was ZnO-Sm_2O_3>ZnO>Sm_2O_3 respectively. The effect of different operational parameters on the photocatalytic performance of ZnO-Sm_2O_3 including catalyst loading, bentazon concentration and pH effect along with reusability experiment was also studied. ZnO-Sm_2O_3 nanocomposite was found to be a potential candidate for wastewater treatment.

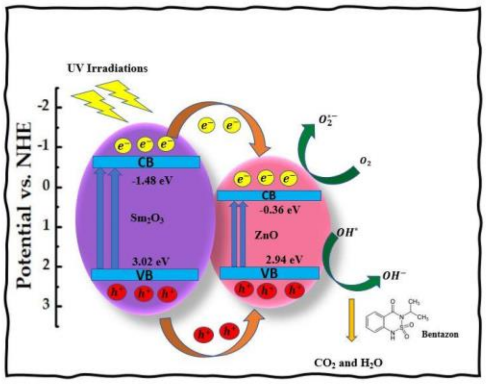

Figure 1: Schematic representation of photocatalytic mechanism of synthesized ZS nanocomposite against bentazon.

Investigation of 316L Alloy produced by Additive Manufacturing for Nuclear Applications

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Nuclear energy has the potential to deliver large-scale, dependable baseline electricity at commercially viable prices with minimal environmental impact. However, the future of nuclear power extends beyond the existing generation of light water reactors. Regardless of reactor design, nuclear reactors provide a severe environment for component service. The core components within a reactor must be able to withstand vigorous neutron environment, and extreme thermal gradient in addition to the exposure of various types of coolants such as liquid metals, liquid salts, gas and high temperature water. The deterioration of reactor material due to this severe environment may lead to diminished performance and instant collapse.

Additive manufacturing (AM) techniques, such as laser and electron beam melting (EBM), provide numerous benefits when fabricating or joining components made from 316L austenitic stainless steel. These advantages include greater part complexity, minimized or eliminated heat-affected zones, higher precision, and the formation of strong metallurgical bonds. As a result, these features can enhance the mechanical performance of the manufactured components and support component repairs in industries like nuclear, aerospace, and chemical processing.

A Pyrolysis-based Hybrid Energy System for flexible H_2 conversion and production from residual biomass

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The need for decarbonization in hard-to-abate sectors, such as industry and transportation, is driving research towards sustainable alternatives [1]. Biomass-based products offer a promising path to replace fossil fuels. We propose an innovative hybrid-biorefinery concept for the integration of bioenergy system with the electric system. The aim of this work is to demonstrate the advantages of fast pyrolysis as key-element of the integration. The system can be operated in H_2 production mode, through steam gasification of pyrolysis char, or in H_2 conversion mode, through hydrotreatment of pyrolysis oil into drop-in fuel. The results showed that pyrolysis char significantly improves steam gasification performance, leading to a drastic reduction of tars (down to 0.3 g/Nm3) and hydrogen enrichment of syngas (up to 60 %) [2]. In the H_2 conversion mode, a very limited amount of hydrogen was required to stabilize the pyrolysis oil, removing the reactive oxygenated groups of phenolics [3].

