

UNIVERSITÀ DEGLI STUDI DI GENOVA
AREA RICERCA, TRASFERIMENTO TECNOLOGICO E TERZA MISSIONE
SERVIZIO RICERCA
SETTORE RICERCA NAZIONALE

IL RETTORE

Vista la Legge 9 maggio 1989, n. 168 - Istituzione del Ministero dell'Università e della ricerca scientifica e tecnologica e ss.mm.ii;

Visto lo Statuto dell'Università degli Studi di Genova;

Visto il Regolamento Generale di Ateneo;

Visto il Regolamento di Ateneo per l'Amministrazione, la Finanza e la Contabilità;

VISTA la legge 7 agosto 1990, n. 241 recante "Nuove norme in materia di procedimento amministrativo e di diritto di accesso ai documenti amministrativi" pubblicata sulla Gazzetta Ufficiale n. 192 del 18/08/1990 e s.m.i.;

VISTO il Decreto del Presidente della Repubblica 28 dicembre 2000, n. 445 (Disposizioni legislative in materia di documentazione amministrativa) e s.m.i.;

VISTO il Decreto Direttoriale MUR n. 341 del 15/03/2022 di emanazione di un Avviso pubblico per la presentazione di Proposte di intervento per la creazione di "Partenariati estesi alle università, ai centri di ricerca, alle aziende per il finanziamento di progetti di ricerca di base" nell'ambito del Piano Nazionale di Ripresa e Resilienza, Missione 4 "Istruzione e ricerca" – Componente 2 "Dalla ricerca all'impresa" – Investimento 1.3, finanziato dall'Unione europea – NextGenerationEU";

VISTO il Decreto Direttoriale MUR n. 1561 dell'11 ottobre 2022 Codice identificativo PE00000021, Acronimo NEST, Titolo "Extended Partnership Network 4 Energy Sustainable Transition" (CUP D33C22001330002) registrato alla Corte dei Conti il 04/11/2022 con prot. n. 2784 e relativi allegati;

CONSIDERATO che l'Università degli Studi di Genova è leader dello Spoke 4, dal titolo "Clean Hydrogen and Final Uses";

CONSIDERATO che gli Spoke possono emanare - nell'ambito dei limiti e con le modalità previste dall'Avviso - "bandi a cascata" finalizzati alla concessione di finanziamenti a soggetti esterni per attività coerenti con il progetto approvato;

VISTA la delibera della seduta del 27 settembre 2023 con cui il Consiglio di Amministrazione dell'Università degli Studi di Genova ha approvato il modello del "Bando a Cascata" per Organismi di Ricerca;

VISTO il Decreto del Direttore Generale n. 5418 del 14 novembre 2023 di nomina del Responsabile del Procedimento;

VISTO il Decreto del Rettore n. 366 del 24 gennaio 2024 di emanazione del Bando a cascata per il



finanziamento di proposte di intervento per attività di ricerca svolte da Organismi di Ricerca nell'ambito del Programma di ricerca "Extended Partnership Network 4 Energy Sustainable Transition – NEST" PE00000021 - SPOKE N. 4 - CUP D33C22001330002 di cui al Decreto direttoriale n. 1561 del 11 ottobre 2022, registrato dalla Corte dei Conti il 04/11/2022 n. 2784;

CONSIDERATO che alla data di scadenza per la presentazione delle proposte progettuali, fissata entro e non oltre il giorno 29 febbraio 2024, per la **Tematica B - Innovation for novel membranes for electrolyzers** era pervenuta a mezzo PEC all'indirizzo air3@pec.unige.it la seguente proposta:

PROPONENTE: Università degli Studi di Milano Bicocca - Prot. 13251_22.02.24

TITOLO PROPOSTA: Piperidinium-based highly stable membranes for anionic electrolyzers (PIPERANION)

TENUTO CONTO che con D.D. 1264 del 18 marzo 2024 la Responsabile del procedimento, Ing. Patrizia Cepollina, ha ritenuto ricevibile, ammissibile e conforme la proposta sopra citata;

CONSIDERATO che nel Bando è previsto che la valutazione di merito tecnico-scientifico dei progetti pervenuti sia affidata ad una Commissione composta da almeno tre esperti esterni al Partenariato, indipendenti e competenti dell'Area tematica dello Spoke;

VISTO il D.R. 1025 del 28 febbraio 2024 di emanazione dell'Avviso di manifestazione di interesse per la costituzione di un Albo di esperti indipendenti a supporto della valutazione di merito dei progetti PNRR presentati sui bandi a cascata del progetto NEST – "Extended Partnership Network 4 Energy Sustainable Transition";

VISTO il D.R. n. 1477 del 26 marzo 2024 che ha costituito l'Albo a supporto della valutazione dei progetti presentati in risposta al bando a cascata, emanato dall'Università degli Studi di Genova in qualità di Leader dello Spoke 4 del progetto NEST – CUP D33C22001330002, con D.R. n. 366 del 24/01/2024;

VISTO il D.R. n. 1549 del 28 marzo 2024 con cui è stata nominata la Commissione di valutazione delle proposte pervenute in risposta al bando a cascata indicato nelle premesse del presente decreto;

ACQUISITO il verbale della Commissione di Valutazione della seduta del 17 maggio 2024 (Prot. 43820 del 20 maggio 2024) per la Tematica B - Innovation for novel membranes for electrolyzers;

