# Letter of Intent for participation in the Advisory Board of the Moonshot research trajectory Electrification & Radical Process Transformation 2024

Undersigned, [Company], with registered seat located at [Address], duly represented by [Name of Legal Representative], confirms it is strongly interested in the technology development within the moonshot research trajectory Electrification & Radical Process Transformation (MOT3).

## Research trajectory ‘Electrification & Radical Process Transformation’

In the third Moonshot research trajectory (MOT3), attention is directly focused on CO2 emissions. The net emission of CO2 must be avoided by radical transformation of current processes, to achieve a carbon-smart industry. A switch to electrified industrial processes (e.g., cracking installations) and the application of innovative and low-energy separation processes and mild biotechnological conversions (cf. MOT1) is part of the solution. There is also a need for innovation in the conversion of electricity to heat, which is much more efficient than the current traditional conversion via resistance. These large efficiency gains are needed to close the price gap between natural gas and electricity as fuel. Extensive research is also needed into capturing carbon that is emitted as CO2. For example, the industry can be fed with smart carbon (cf. MOT2) or the captured CO2 can be stored (temporarily) (so-called ‘Carbon Capture and Storage (CCS)’). However, there is a high cost barrier associated with capture of CO2. Therefore, the challenge here is to capture CO2 efficiently with new technologies and in an integrated way, to subsequently convert it into usable raw materials (such as monomers for plastics, cf. MOT2) or to store them. Carbon-free hydrogen is essential for these conversions and at the same time offers opportunities for sustainable production of ammonia (from nitrogen gas and carbon-free hydrogen); the current production process of ammonia (from nitrogen gas, water vapor and carbon monoxide) is characterized by significant CO2 emissions. Hydrogen and ammonia can also act as an energy carrier in the transport and storage of energy (cf. MOT4).

The following objectives will be pursued:

1. 60% reduction in ‘CO2 emission/ton produced’ by the (petro)chemical industry (main contribution to be expected from electrification of steam cracking and ammonia production, replacement of distillation by membrane processes, substitution of the traditional chemical processes by biotechnology), for which at least 1 technology will be developed to TRL 6 by 2035.
2. Economically profitable CO2 capture & purification, both capture from point sources (originating from chemistry, steel, and energy production) and Direct Air Capture. At least 1 technology will be developed up to TRL 6 by 2025.
3. Economically profitable conversions of captured CO2 as a raw material for the Flemish industry. The most important contribution can be expected from the conversion of CO2 to CO, MeOH and DME; and the subsequent conversion of C1 feedstock into added-value products. At least 1 technology will be developed up to TRL 6 by 2025.
4. Cost-efficient (< €2.000/ton) hydrogen production (either remote or in-situ), characterized by low CO2 emissions. At least 1 technology is to reach TRL 6 by 2025.

Within the precondition that CO2 capture and purification is economically viable for capture at point sources at €20-30/ton and for Direct Air Capture at €50-100/ton.

[Company] is interested in this Moonshot research trajectory because …

*Please describe, as detailed as possible, the interest of your company in this Moonshot research trajectory.*

In addition, [Company] is interested in the following Moonshot Early-Stage Innovation project(s) (ESI, previously referred to as cSBO) within the Electrification & Radical Process Transformation research trajectory:

*Please indicate below in which project(s) your company is interested by deleting or removing the project(s) that is/are not of interest to your company.*

**ALOHA: Allylic Oxidation of Hydrocarbons on Anodes**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners KU Leuven, UAntwerpen and VUB.

**☐ ATLANTIS: Integrated Hydroformylation and Oxidative Coupling of Methane to C2 and C3 base chemicals**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners UGent and UAntwerpen.

**EDLCO2: Electrical Double Layer Modulated Catalysts for CO2 to Methanol Conversion**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners IMEC, KU Leuven and UGent.

**EFFORT: Development of GDE-MEA for CO2-electrolysis with low anolyte contribution**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners KU Leuven, UAntwerpen and IMEC.