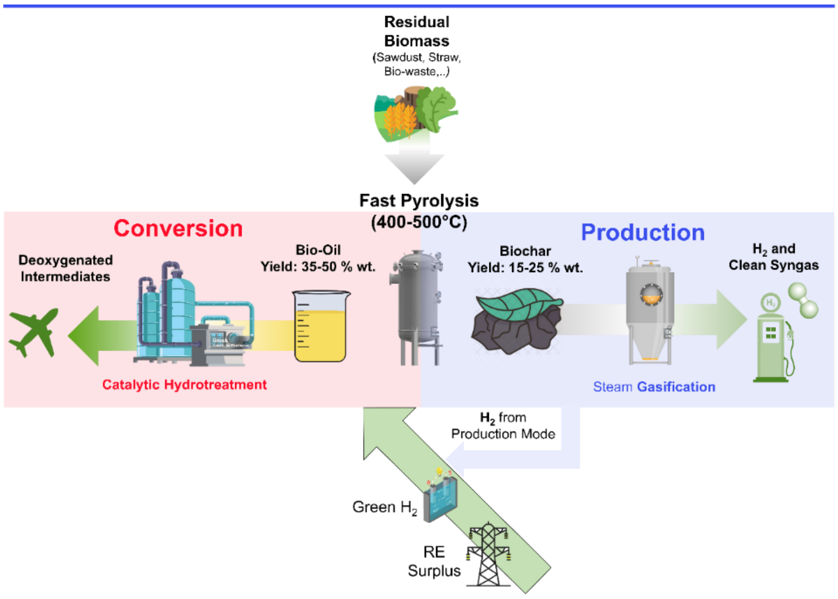

Figure 1: Graphical Concept of the pyrolysis-based hybrid biorefinery, object of this work

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Sustainable Fleet Operations: A Tool for Optimizing Electric and Fuel Cell Hybrid Vehicles in Urban Logistics

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To mitigate greenhouse gas and pollutants emissions, the integration of alternative vehicles, such as electric vehicles (EVs) and Fuel Cell Hybrid Electric Vehicles (FCHEVs), has proven to be essential, especially in urban areas where traffic congestion is prominent. However, their widespread adoption poses several challenges, mainly related to their usage and management. This work lays the foundation for a fleet management support tool in a logistic application, designed to optimize mission schedules to meet requirements while minimizing vehicle impact on the grid. A data-driven model for a light-duty commercial BEVs has been implemented due to its easy integration into a broader framework and low computational costs. Additionally, an innovative Energy Management Strategy (EMS) for FCHEVs sub-optimal control has been developed to improve the hybrid powertrain efficiency. This EMS will be integrated into the tool, promoting sustainability and energy diversification in fleet operations.

Conceptual design of the bolometric diagnostic system for DTT: mechanical layout

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The Divertor Tokamak Test (DTT) facility is currently under construction at the ENEA Frascati Research Centre, Italy, with the aim of study divertor configurations in support to the realisation of ITER and DEMO. In the context of monitoring the radiated power, it is crucial to measure the entire spectrum of electromagnetic radiation emitted by the plasma. This need is particularly relevant in the divertor region, especially in the specific case of DTT scientific programme.

This work presents the conceptual design of the bolometric diagnostic system, aimed at monitoring the total radiated power.

The first main challenge has been identifying an optimised design for the arrays of metal foil bolometers, aimed at minimising the space occupied in the port, at integrating with other devices, and at ensuring the best possible coverage of the lines of sight (LoS) in the vessel.

Finally, the devised layout has been validated with structural and thermo-mechanical simulations, with a focus on the design of the active cooling system, necessary to manage the thermal conditions of the wall, particularly the backing, and the intense loads during machine operation.

Synthesis and Applications of New Non-Fluorinated Ionomers

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The major aim of this research work is the synthesis and applications of new polymeric ionic conducting materials (ionomers) which are sustainable alternative of fluorinated ionomers. These newly sustainable ionomers can be utilized for the development of ion exchange membranes which are helpful in fuel cells, batteries and water purification (mainly heavy metals). To develop new ionomers, we are focusing on polyethersulfone (PES), polyphenylsulfone (PPSU) and polysulfone (PSU). PES and PPSU were functionalized by performing sulfonation under specified conditions and analyzed by using analytical techniques like FTIR and NMR. After electrochemical characterization these ionic conducting polymers will be used in the form of membranes in desired applications like, Li-ion batteries. On the other hand, PSU was functionalized by performing chloromethylation under specified conditions. After characterizing with various techniques, we are incorporating different functional groups as well as covalent organic framework (COF) with polymer chain. These newly developed materials will be used as ionomers in catalytic electrodes for oxygen reduction and hydrogen oxidation in basic environment.