VISTO il verbale della riunione del 21 maggio 2024 (Prot. 45085 del 22 maggio 2024) di presa d'atto dei Verbali della Commissione di valutazione;

TENUTO CONTO che in data 27 maggio 2024 è stata inviata all'Università degli Studi di Milano Bicocca la comunicazione Prot. 46747 in cui si rendevano noti gli esiti della procedura e si richiedeva la documentazione propedeutica all'adozione del provvedimento di ammissione del finanziamento;

TENUTO CONTO che la documentazione ricevuta con nota Prot. n. 48076 del 29 maggio 2024 è stata ritenuta conforme a quanto previsto nel bando a cascata di cui al Decreto del Rettore n. 366 del 24 gennaio 2024, indicato nelle premesse del presente decreto,



DECRETA

ART. 1

L'ammissione a finanziamento del progetto "Piperidinium-based highly stable membranes for anionic electrolyzers (PIPERANION)" per la **Tematica B - Innovation for novel membranes for electrolyzers** con soggetto proponente Università degli Studi di Milano Bicocca - come rappresentato negli Allegati B e C alla proposta presentata con domanda di partecipazione Prot. 13251 del 22 febbraio 2024

ART. 2

L'entità dell'agevolazione concessa, a fondo perduto, ammonta a 74.148 euro complessivi come rappresentati nell'allegato C alla proposta presentata con domanda di partecipazione Prot. 13251 del 22 febbraio 2024. L'agevolazione è pari al 100% dei costi di progetto trattandosi di attività di ricerca fondamentale per Organismi di Ricerca. L'agevolazione è concessa a valere sui fondi PNRR - Programma "NEST – Extended Partnership Network 4 Energy Sustainable Transition" Codice PE00000021 finanziato dalla Missione 4, Componente 2, Investimento 1.3, ai sensi del Decreto Direttoriale N. 1561 del 11 ottobre 2022, registrato dalla Corte dei Conti il 04/11/2022 n. 2784 iscritto al Bilancio di Ateneo sul progetto UGOV 100025-2022-LM-PNRR-PE_NEST_B_C_RICERCA_DIP- (CUP D33C22001330002);

ART. 3

Le attività di realizzazione del progetto, come indicate dettagliatamente negli Allegati B e C alla domanda di finanziamento, non potranno essere superiori a 12 mesi a decorrere dalla data di sottoscrizione del Contratto, salvo quanto previsto all'art. 6.3 del bando.

Le attività dovranno comunque essere concluse entro e non oltre il 31 agosto 2025, salvo proroghe del Programma di ricerca NEST concesse dal MUR, affinché siano rendicontate in tempo utile per consentire la chiusura del Programma di ricerca NEST il cui termine è attualmente previsto al 31 ottobre 2025.

ART. 4

Il presente atto sarà pubblicato sul sito UniGe <https://unige.it/progetti-finanziati-dal-pnrr> e sul sito <https://fondazionecest.it> - sezione Bandi.

Il documento informatico originale sottoscritto con firma digitale sarà conservato presso l'Area Ricerca, Trasferimento Tecnologico e Terza Missione.

IL RETTORE

Prof. Federico DELFINO

(documento firmato digitalmente)



ALLEGATO B

PE00000021

“PNRR MUR - M4C2 – NEST - Extended Partnership
Network 4 Energy Sustainable Transition”

SPOKE N. 4

CUP D33C22001330002

Research proposal

Topic addressed by the project
“Innovazione per membrane per elettrolizzatori”

PIPERANION – Piperidinium-based highly stable
membranes for anionic electrolyzers

- Name of the PIs' host institution for the project: University of Milano Bicocca
- Name of the Principal Investigators (PIs): Piercarlo Mustarelli, Chiara Ferrara (co-PI, under 40)
- Proposal duration in months: 12

- Name and qualification of the Principal Investigator (PI): Piercarlo Mustarelli, Full Professor
- Name and qualification of the co- Principal Investigator (PI): Chiara Ferrara, RTDb
- Name and qualification of the components the research team: Alessandro Ferrari, PhD student.

<i>ROLE IN THE PROJECT</i>	<i>NAME</i>	<i>SURNAME</i>	<i>INSTITUTION/ DEPARTMENT</i>	<i>QUALIFICATION</i>	<i>YOUNG (under 40 al 31.12.2023)</i>	<i>F/M</i>
Principal Investigator	<i>Piercarlo</i>	<i>Mustarelli</i>	<i>Milano Bicocca/ Materials Science</i>	<i>Full Professor</i>	<i>NO</i>	<i>M</i>
co-Principal Investigator (PI)	<i>Chiara</i>	<i>Ferrara</i>	<i>Milano Bicocca/ Materials Science</i>	<i>RTDb</i>	<i>YES</i>	<i>F</i>
<i>Researcher</i>	<i>Alessandro</i>	<i>Ferrari</i>	<i>Milano Bicocca/ Materials Science</i>	<i>PhD student</i>	<i>YES</i>	<i>M</i>

ABSTRACT

Combining the current advantages (chiefly low cost) of liquid-electrolyte electrolyzers, AELs, with those of the proton electrolyte membrane electrolyzers, PEMELs (pressurized and ultrapure hydrogen, increased safety, low internal resistance), while leveraging on the fact that non-critical raw materials can replace expensive Pt-group chemical elements when operating under alkaline conditions, can be a true breakthrough towards the realization of the Hydrogen Economy.