**HEATCAP: Waste Heat driven Carbon Capture**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners VUB, KU Leuven and UGent.

**☐ SAFARI: Sustainable Aviation Fuels from (bio)Alcohols through Reactor Integration**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners UGent, KU Leuven, Université Lille ENS Paris.

**☐ SUSPLASM: Sustainable low-carbon thermal plasma processing platform for valorisation of challenging waste**, ESI with a proposed starting date on 1 January 2025 and a proposed duration of 48 months, with partners UGent, UAntwerpen and Institute of Plasma Physics Prague.

[Company] is interested in this/these Moonshot project(s) because …

*Please describe, as detailed as possible, and for each of the projects in which you are interested individually, how this project fits in your company’s innovation roadmap. Additionally, please describe how the project results could contribute to your company’s present and future activities.*

The next steps after this/these Moonshot project(s) are …

*Please describe step-by-step, as detailed as possible, and for each of the projects in which you are interested individually, how your company will organise follow-up activities for implementation and valorisation of the project results.*

[Name of company employee] ([employee email address]) will act as [Company]’s main point of contact for the purposes of this Letter of Intent (the “**Representative**”). The Moonshot operational team will deliver all relevant communication related to this Letter of Intent to the Representative (including - upon approval of at least one of the Moonshot Early Stage Innovation projects selected above - invitations for Advisory Board meetings for such projects and information relevant thereto).

Subject to the condition precedent of the approval for funding by VLAIO of at least one of the Moonshot Early Stage Innovation project selected above, [Company] (i) engages to actively follow up on the Moonshot research trajectory and/or such project(s) and to have the Representative take part in Advisory Board meetings for such project(s); and (ii) hereby accepts the terms and conditions of the Moonshot SBO Advisory Board Accession Form, which is attached hereto as Exhibit 1, in relation to the advisory board for each such project and the confidential information disclosed in connection therewith.

Sincerely,

[Signature authorized representative]

[Name, Function, Company]

[Date]

## Abstract ALOHA

**Allylic Oxidation of Hydrocarbons on Anodes**

*Problem:* Key monomers like acrylic acid or methacrylic acid are currently produced in high temperature oxidation reactions of alkenes (propylene, isobutene) on multimetal oxide catalysts. It is however difficult to control the selectivity in these reactions; even if the reaction is conducted in 2 separate steps (propene → acrolein; acrolein → acrylic acid), still up to 10% of the feedstock may be lost by deep oxidation to CO2. Chemicals like (meth)acrylic acid and acrylate derivatives are currently produced at large scale in Flanders’ petrochemical cluster; there is a strong need to pioneer alternative technologies that emit less CO2.

*Idea:* ALOHA targets electrochemical activation of alkenes for allylic oxidation at much lower temperatures. The central idea is that at lower temperatures (≤ 100°C), it will be possible to exert better control over selectivity and to avoid aselective oxidation to CO2. An anodic process implies that the initial activation of the alkene is driven by electricity, at a specifically selected electrode; next dioxygen is used as oxidant to fully convert the intermediates to the unsaturated acid. The anodic activation of the olefin fits with the need to use renewable electric power in large scale chemical processes. Ideally, the electron can be envisioned as a catalyst: we only need to invest the initially necessary activation energy via renewable electricity for an otherwise exothermic reaction. This operation minimizes voltage and power consumption as much as possible.

*Approach:* To bring these ideas via the proof-of-concept to credible upscalability, a stepwise strategy is followed:

* After rationally designing a homogeneous electrocatalytic system, we will fabricate effective electrodes for the electrocatalytic allylic oxidation, e.g. by anchoring redox mediators like NHPI (*N*-hydroxyphthalimide) ontothe backbone of graphite (see Figure 1). Understanding the electrode surface and controlling its properties (e.g. hydrophobicity) are the handles to steer the reaction selectivity and rate. Such electrodes can also be applied for other selectivity enhanced electrochemical reactions;
* With these electrodes, we bring the oxidation of propylene to industrially relevant values, by selecting appropriate voltage, solvent, O2 partial pressure etc. The target is a 90 % acrylic acid yield. Reaction improvement is intertwined with mechanistic electrochemical experiments and electrode monitoring;
* The new reaction concept will be demonstrated in an electrochemical flow cell, which will be designed and constructed. Depending on whether sufficient yield is obtained in one step, one or more consecutive cells are envisioned, allowing optimal conditions for each oxidation step, coupled with cathodic hydrogen evolution;
* Afbeelding met klok, schermopname, tekst, cirkel

