Program Card

Activation within the PhD course in Advanced Catalytic Processes for Using Renewable Energy Sources (ACCESS) of the following Research Program, based on the resources referred to Ministerial Decree no. 351/2022, related to the following Measure:

☐ **M4C1- Inv. 3.4** "*Didattica e competenze universitarie avanzate*" → **Dottorati dedicati alle transizioni digitali e ambientali.**

☐ **M4C1- Inv. 4.1** *"Estensione del numero di dottorati di ricerca e dottorati innovativi per la pubblica amministrazione e il patrimonio culturale".* In particolare:

☒ **PNRR Doctorates**

☐ **Dottorati per la Pubblica Amministrazione**
(selezionare l'area/le aree CUN di riferimento del programma tra quelle di seguito indicate)

- ☐ Area 09 – Ingegneria industriale e dell'informazione
- ☐ Area 11 – Scienze storiche, filosofiche, pedagogiche e psicologiche
- ☐ Area 12 – Scienze giuridiche
- ☐ Area 13 – Scienze economiche e statistiche
- ☐ Area 14 – Scienze politiche e sociali

☐ **Dottorati per il patrimonio culturale**
(selezionare l'area/le aree disciplinare/i e la tematica del programma tra quelle di seguito indicate)

- ☐ Area 01 – Scienze matematiche e informatiche **Tematica** – Informatica, patrimonio e beni culturali
- ☐ Area 02 – Scienze Fisiche **Tematica** – Fisica applicata al patrimonio culturale e ai beni culturali
- ☐ Area 03 – Scienze chimiche **Tematica** – Chimica, ambiente, patrimonio e beni culturali
- ☐ Area 04 Scienze della Terra **Tematica** – Georisorse minerarie per l'ambiente, il patrimonio e i beni culturali
- ☐ Area 05 Scienze Biologiche **Tematica** - Ecologia, patrimonio e beni culturali
- ☐ Area 08 – Ingegneria civile e Architettura **Tematiche** 1) Architettura, ambiente antropizzato, patrimonio e beni culturali 2) Architettura e paesaggio 3) storia dell'architettura; 4) Restauro; 5) Pianificazione e progettazione dell'ambiente antropizzato; 6) Design e progettazione tecnologica dell'architettura
- ☐ Area 10 Scienze dell'antichità, filologico-letterarie e storico -artistiche **Tematiche** 1) Archeologia; 2) Storia dell'arte; 3) Media, patrimonio e beni culturali
- ☐ Area 11 – Scienze storiche, filosofiche, pedagogiche, psicologiche **Tematiche** 1) Biblioteconoma; 2) Archivistica; 3) Storia del patrimonio e dei beni culturali 4) Paleografia; 5) Estetica; 6) Didattica dell'arte; 7) pedagogia dell'Arte
- ☐ Area 12 - Scienze giuridiche **Tematica** Diritto del patrimonio culturale
- ☐ Area 13 - Scienze Economiche e statistiche **Tematiche** 1) Economia della cultura e dell'arte 2) Economia e gestione delle imprese artistiche e culturali; 3) Statistica e Data Analytics per i beni culturali
- ☐ Area 14 Scienze Politiche e sociali **Tematiche** 1) Sociologia dei beni culturali 2) sociologia dell'ambiente e del territorio

- **Research Program Title**: Development of devices and electrodes for direct storage of solar energy into energy carriers

- **Description** (MAX 5000 CHARACTERS, SPACES EXCLUDED)**:**

The objective of the PhD is to develop the scientific-technological basis for innovative technology for the direct conversion (in a single stage without intermediate production of H_2) of renewable energy into chemical energy in a form easy to store and transport. Energy carriers, also referred to as e-fuels or solar fuels, are a necessary element in the renewable energy development chain and the replacement of fossil fuels to achieve the net-zero emissions (NZE) of greenhouse gases, as they are necessary to i) mitigate the dependence on temporal fluctuations in renewable energy production, ii) allow a geographical balance between demand and production, iii) reduce CO_2 emissions in energy-intensive industrial sectors, where direct use of renewable energy is not possible. The development of efficient technologies to produce these energy carriers is, therefore, necessary to achieve the transition to NZE in 2050 as set at the European level.