This objective can be reached by developing new-generation anionic electrolyte membrane electrolyzers, AEMELs, able to work at low temperature (i.e. 60 C), with pure water or low KOH content in the electrolyte, without utilization of critical raw materials (CRMs), and fluorine, so opening new venues for massive and sustainable production of green hydrogen. To achieve this goal, it is mandatory the synthesis of anion exchange membranes (AEMs) and ionomers (AEI) fully fluorine-free, capable of operating with reduced or even without KOH in the liquid electrolyte.

PIPERANION has the ambition of developing new-generation anion conducting membranes which can be implemented in AEMEL totally without critical raw materials (CRMs). If successful, PIPERANION will have important scientific, economic, technological, and societal impacts leading to a novel class of AEMEL to produce green hydrogen.

PIPERANION is entirely performed at the University of Milano Bicocca, inside the Electrochemistry Group of the Department of Materials Science. It is organized into three tasks and the duration is 12 months.

RESEARCH PROPOSAL

Sections (a) and (b) should not exceed 4 pages. References do not count towards the page limits.

Section a. State-of-the-art and objectives

State-of-the-art

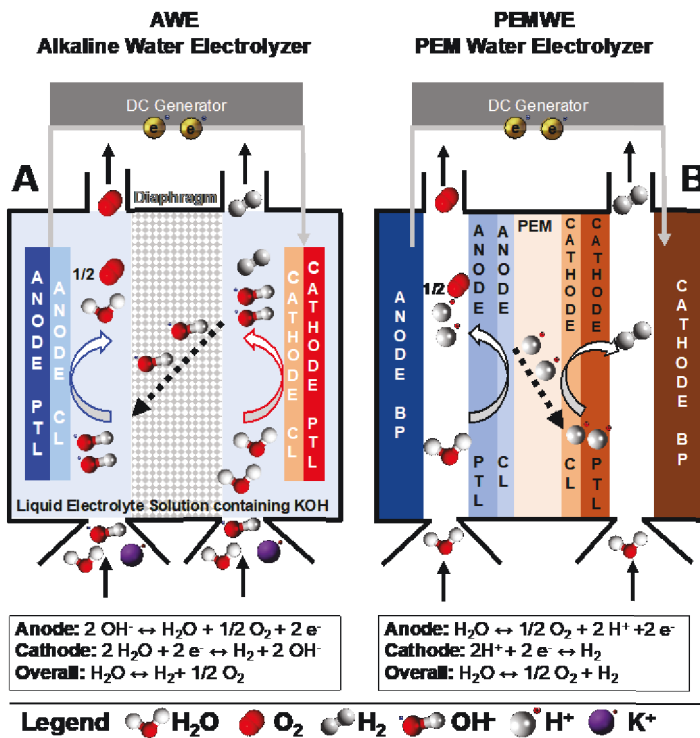


Figure 1.1. Schematic of an alkaline water electrolyzer (AWE) (A) and a proton exchange membrane water electrolyzer (PEMWE) (B)

AWE does not contain CRMs, as shown in Table 1.1 (red pentagons are absent). However, fluorinated polymers (blue pentagons) might be used as sealings, although non-fluorinated materials might also be adopted as alternatives.

PEM is another low temperature WE technology (Fig. 1.1.B). Due to the low ohmic resistance of PEM and its mechanical robustness, PEMWE can operate at a higher current density than AWE ($> 1 \text{ A/cm}^2$) and directly produce H_2 pressurized at 15-50 bars. Unfortunately, the acidic medium of PEMWE requires electrocatalysts (ECs) based on platinum group metals (PGMs), and porous transport layer (PTL) and bipolar plates (BPs) made of titanium, making PEMWEs prohibitively expensive and currently non-sustainable at large-scale production. This criticality is reported in Table 1.1 where practically all the components are based on CRMs, except the cathode PTL that can be substituted by carbon cloth. Large-scale utilization of CRMs for WE would translate Europe's current dependence on fossil fuels to a new or exacerbated dependence on CRMs in the future.

Using iridium, the scarcest metal on Earth, to catalyze the anodic oxygen evolution reaction (OER) in PEMWE is non-scalable. The Ir price increased from 1600 to 6100 US\$/oz between 06-2020 and 06-2021, remaining on average at 4800 US\$/oz over the last 18 months, giving a taste of the criticality of this element and how its price fluctuates with the demand.^[4] Moreover, it was underlined that the criticality of Iridium is fundamentally

Global climate change is calling for a paradigm change (Hydrogen Economy, HE) in the way we produce and use energy. HE substantially relies on green hydrogen produced from water electrolyzers (WE) powered by sustainable energy sources. Now, WEs are the only technology capable of producing hydrogen at intensity high enough to satisfy the projected consumption of hydrogen. Alkaline Water Electrolyzers (AWEs) (Fig. 1.1.A) is the most common commercial electrolyzers' technology to-date. The materials used in AWE are described in Table 1.1.^[1] Their electrodes are free of critical raw materials (CRMs-free) (Table 1.1) dipped in liquid alkaline electrolyte, separated by a diaphragm.^[2] This technology is limited to producing unpressurized H_2 (due to the crossover through the diaphragm) and at a maximum current density typically of 0.5 A/cm^2 . In addition, AWE operates with concentrated KOH ($\sim 6 \text{ M}$) posing important challenges to cell materials and safety.^[3] These factors translate to a relatively high H_2 production cost and low durability for AWE.