  Automatisch gegenereerde beschrijvingWe aim at obtaining reactor effluents that can be directly purified in the current downstream trains (i. e. distillation of aqueous mixtures), ideally using reaction enthalpy as energy source in the workup.

*Figure 1: Low temperature oxidation of propene to acrylic acid, driven by electricity at low temperature.*

*For substantive questions about this project proposal, please* [*moonshot@catalisti.be*](mailto:moonshot@catalisti.be)*.*

## Abstract ATLANTIS

**Integrated Hydroformylation and Oxidative Coupling of Methane to C2 and C3 base chemicals**

Enhancing the conversion of CH4 into high-value hydrocarbon chemicals is increasingly vital due to the rising availability of methane, thanks to electrification in high-temperature processes and growing chemical demands. Our project, ***ATLANTIS***, aims to tap into methane's potential as a chemical feedstock. **We achieve this by synergizing the exothermic non-catalytic oxidative coupling of methane (OCM) with heterogeneous reductive hydroformylation (HF)**. This innovative approach efficiently transforms underutilized methane into valuable hydrocarbons like ethylene and 1-propanol. Not only does this process yield easily transportable liquids, but it also generates high-temperature waste heat, which can power energy-intensive processes such as ethane steam cracking (SC). Leveraging the exothermic nature of homogeneous OCM proves financially advantageous compared to relying on costly and limited renewable electricity sources and thus also offers substantial CO2 savings of at least one ton CO2 per ton of ethylene produced. Furthermore, integrating SC with our novel methane-to-propanol conversion allows for utilizing methane derived from, for example, the SC process or biomethane as a carbon feedstock, promoting a sustainable energy paradigm. **Our technology employs 3D printable or machinable SIC reactors, offering excellent scalability at a modest investment cost.**

***ATLANTIS*** is in line with the high-level objectives of the Moonshot initiative to develop breakthrough technologies by 2040 to create new climate-friendly processes and products, especially in light of the track record of the research groups involved towards high TRL (UGent’s LCT, as well as Blue App offering scale-up & prototyping opportunities). It is also in direct line with the specific KPIs of MOT3. By considerably simplifying the process leading to the production of 1-propanol from methane, the CO2 emissions are considerably decreased: The proposed technology offers a two steps process replacing the combination of SMR (9-12 t CO2/t H2), methanol synthesis, MTO (methane to olefins, with 0.5 t CO2/t HVC), followed by the hydroformylation of part of the ethylene. This allows to convert all the CO in the OCM product, creating extra value but also simplifying the separation from a complex and energy-intensive distillation train to a gas/liquid separation. On top of that, by releasing high-temperature waste heat due to the strongly exothermic reactions of OCM, we can displace the CO2 emissions released for the generation of high-temperature heat used in SMR, steam cracking, etc. The hydroformylation reactor happens at mild conditions (100 to 200°C) in a reactor that is electrically heated, avoiding CO2 emissions. This, of course, also corresponds to the KPIs of MOT4 where CO2 neutral energy is aimed. In addition, if bio-methane is used, it will further allow the reduction of the SCOPE 3 emissions.

Supported by the considerable expertise of the consortium coordinator and **ERC advanced grant** holder (Kevin Van Geem, TREE, UGent), as well as the presence of key actors from the field of catalysis (Joris Thybaut, CaRE, Ugent, also ERC consolidator grant holder), techno-economic analysis (Jo Dewulf, STEN, UGent) as well as electrification and process upscaling (Patrice Perreault from UA/ Blue App), we ensure a smooth commercial deployment of our proposed disruptive technology to higher TRL in the 2030-2040 timeframe. The successful technology transfer of the ***ATLANTIS*** technology will be favoured by the presence of both CleanChem at UGent and the Blue App preincubator from UA. The proposed process will be further developed and scaled up within CleanChem and BlueApp after the MOT.