Current processes to produce these energy carriers (referred to as power-to-X, PtX) are multistage and not efficient. Furthermore, the costs, even considering the possible developments up to 2050, will be too high for a significant impact. It is, therefore, necessary to develop a new generation of processes that go beyond the intrinsic limits of PtX technology. The study's objective is to create an integrated device, and the necessary electrodes, for the efficient direct electrocatalytic conversion of CO_2 from emissions (eliminating the need for its capture and separation, which drastically increases costs) into energy carriers such as CH_4 or CH_3OH.

The innovative aspects of the proposed technology concern i) the possibility of operating directly with diluted CO_2 solutions through the development of innovative membranes integrated into the electrocatalytic device, capable of increasing the effective concentration of CO_2 at the surface of the electrocatalyst, ii) the development of solid-state redox mediators at the anode that allows decoupling the anodic and cathodic reactions, replacing the anodic oxygen evolution process with a reaction cycle that increase the efficiency and speed of the process, iii) the development of an integrated device which captures CO_2 and converts it to energy carriers such as CH_4 or CH_3OH using solar energy and water. The general objective is to develop knowledge for a technology that converts CO_2 to energy carriers with lower costs and a lower carbon footprint than the current processes under development PtX. This technology is suitable for distributed and/or remote production of these energy carriers.

The PhD course is perfectly consistent with the PNRR PhDs, as the issue of the production of low-cost energy carriers and carbon footprint is among the priorities present in the PNRR for the improvement of environmental sustainability, the reduction of greenhouse gas emissions, and its impact on climate change, the development of sustainable technologies for an improvement of integration with the resources of the territory that increase its resilience.

The activities planned for the PhD student relate to the development of fundamental knowledge for the demonstration of the feasibility (proof-of-the-concept - PoC) of the technology. They will therefore focus on the following aspects: i) synthesis, characterization, and evaluation of electrodes and electrocatalysts for the selective reduction of CO_2, ii) development of regenerable $Ni(OH)_2$ supported anodes that act as redox storage devices, and allow the efficiency and speed of the CO_2 reduction process improvement, iii) development of membranes to be able to operate the devices in the presence of diluted CO_2 emissions, iv) development of a device for the PoC of the technology and preliminary assessment in terms of cost and emissions of CO_2 compared to PtX type multistep production.

The PhD student’s main activity will be at the CASPE Laboratory (Catalysis for Sustainable Production and Energy) of the University of Messina, which will be integrated into two training periods for the PhD student, one abroad (6 months) at the IRCELYON (Francia) for an improvement of knowledge relating to membranes for CO_2 concentration on the surface of the electrocatalyst, and one at the CNR research centre (specifically to ITAE Advanced Technology for the Energy Institute “N. Giordano”, 6 months) for the development and scale-up of electrocatalytic storage devices.

The dissemination and communication of the results will be aimed at enhancing the research results and protecting intellectual property that ensures open access to the public, the research results, and related data in the shortest time and with the least number of possible limitations, according to the "Open science" and "Fair data" principles.

❖ **TIME TO BE SPENT AT ENTERPRISE – RESEARCH CENTERS – P.A.:**

The research program will be carried out in collaboration with the following subject:

Business name: CNR Consiglio Nazionale Delle Ricerche - National Research Council
Registered office: Piazzale Aldo Moro n. 7, cap. 00185, Rome
Corporate Legal Representative: Emilio Fortunato (CNR President's delegate)

The aforementioned institution will host the PhD student beneficiary of the scholarship financed on the resources of the DM DM 351/2022 for n. **6** months **(min 6 max 12)** during the PhD course.

❖ **PERIOD ABROAD**

The research program provides for a period abroad of n. 6 months **(min 6 max 18)** at the following institution:
IRCELYON (Institut de recherches sur la catalyse et l'environement), Lyon (Francia)

We also declare that this program complies with the principle "not to cause significant damage" (DHSH) pursuant to art. 17 of regulation (EU) 2020/852 in coherence with the technical guidelines prepared by the European Commission (Communication of the European Commission 2021 / C58 / 01) and guarantees compliance with the horizontal principles of the PNRR (contribution to the climate and digital goal so-called tagging, the principle of gender equality and the obligation to protect and enhance young people).