	Alkaline	PEM
Electrolyte	Potassium hydroxide (KOH) 5-7 molL ⁻¹	PFSA membranes
Separator	ZrO ₂ stabilized with PPS mesh	Solid electrolyte (above)
Electrode / catalyst (oxygen side)	Nickel coated perforated stainless steel	Iridium oxide
Electrode / catalyst (hydrogen side)	Nickel coated perforated stainless steel	Platinum nanoparticles on carbon black
Porous transport layer anode	Nickel mesh (not always present)	Platinum coated sintered porous titanium
Porous transport layer cathode	Nickel mesh	Sintered porous titanium or carbon cloth
Bipolar plate anode	Nickel-coated stainless steel	Platinum-coated titanium
Bipolar plate cathode	Nickel-coated stainless steel	Gold-coated titanium
Frames and sealing	PSU, PTFE, EPDM	PTFE, PSU, ETFE

Table 1.1. Components of AWE and PEMWE. (Coloured cells represent components with significant variation among different companies.)

🔴 CRM. 🟠 Potential CRM. 🔵 Fluorinated

related to its scarcity,^[5] implying that increased production will be limited. In addition, PEMWEs currently lean on fluorine-based polymers both for their proton exchange membrane and the sealing (blue pentagons in Table 1.1), with strong environmental impact due to the emission of fluorocarbon gases at the production stage of tetrafluoroethylene.^[6-7] Some institutions recently proposed the phasing-out of fluoropolymers for environmental reasons^[6-7] and the European Commission is currently active in restricting their use in the near future.^[8]

The advantages of AWEs and PEMWEs can be combined by developing systems based on anion-exchange membranes (AEMs), also leveraging on the fact that CRMs can be replaced by ECs based on Earth-abundant elements when operating under alkaline conditions (Figure 1.3). **PIPERANION aims at developing an innovative class of low-temperature anion-exchange membrane able to be integrated in WEs (AEMWE) working with pure water (or diluted KOH) electrolyte at reduced cost, without utilization of CRMs and fluorine.**

The presence of the polymeric membrane in WE has a positive feedback on hydrogen and oxygen separation, improving the

device safety and H₂ purity. Moreover, the AEM allows a zero-gap configuration of the membrane-to-electrode-assembly (MEA), reducing the ohmic cell resistance. At last, a mechanically robust polymeric membrane allows producing pressurized hydrogen, which is desired as it does not affect much the cell voltage needed to reach a given current density. In AEM electrochemical technologies (both fuel cells and WEs), AEMs and the ionomers (AEIs) are critical components and their stability (thermal, chemical and mechanical)

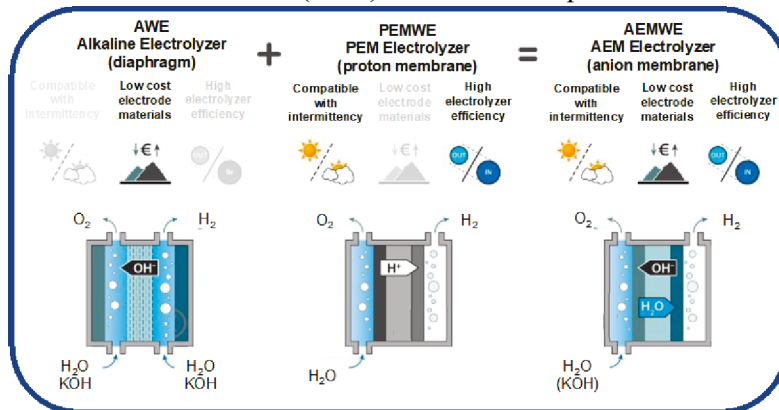


Figure 1.3. Advantages of AEMWE

hydroxide anions attack the positively charged cations through Hofmann elimination (E2), SN2, and N-ylide formation in the case of trimethylbenzylammonium (TMBA) cation group.^[11] Such a chemical attack of cationic groups progressively decreases the AEI/AEM's IEC, and thus OH⁻ conductivity, over time. Moreover, this degradation leads to a reduction of membranes mechanical strength.

Beyond the state of the art.

The development of disrupting and stable polymeric AEMs with minimal thickness to reduce the ohmic losses is crucial for the success of AEMWEs. Novel AEMs will be synthesized using safe and sustainable methods.

Importantly, compared to SoA PEM, the AEM and AEI developed will not contain fluorine, making the system more environmentally friendly and easy to recycle at the EoL. Complementary strategies will be pursued during the synthesis to improve material conductivity, reduce the crossover of undesired species, and increase mechanical strength. We will focus our attention on systems based on poly(aryl piperidinium)s (PAPs), which combine a heteroatom free backbone with the stable piperidinium cationic group. The simplest and less expensive chemistry in this family is poly(biphenyl piperidinium), whose mechanical properties will be improved by tuning polymer chain distribution, and/or by adding proper fillers/additives. [12] AEIs will be obtained by dissolving polymers developed for AEMs. AEMs will first be characterized by physico-chemical measurements e.g., water uptake, swelling behavior, ion-exchange capacity, mechanical strength, rheological properties, ionic conductivity, etc. AEMs/AEIs will be then studied *ex-situ* by a wide array of microscopic and spectroscopic tools, including SEM, solid-state NMR, micro-Raman, EIS.