The ***ATLANTIS*** technology presents a significant advancement in simplifying the current chemical pathway from methane to olefins and syngas to propanol. To assess its efficacy, we will conduct benchmarking in two phases. Firstly, we'll compare the utilization of homogeneous OCM with the observed 25% yield limitation of heterogeneous OCM, alongside the combination of SMR, methanol synthesis, and MTO. Secondly, we'll benchmark our proposed heterogeneous HF against the two-step HF process for ethylene production at 20 MPa syngas partial pressure (oxo process). Additionally, our technology will generate low-cost H2 as a byproduct, showcasing its potential. With Antwerp being a major hub for olefin production in Europe, the feedstock required for our project is readily available at an industrial scale. The output of ***ATLANTIS*** includes H2, ethylene, and easily transportable 1-propanol. This simplified chemical pathway opens avenues for widespread adoption, particularly among chemical manufacturers, polymer processors, olefin producers, and SMEs seeking sustainable solutions. Regions like Antwerp, with robust infrastructure and a keen interest in innovative technologies, stand to gain significantly from the implementation of ***ATLANTIS***, which has the potential to revolutionize methane conversion processes.

*For substantive questions about this project proposal, please* [*moonshot@catalisti.be*](mailto:moonshot@catalisti.be)*.*

## Abstract EDLCO2

**Electrical Double Layer Modulated Catalysts for CO2 to Methanol Conversion**

1. Project Idea and Alignment with Strategic Priorities

Our project proposes the development of an innovative smart thermo-catalyst platform for CO2 conversion, demonstrated for the case of methanol, directly addressing the pressing need for carbon emission reduction by carbon capture and utilization (CCU). Our initiative aims to significantly enhance reactant specificity and finely tune activation energy during catalysis by adding capacitive modulation of the electrical double layer (EDL) on a catalyst surface. This cutting-edge approach aligns well with the global drive towards sustainable fuel solutions and resonates with EU’s and Flanders' focus on emission reduction and green hydrogen utilization.

1. Goals

Our primary objective is to surpass the limitations of traditional catalysts in the stepwise CO2 hydrogenation reaction on a catalyst surface by developing EDL-modulated catalytic conversion strategies. This entails the technical steps of (1) creating high surface area electrode structures and coated by suitable catalyst coating, and (2) providing proof-of-concept for selectivity/rate changes induced by an electric field. Previous experience on creation of high surface area nanostructure and introduced coating is shown in the picture below. Ultimately, we strive to produce a stable thermo-catalyst with high selectivity for methanol at lower temperatures and/or pressures for higher productivities and selectivity, thus revolutionizing chemical manufacturing practices. The proof-of-concept will establish a fundamental principle that can be applied not only to the conversion of CO2 to methanol, but also to other catalysts in the future.

A close-up of a device

Description automatically generated

Anticipated Outcomes:

* Enhanced surface area via nanostructure
* Greater number of active sites for optimized catalytic activity
* Higher catalyst activity to improve conversion rates
* Reducing energy consumption, contributing to sustainability efforts.
* Increasing selectivity and heightening productivity

1. Partners & Description of Tasks:

Our consortium comprises the nanotechnology experience of imec (prof. Philippe Vereecken), the thin-film coating expertise of CoCoonN group at UGent (prof. Christophe Detavernier), and the catalysis and reactor expertise of CSCE at KU Leuven (prof. Michiel Dusselier), forming a cohesive team capable of addressing the project's multidisciplinary challenges and delivering impactful results.

1. Conclusion:

The EDLCO2 project provides a new approach to influence /control catalyst behaviour. It is intended to advance sustainable chemical manufacturing practices, contributing to emission reduction goals.