* This work is supported by PRIN 2022 D.D. 104 02-02-2022 – (GreenCore) (CUP N: E53D23001030006, J53D23000910006).

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Design of gynecologic surgical manipulator

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Today, gynaecological surgeries are performed mostly via laparoscopic surgery, which consist in creating small incisions through the abdomen of the patients to access reproductive organs to treat problems such as fibroids or endometriosis. However, given the limited manipulation space, it is not uncommon to perform total or partial hysterectomies (ablation of reproductive organs) which are highly invasive and have undesirable long-term side effects on women. The goal of my PhD is to develop a device able to navigate the natural channel of the reproductive organs to reduce invasiveness of gynaecological operations. It could also be used for retrieval of IUDs (contraceptive device) or extraction of tissues ex-vivo analysis. The proposed device is a continuum robot, as they are known to comply to their surroundings, to deliver surgical tools directly through the natural channel and allow less invasive operations. [1] [2]

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Plasma-assisted surface treatments on additively manufactured 316L austenitic stainless steel

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Austenitic stainless steels exhibit excellent corrosion resistance but suffer from low hardness and poor wear resistance, therefore carburizing treatments are often required. To prevent detrimental effects on corrosion resistance, the treatment must be carried out at low temperatures (< 500 °C).

Therefore, low temperature plasma-assisted carburizing treatments, carried out at 475 °C using a microwave plasma enhanced chemical vapour deposition (CVD) reactor, have been employed to improve surface hardness of a 316L stainless steel produced by L-PBF.

A set of carburizing atmosphere compositions (amounts of CH_4 and H_2) and treatment time frames (from 30 minutes to 7 hours) have been tested to investigate their effects on surface hardening and wear behaviour.

The treated samples have been characterized by Light Microscopy, Scanning Electron microscopy, Atomic Force Microscopy, X-ray Diffraction, Raman Spectroscopy, X-ray Photoelectron Spectroscopy, Vickers Micro-hardness tests, Glow-discharge optical emission spectroscopy and wear tests.

The thesis work led to determine the optimal treatment parameters: 90 minutes in atmosphere composition of 2.5% CH_4 and 97.5 % H_2.

A data-integrated approach for experimental phenomena reconstruction and diagnostic analysis through Physics-Informed Neural Networks (PINNs).

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In experimental physics and engineering, discrepancies between measurements and physical models can arise due to inaccurate diagnostics or the lack of necessary prior information in the models. Additionally, some problems require iterative parameters selection for their solution. Physics-Informed Neural Networks (PINNs) offer a machine learning-based method to integrate physical laws and experimental data, enabling the prediction of unknown variables through neural networks. Although not suitable for real-time applications, PINNs are valuable for providing a deeper understanding of the studied phenomena, improving diagnostic systems, and enabling high resolution reconstructions of experimental data.

These capabilities make PINNs a powerful tool for addressing complex challenges in physics and engineering. This doctoral research has the aim to apply PINNs to physics and engineering challenging reconstruction problems in thermonuclear plasmas.

Synthesis and characterization of Furan-based polymers for Anion Exchange Membrane Fuel Cells from Biomass Resources

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Biomass is a sustainable energy source that can help reduce the environmental impact offering renewable resources for fuel cell technology. Anion exchange membrane fuel cells (AEMFCs) have significant potential in developing environmental sustainability and enhancing the components derived from biomass resources. In this study, we focused on the synthesis of furan-based polymers starting from 2,5 furan dicarboxylic acid (FDCA) as biomass-derived components used for anion exchange membrane. The reaction steps include the transformation of FDCA to acid chloride followed by interfacial polymerization to obtain the polyamide. These polyamides are modified by introducing long or short chains into the matrix, which are then quaternized by the introduction of ammonium groups. The resulting anion exchange polymers can be used inAEMFCs. The polymers are currently being characterized.