Section b. Methodology

The work will be divided into three tasks:

Task 1. Development of AEMs (M1-M10)

We will synthesize AEMs based on poly(aryl piperidinium)s (PAPs), which combine an heteroatom-free backbone with the stable piperidinium cationic group. The backbones could be further functionalized with suitable side chains, followed by: (i) amination; (ii) quaternization; (iii) anion-exchange. As anticipated, we will start from poly(biphenyl piperidinium), whose mechanical properties will be improved by tuning polymer chains distribution, and/or by adding proper fillers. In this last case, hybrid inorganic-organic AEMs will be obtained by dispersing the fillers, also with scavenging properties, into the macromolecular matrices. The nanostructured fillers could have a “core-shell” morphology, including a “core” with basic species (e.g., mesoporous silica, etc.). The “shell” will consist of species with a low Mohs hardness able to wrap the “core” (e.g. carbonaceous 2D structures such as graphene and related materials (GRMs) or functionalized CeO₂ layers). The fillers may also undergo further functionalization with suitable OH-exchange groups.

For AEM formation different approaches based on the phase inversion casting technique will be evaluated, considering solvent evaporation and /or a coagulation bath containing nonsolvent. Different temperatures and times will be studied to select the best operative parameters for AEMs manufacturing. An evaluation of post-casting procedure in terms of chemical and thermal treatments will be performed.

An investigation of the optimal quantity of fillers to be introduced as a function of membrane properties (IEC, thermal stability, conductivity, etc.) will be performed. Different procedures, e.g. sonication, magnetic stirring, ball milling, to obtain homogeneous and stable polymer dispersion together with the possibility to introduce a dispersant will be studied. In addition, the possibility to realize reinforced membranes by using a thin, porous support, e.g. high molecular weight polyethylene, with the aim to improve mechanical properties under stress conditions of operative pressure will be evaluated. AEMs with a thickness lower than 20 μm and with an area higher than 100 cm^2 will be developed.

Task 2. Development of AEIs (M1-M6)

The approach for novel AEIs will be based on the use of dissolved polymers developed for AEMs in Task 1. The AEIs will be developed by optimizing the preparation operative conditions in terms of solvents (alcohols at different C length, water, etc.), mixture of alcohols/water and its ratio, temperature, and times of dispersion/solubilization steps. The most appropriate ionomer concentration (wt%) to be used in the catalyst layer preparation will be selected, following preliminary electrolyzer tests. The use of scavengers/fillers in the ionomer formulation will be also investigated to enhance the chemical stability of the ionomer in the cathode catalytic layer.

Task 3. Characterization of AEMs/AEIs (M2-M12)

The thermal stability of the AEMs will be investigated with HR-TGA and MDSC. The thermomechanical characterizations will be carried out by DMA and rheometry. DMA will provide inputs regarding nano- & mesoscale domains, which strongly affect the overall charge migration phenomena. The structure of the AEMs

will be probed by FT-IR in the medium and far infrared, FT-Raman, and confocal micro-Raman. The crystalline phases of the AEMs will be probed by wide-angle X-Ray diffraction (WAXD). The chemical state of the AEMs will be investigated by means of XPS. The AEMs will be characterized by their true OH-conductivity, using a method recently developed by Dekel's group^[13] which involves an in-situ generation of OH⁻ ions in the AEM surface, avoiding then to use KOH liquid solution. Water uptake, swelling, and IEC will be determined by standard physico-chemical methods.^[14] The alkali stability of the developed AEMs will be characterized by a recently developed technique mimicking an *operando* AEMWE environment.^[15] The diffusivity of H₂O, OH⁻, and HCO₃⁻ will be measured using NMR tests at different humidity levels and temperatures.

Section c. Available instrumentations and resources

The work will be carried out by a team composed by P. Mustarelli, Full Professor of Physical Chemistry and Electrochemistry, C. Ferrara, RTDb (Assistant Professor) of Physical Chemistry, and A. Ferrari, PhD student in Materials Science.

The team will benefit of the complete set of instruments and apparatus available at the Electrochemical Laboratory of the University of Milano Bicocca.

Apparatus: wet chemistry facilities (e.g. nitrogen-vacuum lines), glove-boxes (MBraun), wet-boxes (homemade), ball-milling (Retsch), several ovens, high-performance microwave oven, doctor blade.

Instruments: Hi-Res TGA, DSC, MDSC, DMA (Netzsch), Rheometer (Netzsch), hyphenated TGA/GC-MS/FTIR line (Perkin Elmer), SEM/EDX (Thasar), ICP (Perkin Elmer), Raman (Jobin Yvon), solid state NMR (Bruker), electrolysis test stations (homemade), Impedance spectroscopy (Biologic). XPS will be performed in cooperation with Prof. Vito di Noto (UNIPD).