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## Abstract EFFORT

**Development of GDE-MEA for CO2-electrolysis with low anolyte contribution**

**Idea** - **CO2 electrolysis** **is an excellent technology to convert captured CO2 into valuable chemicals**, generating a carbon cycle for molecules with net-zero emissions. It offers a viable addition to underground carbon storage, catalyzing the breakthrough of carbon capture and utilization (CCU). The technology that enables the co-electrolysis of gas (CO2) and water at high reaction rates is the so-called **gas diffusion electrode (GDE)**. This GDE is open on both sides and has one side exposed to the gas phase and the other side to a liquid or to an ion and fluid-permeable membrane. While still in its early stages, this technology offers potential advantages over thermo-catalysis routes.

The main technological challenges of the GDE CO2 electrolyzer are throughput (current density), lifetime and efficiency. Also, product selectivity and the stability over time of product selectivity and yield are still not optimal. Even though best in class cells can already achieve industrially relevant throughput with current densities >200mA/cm2, cell voltages are often still larger than 3.5 or even 4V. Hence the energy efficiency is well below 50% where best in class water electrolyzers are near 80% efficiency.

Unfortunately, the use of high alkaline electrolytes, which would serve well as anolyte, are not well suited as the catholyte GDE wetting layer as the CO2 is lost by formation of carbonate ions which are not suitable for the electrochemical reduction. Hence, the control of the CO2(g)-HCO3-(aq)-CO32- equilibria is key for designing the cell voltage and its energy efficiency. The development of GDE chemistry controlling membranes and **membrane electrode assemblies (MEA)** is the key to solving this problem. By combining expertise in membrane technology from the group of prof. Vankelecom (KU Leuven), with expertise in electrocatalysis (prof. Vereecken (imec) and prof. Breugelmans (UA), and expertise in nanofabrication (imec) and reactor design (UA), the CO2-ANOLYTE project aims at tackling this difficult but technological important issue.

**Goal** - EFFORT proposes a **novel CO2 electrolysis system composed of a silver-based gas diffusion electrode (GDE) and a thin anion exchange membrane (AEM)** selective towardsOH**-** with additional **gating-control of ions such as carbonates**, resulting in a system with stable operation at high energy **efficiency and extended lifespan**. AEMs are one of the key elements in alkaline CO2 electrolyzers. This technology is preferred over electrolyzers equipped with cation exchange membranes as it allows to suppress the hydrogen evolution reaction (HER) and enables the use of cheap non-noble metal anodes. However, operating at alkaline condition presents certain issues with membrane performance. For example, inadequate separation of CO2 and ions, such as potassium from KOH electrolyte, leads to precipitation of potassium bicarbonate salt on the cathode. Additionally, current commercial AEMs (e.g., Sustainion X37-50, piperIONE), lack stability and performance under such harsh conditions, particularly when operating at high current density and pH levels.

**Three major objectives** are defined: (1) CO2 electrolyzer for syngas operation at cell voltage <2.5V, (2) development of AEMs stable at pH 12-14 with good ion-selectivity toward carbonates, (3) GDE with a wetted Ag catalyst layer with controlled CO2(g)-HCO3-(aq)-CO32- equilibria during operation, and the elimination of carbonate precipitation in the GDE and membrane.

**Impact** - As we transition away from fossil fuels advances, an urgent need arises for sustainable alternatives for traditional carbon sources. This project focuses on the route to green carbon, with syngas serving as its simplest form. This highly versatile gas mixture is a pivotal component in many large-scale applications in steel, chemical and hydrogen industries, and can thus be directly used in current applications.

Significant advancements are also underway (among others at KU Leuven, thanks to recent LSI-funding) in scaling up carbon capture (CC) membrane technology to enrich CO2 from flue gases from chemical, food and metallurgical industry. This enriched stream could be harnessed in power-to-molecule processes like Steelanol, the CO2 electrolysis process from current application or other innovative ventures.

