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 new technology to produce H_2 with a negative carbon footprint by catalytic cracking of activated biomethane for non-thermal plasma

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

The objective of the PhD is the development of the scientific-technological bases for innovative technology, an alternative to that of electrolysis to produce hydrogen with an ultra-low or negative carbon footprint (depending on the degree of development and optimization of the process) through the cracking of biomethane to low temperature (around 600° C) combining innovative catalysts based on defective nanocarbon and non-thermal plasma.

The proposed technology is aimed to be competitive both in terms of cost and CO_2 emissions compared to the production of "green" hydrogen by electrolysis and innovative compared to state of the art for methane cracking, as there are no similar industrial processes. Cracking processes (also called pyrolysis or decomposition) of methane to produce H_2, but which operate at high temperatures (above 1000° C), which reduce the efficiency of the process, are being studied in some industries, such as BASF, the obtainable production of H_2, as the latter must be used in part to produce the heat necessary for operations at such high temperatures. There are also material problems with such high-temperature operations. Furthermore, the carbon material obtained from methane cracking is of low quality and commercial value.

By introducing an activation of methane by non-thermal plasma, and catalysts based on defective nanocarbons, the goal is to lower the operating temperatures to around 600° C, allowing considerable advantages from the point of view of the industrial process: i) it is possible to operate the process using only renewable energy, ii) the carbon obtained from the decomposition of methane grows in the form of nanofilaments on a nanocatalyst, allowing to obtain a material that can be used as an additive to produce advanced materials such as reinforced polymers, iii) it can be operated with a continuous process, iv) the sensitivity to impurities is reduced thus allowing to operate with biomethane. Therefore, it is possible to obtain a process with a reduced carbon footprint, lower costs, and higher productivity compared to the methane cracking technologies under development, resulting in a competitive alternative to electrolysis to produce H_2 in distributed processes.

The PhD course is perfectly coherent with the objectives of the PNRR PhD courses, as the issue of low carbon footprint and H_2 production is among the priorities present in the PNRR for the improvement of environmental sustainability, the reduction of gas emissions greenhouse and its impact on climate change, the development of sustainable technologies to improve integration with local resources (biogas plants, renewable energy) that increase their resilience.

The PhD student's planned activities are related 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 defective nanocarbons in relation to their activity in methane cracking, ii) development of plasma jet type microreactors for the activation of methane, and their integration in a circulating bed reactor containing the catalyst, iii) evaluation of the characteristics of the carbon material growing on the catalyst as a result of methane cracking, and effect of the reaction and activation conditions of methane for non-thermal plasma, iv) development of a device for PoC of technology and preliminary assessment in terms of cost and CO_2 emissions compared to H_2 production by electrolysis.

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 Technische University of Eindhoven (The Netherlands) for an improvement of knowledge relating to non-thermal plasma and design of plasma-catalysis reactors, and one at the Snam Company (6 months) for the evaluation of the technical-economic feasibility of the developed technology.

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: SNAM Spa
Registered office: San Donato Milanese (MI), Piazza Santa Barbara 7, 20097
Corporate Legal Representative: Marco Alverà

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:
Technische Universitat of Eindhoven (Netherlands)

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).