Section d. GANTT diagram

Task	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12
1												
2												
3												

Section e. Milestones, Deliverables and KPI

#	Milestone name	Related task(s)	Due date	Means of verification
MS1	1 st generation AEI and AEM stable at 60 °C > 100 h delivered	1,2	6	Deliverable D1
MS2	2 nd generation AEI and AEM stable at 60 °C > 300 h, with conductivity >100 mS/cm	1,2	12	Deliverable D2

#	Deliverable name	Related task(s)	Type	Level	Date (M)
D1	First generation of AEM and AEI materials for AEMWE	1,2	Report	Co	6
D2	Second generation AEM stable in the alkaline environment, with OH ⁻ conductivity >100 mS/cm	1,2	Report	Co	12
D3	Publications	All	Report	Pu	12

KPIs

- Membrane thickness: < 20 μm
- Ionic conductivity (KOH 1M, 60C): > 100 mS cm^{-1}
- Stability (KOH 1M): > 500 hours

References

- [1] IRENA (2020), Green Hydrogen Cost Reduction: Scaling up Electrolysers to Meet the 1.5°C Climate Goal, International Renewable Energy Agency, Abu Dhabi.
- [2] S. Marini et al. *Electrochim. Acta* 82 (2012) 384-391.
- [3] K. Zeng et al. *Prog. Energy Combust. Sci.* 36 (2010) 307-326.
- [4] <https://matthey.com/products-and-markets/pgms-and-circularity/pgm-management>
- [5] S. Kiemel et al. *Int. J. Energy Res.* 45 (2021) 9914– 9935
- [6] L. Duclos et al. *J. Clean. Prod.* 142 (2017) 2618-2628.
- [7] I.T. Cousins et al. *Environ. Sci.: Processes Impacts* 21 (2019) 1803-1815.
- [8] https://ec.europa.eu/environment/pdf/chemicals/2020/10/SWD_PFAS.pdf.
- [9] https://www.clean-hydrogen.europa.eu/about-us/key-documents/strategic-research-and-innovation-agenda_en. Strategic Research and Innovation Agenda (SRIA)
- [10] Santoro et al. *ChemSusChem* 15(8) (2022) e202200027
- [11] S. Gottesfeld, et al. *J. Power Sources* 375 (2018) 170–184.
- [12] T. Caielli, et al. *J. Power Sources* 557 (2023) 232532.
- [13] A. Zhegur-Khais et al. *J. Membrane Sci.* 612 (2020) 118461.
- [14] S. Bonizzoni et al., *ChemElectroChem* 10 (2023) e202201077
- [15] J. Muller et al. *ACS Mater. Lett.* 2 (2020) 168–173.

Annexes: Curriculum vitae research team

Appendice dell'Allegato B

Curriculum vitae PI (max. 5 pages)

PERSONAL INFORMATION

Family name, First name: MUSTARELLI Piercarlo

Researcher unique identifier(s) ORCID: orcid.org/0000-0001-9954-5200

URL for web site:

• EDUCATION

1992 PhD in Chemistry, Department of Physical Chemistry, University of Pavia

1987 Advanced School in Physics, University of Pavia

1983 Master, Department of Physics, University of Pavia

• CURRENT POSITION(S)

2018 – Full Professor, Department of Materials Science, University of Milano Bicocca

2001 – 2018 Associate Professor, Department of Chemistry, University of Pavia

1998 – 2001 Assistant Professor, Department of Physical Chemistry, University of Pavia

1993 – 1998 Research Fellow, Centre for Thermodynamics/ National Research Council

• PREVIOUS POSITIONS

2001 – 2018 Associate Professor, Department of Chemistry, University of Pavia

1998 – 2001 Assistant Professor, Department of Physical Chemistry, University of Pavia

1993 – 1998 Research Fellow, Centre for Thermodynamics/ National Research Council

• FELLOWSHIPS AND AWARDS

2020 Top 2% in World Ranking Scientists Lists, 1996-2019, Stanford University.

2016 Visiting Professor, Tel Aviv University/Tel Aviv/Israel

2012 Award received from Fondazione Cariplo/Italy. Prize Frontier Research in Chemistry
Title: "Electrochemical NMR microscope: the ultimate challenge". Jury made,
among the others, by the Nobel medalists Aaron Ciechanover and Gerhard Ertl, and
by Philip Szuromi (Science Senior Editor).

2007 – 2008 Visiting Professor, Faculty of Physics/Technical Univ.
Warsaw/Poland

2000 – 2001 Visiting Scientist, Osaka National Research Institute/Osaka/Japan

1983 – 1983 Scholarship, Centre of Casaccia, ENEA, Rome, Italy

- **SUPERVISION OF GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS (if applicable)**

2001 – 2018 Number of Postdocs: 15/ PhD: 5/ Master Students: many
Department of Chemistry/University Pavia/Italy

2018 – Number of Postdocs: 8/ PhD: 6/ Master Students: many
Department of Materials Science/University Milano Bicocca/Italy

- **ORGANISATION OF SCIENTIFIC MEETINGS (if applicable)**

1999: 50th ISE Meeting, Pavia, Member of the Organizing Committee.

2009: Symposium “Carbon Nanotubes in Nanomedicine”, Pavia, Member of the Organizing Committee.

2009: 2nd National Conference on Nanomedicine, Pavia, Member of the Organizing Committee.