Moreover, innovations like the CO2 electrolysis process could potentially integrate into segments of the Flemish hydrogen value chain, offering new opportunities for companies like Bekaert, AGFA, Emerson and C-Energy. While not directly focused on hydrogen production, the CO2 electrolysis concept shares similarities in process design and materials with water electrolyzers, hinting at potential new business avenues for these companies.

*For substantive questions about this project proposal, please* [*moonshot@catalisti.be*](mailto:moonshot@catalisti.be)*.*

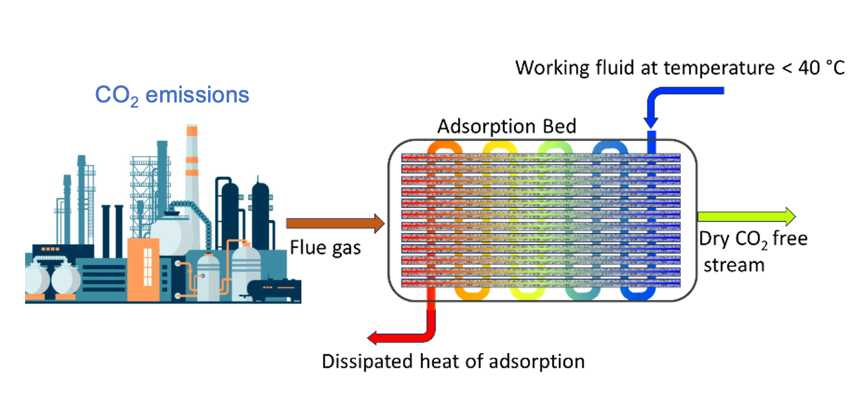
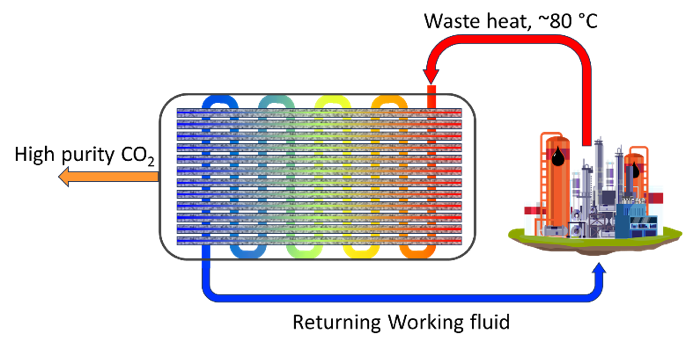
## Abstract HEATCAP

**Waste Heat driven Carbon Capture**

A 90% global CO2 emission reduction is due by 2040. Carbon tax, Carbon credits and ETS trading mechanisms are becoming more stringent and will soon be applied to more sectors, with economical and business challenges at the company but also regional cluster level. Holistic solutions are needed on increasingly shorter term. Combining carbon capture with opportunities for conserving energy resources is one of them.

A major hurdle in Carbon Capture (CC) is namely the high energy cost of the capture process, regardless the technology. At the same time, there remains a huge potential of low-grade thermal waste energy which is not always easily used. This is also the case for traditional liquid amine absorption CC-technology, where the solvent is regenerated by heating the whole solution to 110-125°C with saturated steam of at least 110-135°C, requiring huge amounts of energy.

The **HEATCAP project aims at a dramatical decrease in energy demand of CC-technology, reducing the footprint of the carbon capture process itself and making carbon capture economically more feasible**. The proposed HEATCAP applies a radically new approach in gas separation with an integrated design of a novel low temperature (<90°C) regeneration process at low energy intensity and tailored capture materials, making it possible to exploit the use of low-grade waste heat streams to drive these processes. The HEATCAP route, starting with insights from previous Moonshot projects (CAPTIN/ARCLATH), is expected to have a faster upscaling and exploitation route compared to other interesting alternatives and energy performance will be drastically better compared to amine-based scrubbing.



**HEATCAP principle:** Left: CO2 capture using integrated adsorption / heat exchange unit. Right: Low temperature adsorbent regeneration and CO2 recovery using low grade waste heat.