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Study and characterization of electromagnetic pulse in the radiofrequency-microwave band and particles generated by high intensity laser-matter interaction

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The study of Electromagnetic pulses (EMPs) generated in laser-matter interaction is of high importance for present and future laser facilities at high power and high energy[1]. There, in fact, extremely intense EMP emissions will be produced and set severe problems for mitigation. A full comprehension of the physics of EMP generation and mechanism of their operation is of primary importance for multidisciplinary range of applications: biological[2], aerospace[3], medical[4], among others.

Different possible sources of EMPs are to be considered and studied[5]; an use of unconventional diagnostics such as the Thomson Spectrometer[6] and more conventional ones were used in experimental campaigns. During an experimental campaign at ELI-Beamlines in Dolni Breznani (Czech Republic) focused on proton-boron nuclear reaction, different diagnostics were used for electric field measurement build by the company Kapteos (Sainte-Hélène-du-Lac, France): D-DOT (differential conductive probe) & EOP (electro optical probe).

* This work is supported by the university of Rome "Tor Vergata" along with ENEA Frascati

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Hunting particles in donut-shaped nuclear reactors: neutron diagnostics for fusion

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Nuclear fusion power production replicates the process that powers the Sun, where atomic nuclei in a high-temperature plasma are forced to fuse, releasing vast amounts of energy carried mainly by neutrons. Fusion offers the potential for a nearly limitless and sustainable energy source, with minimal radioactive waste and no risk of a meltdown.

The tokamak, a toroidal reactor, is to-date the most promising design for achieving controlled fusion, where the plasma is confined in a donut shape. Due to the high-energy neutrons produced during fusion, advanced diagnostic systems are essential to monitor their behaviour and their interactions within the reactor. This work provides an introduction to thermonuclear fusion and offers a glimpse into the complex diagnostic systems [1] used to monitor these fascinating particles: the neutrons. These diagnostics are crucial for understanding fusion performance, optimizing reactor design, and ensuring the safe operation of such reactors, as commercial fusion moves closer to reality.

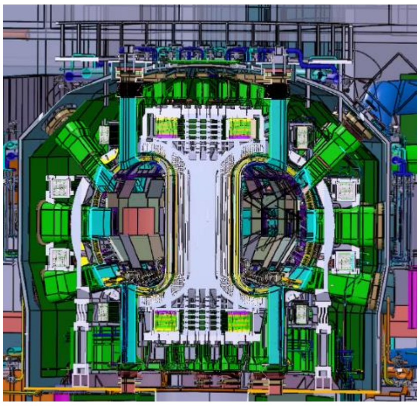

Figure 1:Cross section of a tokamak

* This work is supported by a scholarship funded by DTT Scarl.

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GENeuSIS: a novel concept of neutron test bed facility for diagnostics and critical components of ITER

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The radiation environment in ITER and other high-performance fusion machines shows a significant spatial, temporal, energy, and angular variability. Several responses and effects on materials and components depend on the energy spectra distribution. Regrettably, the currently available neutron facilities are not able to replicate the complexity and variability of the energy spectra distribution of the radiation field that the systems of interest will be subjected in ITER. As a result, conducting a comprehensive experimental test under ITER-like conditions is currently unfeasible. To address this challenge, a novel concept known as GENeuSIS (General Experimental Neutron System Irradiation Station) has been developed. GENeuSIS is a modular, flexible, customizable, and transportable test bed assembly constructed from standard materials for neutron facilities. Its purpose is to replicate the desired neutron and gamma energy spectra distribution. The focus of GENeuSIS studies has been to reproduce the expected neutron energy spectra at relevant ITER locations using 14 MeV neutrons generated at the Frascati Neutron Generator (FNG).

In 2023, a conceptual study using the MCNP Monte Carlo code demonstrated the feasibility of the GENeuSIS concept for ITER applications. The study provided the design of two assemblies, GENeuSIS-I and GENeuSIS-II, capable of replicating the neutron flux energy spectra expected in the ITER Port Interspace and Port Cell, respectively, within one of the Diagnostic Equatorial Ports. These simulations generated a valuable database, which was then utilized to train a machine learning model based on a neural network. The objective of this model is to accelerate pre-analysis and facilitate the selection of the optimal combination of materials to reproduce any desired neutron/photon energy spectra in future experiments.