2010: 3rd Annual World Congress of Industrial Biotechnology, Dalian, China, Member of the Scientific Advisor Board.

2010: XII International Symposium on Polymer Electrolytes, ISPE-12, Padova, Member of the Local Committee

2012: International Symposium on Boron Neutron Capture Therapy, Pavia, Member of the Organizing Committee.

2013: Giornate dell'Elettrochimica Italiana, GEI 2013, Pavia, President of the Organizing Committee.

2014: 7th German-Italian-Japanese Meeting of Electrochemists, Padova, Member of the Organizing Committee.

2014: EmHyTec 2014, Taormina, Member of the International Advisory Board.

2015: Congress on Materials Science and Polymer Engineering, Dubai, Member of the Organizing Committee.

2016: EmHyTec 2016, Tunis, Member of the International Advisory Board.

2016: 1st Italian Congress of Enerchem Group, Firenze, Member of the Scientific Committee.

2017: XXI International Conference on Solid State Ionics, Padova, Member of the Organizing Committee and Symposium organizer.

2018: 69th ISE Annual Meeting, Bologna, Symposium organizer.

2021: 14th Electrimacs Conference, May 17th to 20th, Nancy – France, Member of the Scientific Committee.

2021: 1st Italian Workshop on Energy Storage (IWES 2021) – 24-26 February 2021, online, Member of Scientific and Organizing Committees.

2021: Italian Virtual Workshop on Fuel Cells (IVWFC 2021) – 16-19 March 2021, online, Member of Scientific and Organizing Committees.

2023: 2nd Italian Workshop on Energy Storage (IWES 2023) – 25-27 January 2023, Bressanone (Italy), Member of Scientific and Organizing Committees.

2023: FEMS Euromat 2023 – 3-7 September, Frankfurt (Germany), Proton Exchange Membrane Fuel Cells and Electrolyzers, Symposium Organizer.

2024: ISE Topical Meeting “Electrochemical Energy for a Greener and more Sustainable Future Society” – 19-22 May 2024, Stresa (Italy)

- **INSTITUTIONAL RESPONSIBILITIES (if applicable)**

- 2021 – 2024 Responsible for University of Milano-Bicocca of R²BATT lab. on circular economy.
2021 – 2024 Vice-dean Department of Materials Science, University of Milano-Bicocca
2020 – 2021 Coordinator of the INSTM National Reference Centre for Electrochemical Energy Storage (GISEL-INSTM)
2020 – 2021 President of the Italian Association of Electrochemical Energy Storage
2011 – 2015 Director of Centre for Advanced Materials, University of Pavia
2012 – 2016 President of CESCRI Consortium Pavia
2013 – 2016 Board of Directors, Enerchem Group/ Italian Society of Chemistry
2017 – 2018 Director of the PhD program in Chemistry, Pharmaceutical Sciences and Industrial Innovation, University of Pavia

- **REVIEWING ACTIVITIES (if applicable)**

- 1995 – 2022 Scientific evaluation, Ministero dell'Università e della Ricerca, Italia.
2005 – 2017 Scientific evaluation, Ministero dello Sviluppo Economico, Italia.
2005 – 2017 Scientific evaluation, Università di Modena and Padova, Italia.
2016 – 2016 Scientific evaluation, Department of Energy, USA.
2016 – 2023 Scientific evaluation, Israeli Science Foundation, Israeli.
2017 – 2022 Scientific evaluation, Fundacao para a Ciencia e a Tecnologia, Portugal.
2019 – 2019 Scientific evaluation, American University of Sharjia, Emirati Arabi Uniti.
2019 – 2019 Scientific evaluation, Danish Agency for Science and Higher Education, Denmark.
2020 – 2020 Scientific evaluation, ERC Starting.
2023 – 2023 Scientific evaluation, National Science Centre, Poland.

- **MEMBERSHIPS OF SCIENTIFIC SOCIETIES (if applicable)**

- 2020- GISEL-INSTM, Founding member
2012 – 2017 International Society of Electrochemistry, Member.
2014 – 2016 Electrochemical Society, Member.
2000 – 2017 Italian Chemical Society, Member.
2015 – 2016 Materials Research Society, Member

- **MAJOR COLLABORATIONS (if applicable)**

- S. Passerini/Batteries/KIT/Karlsruhe/Germany
Y. Saito/NMR/Osaka/Japan
E. Peled/D. Golodnitsky/Batteries/TAU/Israel
V. Di Noto/Batteries/UNIPD/Italy

Curriculum vitae CO-PI (max. 5 pages)

PERSONAL INFORMATION

Family name, First name: FERRARA Chiara

Researcher unique identifier(s): <https://orcid.org/0000-0002-5834-8646>

URL for web site:

• EDUCATION

- 2014 PhD in Chemistry /Chimie Department of Chemistry, University of Pavia (Prof Piercarlo Mustarelli) – Centre de RMN à Très Hauts Champs de Lyon, Ecole Normale Supérieure de Lyon (Prof Guido Pintacuda)
- 2010 Master degree in Chemistry, Department of Chemistry, University of Pavia (Prof Piercarlo Mustarelli)

• CURRENT POSITION(S)

- 2021 – RTDB, Department of Materials Science, University of Milano Bicocca

• PREVIOUS POSITIONS

- 2019 – 2021 RTDA, Department of Materials Science, University of Milano Bicocca