This work presents the conceptual study and simulations conducted for GENeuSIS, highlighting its potential as a valuable tool for studying and replicating the complex radiation environment expected in ITER.

Design a robotic cell for car batteries disassembly: a new criteria for human robot-task distribution

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The increasing integration of robots into various industrial processes has led the way for enhanced efficiency and safety. In the automotive industry, the disassembly of lithium-ion batteries represents a challenge that can be addressed through collaborative efforts between humans and robots. Human-robot cooperation represents a versatile semi-automated strategy to counterbalance the impacts of uncertainties related to the frequency, quantity, and quality of End-of-Life (EoL) batteries. My work suggests the use of criteria useful for distributing tasks between robots and humans, analyzing the economic aspect and subsequently theorizing a parameter dependent on logistical factors such as base time, repetitiveness, accessibility and safety factors such as the operator's health. In the end, a case study by highlights the operation of screw loosening, comparing the results achieved by human with those of the robot, in this way, it is possible to determine the most suitable entity for performing such task.

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Multi-criterial evaluation of biomass energy conversion into energy carriers

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According to the last Intergovernmental Panel on Climate Change (IPCC) report [1] a significant revision of the planned milestones for the energy transition is required in order to mitigate global warming. The conversion of biomass into valuable energy carriers is a promising approach to supporting the energy transition. Its potential for polygeneration, combined with the flexibility of biomass conversion systems, makes it particularly appealing.

The aim of this analysis is to conduct a comprehensive evaluation of a biomass conversion pathway for the production of multiple energy carriers [2], considering both its energy performance and environmental impact (LCA). The results indicate that greater process integration leads to improved energy performance [3]; however, the environmental outcomes do not fully align with the energy results. It is therefore essential to define a more advanced evaluation methodology to find the multidimensional optimal solution, based on Multi-Criteria Decision-Making theory.

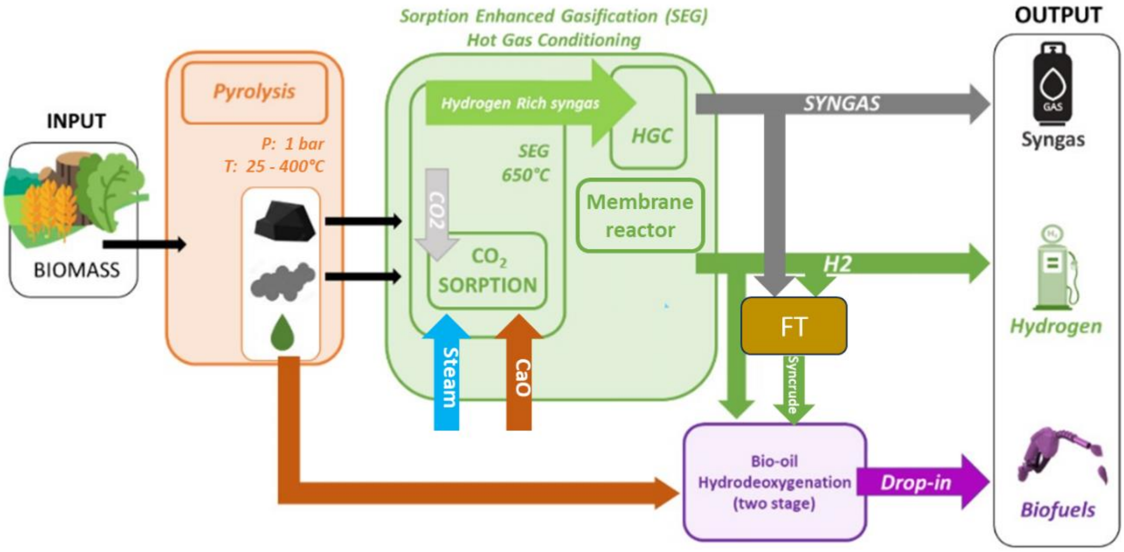

Figure 1: integrated process for energy biomass conversion

References

[1] Intergovernmental Panel on Climate Change, "Climate Change 2022: Mitigation of Climate Change - Summary for Policymakers," 2022