• FELLOWSHIPS AND AWARDS

- 2022 Giovani Talenti Award 2022 – University Milano Bicocca – Accademia dei Lincei
- 2011-2013 Grant of the France Embassy in Italy (Campus France) to support the stays in France during the co-shared PhD project due to the excellent PhD project proposal

• SUPERVISION OF GRADUATE STUDENTS AND POSTDOCTORAL FELLOWS (if applicable)

- 2018 – 1PhD/ 10 Master Students, Department of Materials Science, University of Milano Bicocca

• ORGANISATION OF SCIENTIFIC MEETINGS (if applicable)

- 2023 Co-chair of the ISE Topical Meeting 2024 “Electrochemical Energy for a Greener and more Sustainable Future Society”, Stresa (Italy)
- 2023 Co-organizer of the symposium “E05-Lithium Batteries” in the framework of the FEMS EUROMAT 2023 conference, Frankfurt Main (Germany)
- 2021 Organizing committee member of the “First Italian workshop on energy storage”, virtual workshop

2018 Organizing committee member of the Italian-korean Bilateral Workshop on Electrochemical Energy Storage (ITAKA), University Milano Bicocca (Italy)

• **REVIEWING ACTIVITIES (if applicable)**

- 2023 – Scientific committee of the Institut Laue-Langevin (ILL), Grenoble
- 2023 – Expert evaluator for the Horizon Europe program
- 2023 – Early Career Board member of ACS Sustainable Chemistry and Engineering
- 2023 – Scientific committee member of the symposium “Energy materials” in the framework of the E-MRS Fall Meeting 2024
- 2022 – Review panel member, National Science Centre, Poland

• **MEMBERSHIPS OF SCIENTIFIC SOCIETIES (if applicable)**

- 2020- GISEL-INSTM, member
- 2022 – International Society of Electrochemistry, Member.
- 2018 – Italian Chemical Society, Member

• **MAJOR COLLABORATIONS (if applicable)**

Name of collaborators, Topic, Name of Faculty/ Department/Centre, Name of University/ Institution/ Country

• **CAREER BREAKS (if applicable)**

Jan – Jun 2021 Maternity leave

Appendix: All current grants and on-going and submitted grant applications of the PI and Co PI (Funding ID)

Mandatory information (does not count towards page limits)

Current grants (Please indicate "No funding" when applicable):

<i>Project Title</i>	<i>Funding source</i>	<i>Amount (Euros)</i>	<i>Period</i>	<i>Role of the PI</i>	<i>Relation to current proposal</i>
Towards sustainable, high-performing, all-solid-state sodium-ion batteries	MIUR	606000	2018-2022	National P.I.	None

New green and environmentally friendly materials for lithium and beyond-lithium batteries	MAECI Italy-Israeli bilateral	100000	2021-2022	Italian P.I.	None
Alkaline Membranes and (Platinum group metals)-free catalysts Enabling innovative, open electrochemical devices for Energy storage and conversion	MUR-FISR	1656000	2021-2023	National P.I.	Scientific basis, same topic
Materiali e componenti avanzati per celle a combustibile PEM con innovativa strutturazione multi-scala per il miglioramento di durabilità e stabilità	MUR-PNRR	3400000	2023-2025	University of Milano Bicocca's P.I.	Proton-conducting membranes for fuel cells
A circular and chemistry-neutral approach for recycling and recovery of battery waste feeds	European Commission	5000000	2024-2026	University of Milano Bicocca's P.I.	None
Self-healing strategies towards next-generation lithium rechargeable batteries	MUR-PRIN	200000	2023-2025	University of Milano Bicocca's P.I.	None
Cathode Recovery for Lithium Ion Battery Recycling - COLIBRI	Fondazione Cariplo	300000	2023-2025	University of Milano Bicocca's P.I. (Ferrara)	None
Enhanced metals Recovery by COordination chemistry from Lithium batteries waste - ERCOLE	MUR-PRIN	249997	2023-2025	University of Milano Bicocca's P.I. (Ferrara)	None

Finanziato
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TABELLA COSTI PERSONALE STANDARD				COSTO DEL PERSONALE	TD
FASCIA DI COSTO /LIVELLO	NUMERO SOGGETTI	COSTO ORARIO vedi nota	MONTE ORE		
Basso				- €	
Medio				- €	
Alto	1	73 €	240	17.520 €	
TOTALI	1		240	17.520 €	

COSTO ORARIO: si deve far riferimento al Decreto Interministeriale n. 116 del 24/1/2018

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Legale rappresentante del Proponente*



BUDGET DI PROGETTO	COSTO DEL PERSONALE	OVERHEAD	Costi per servizi di Consulenza Specialistica	Costi per licenze direttamente imputabili al progetto	Costi per materiali e attrezzature direttamente imputabili al progetto	Costi per altre tipologie di spese direttamente imputabili al progetto	COSTO TOTALE
Partecipante 1	17.520,00 €	2.628,00 €			34.000,00 €	20.000,00 €	74.148,00 €
Partecipante 2		0,00 €					0,00 €
Partecipante		0,00 €					0,00 €
Totale							74.148,00 €

*Firma digitale del
Legale rappresentante del Proponente*