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Quantification and Classification of Fluorescent Dye-Labelled Microplastics in Water Samples

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Microplastics (MPs) with a size of less than 5 mm are emerging contaminants that are ubiquitous in our daily lives. Despite a great research effort, the methods for quantitative identification still rely on long and subjective visual counting procedures carried out on optical microscopes by skilled human operators. This study presents a new automatic, portable, low-cost, and fast method for quantitatively detecting MPs in water. The proposed method automatically processes and counts the fluorescence pulses emitted by dye-stained MPs in flowing liquids after excitation with a low-power laser beam. Nile Red dye was used for the quantification of MPs in commercial bottled water and tap water samples after staining parameter optimization for higher fluorescence signal-to-noise level, the result is in good agreement with microscope observations. In addition, for further studies on polymer identification and classification with selective fluorescent dyes, solvachromic dye DANS was also investigated and optimized with fluorescence microscopy and spectroscopy. Image analysis with machine learning of fluorescent channel images (RGB) proved the ability of DANS to selectively classify polymer types. The present investigation demonstrated a methodology for quick automated counting and classification of MPs with fluorescent dyes in water through a cost-effective and efficient approach.

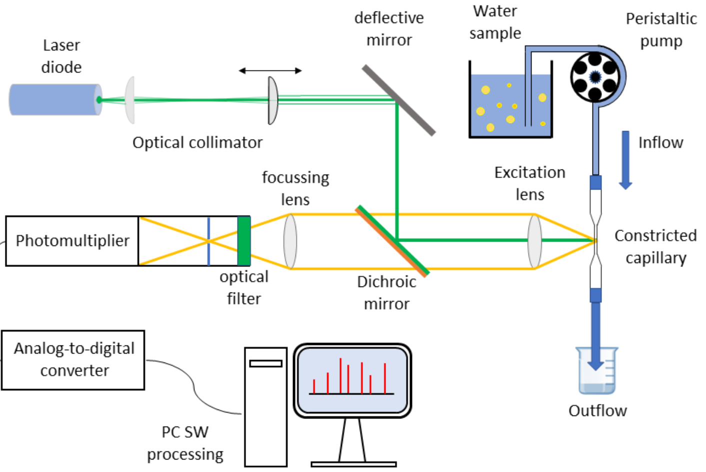

Figure 1: Schematic illustration of the detection method of microplastics based on fluorescence signals.

Integrating IMU and Video Motion Capture System: developing a protocol for real-time monitoring of ankle mobility

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The global population of elderly individuals is steadily rising, and as people grow older, they often become more hesitant to engage in physical exercise, leading to a higher risk of injury correlated with age. Ankle rehabilitation plays a vital role in restoring mobility and functionality after an injury, while also enhancing stability and preventing future injuries.

In response to these factors, the concept of developing a simple, lightweight, portable wearable device emerged. This device is designed to be user-friendly and can be operated independently, featuring intelligent control to ensure proper usage. It is applicable for rehabilitation purposes and as a motion assistance tool for the elderly. The proposed solution involves a cable-driven parallel mechanism robot that meets all these criteria.

This study is aimed at examining the ankle motion that can be used for motion analysis and characterization studies as well as for reference trajectory of assistive devices by using inertial measurement units (IMU) and video motion capture systems. The aim is to create a new protocol using easy-to-wear sensors that will enable continuous real-time tracking of ankle mobility and muscle performance. This will improve overall rehabilitation outcomes or motion assisting daily life activities especially in elderly people. This approach aims to enhance rehabilitation outcomes and assist with daily activities, particularly benefiting elderly individuals.