The ultimate HEATCAP goal is utilizing low-grade waste heat for intensified carbon capture, in modular units with potential retrofitting in existing infrastructure, operated in fast and energy-efficient process cycles, to obtain a sustainable and economically viable technology for CO2 capture and purification. **A reduction of the overall energy demand of carbon capture to 0.5 MJ/kg CO2 (for the flue gas case) is targeted** (current benchmark amine technology > 2.5 MJ/kg CO2 for absorption).

The HEATCAP project is led by Prof. Joeri Denayer (VUB, expertise on intensified separation processes), in consortium with Tomas Wyns (VUB, expertise on transition roadmaps, economic & policy framing), Frederik Lynen (UGent, thermoresponsive materials), Michiel Dusselier and Prof. Johan Martens (KULeuven, absorbent materials). The multidisciplinary complementarity in research expertise will lead to i) the design of an integrated carbon capture process using waste heat and (sub)system devices for demonstrating energy-lean carbon capture performance; ii) the provision of data on economic feasibility, sustainability footprint,waste energy utilization and CO2 emission reduction potential for industries and sectors in Flanders (and beyond) and iii) a further optimalisation of the novel process via tailor made materials.

The **selection and finetuning of appropriate business case(s)** **for waste heat driven carbon capture** is hence an important step at this moment, for which we believe the voice of future beneficiaries is essential, now and during execution of the project. On the radar are companies with **either or both** i) problematic CO2 emissions and/or ii) availability or access to a grid with of low grade waste energy streams (60-120°C), likely in sectors as refineries, chemicals, plastics, steel and cement, incinerators, power plants, biogas production,.... We also reach out to technology providers, energy-grid exploiters, large datacenters and associations representing clustered industrial regions.

We invite interested parties to contact Prof. Joeri Denayer ([joeri.denayer@vub.be](mailto:joeri.denayer@vub.be)) as soon as possible for a discussion on relevant “HEATCAP” business cases and interest to support and advice further HEATCAP development.

*For substantive questions about this project proposal, please* [*moonshot@catalisti.be*](mailto:moonshot@catalisti.be)*.*

## Abstract SAFARI

**Sustainable Aviation Fuels from (bio)Alcohols through Reactor Integration**

The project ***SAFARI*** aims to develop a flow process that combines **heterogeneous and electrocatalysis** for the conversion of **aqueous bio-alcohols into long-chain alcohols, which will then** be further processed into Sustainable Aviation Fuels (SAF).

An electrified, continuous-flow reactor will be used to supply reaction energy and drive the reaction. **We propose a radically new route from aqueous bio-alcohols to C8-C16 alcohols as SAF precursors at low temperature and in an aqueous environment**. This directly results in **high-purity branched C8-C16 alcohol SAF precursors that are easily separated and upgraded**, thereby avoiding the energy-intensive azeotropic bio-ethanol/water distillation. Additionally, the resulting SAF will be free of aromatic, sulfur, and nitrogen compounds, leading to longer engine lifetimes, lower emissions, and lower soot formation.

Compared with conventional conversion routes for ethanol to SAF, which are energy-intensive and require pure ethanol feed and endothermic reaction steps, SAFARI has the potential to drastically reduce costs by requiring minimal distillation and avoiding stand-alone H2 production facilities. As such, ***SAFARI*** could mean a **serious reduction in both CAPEX and OPEX to produce SAF**.

This cost reduction is crucial to compete with conventional aviation fuels and allow EU airports to remain competitive when the ReFuelEU Aviation Initiative comes into effect. This obliges EU airports to use aviation fuels with a minimum SAF content of 2% by 2025; by 2050, this will increase steadily to 63%. These ambitious blending targets require rapid development and investment in technologies that are not yet commercially ready. Therefore, the project should be benchmarked against SAF production processes rather than conventional fuel production processes. Currently, only two processes are commercially available: HEFA, based on lipid conversion through hydrolysis and hydrogenation, and FT-SPK, based on lignocellulose conversion through gasification and Fischer-Tropsch synthesis. Additionally, Alcohol-To-Jet Fuel (ATJ) processes are being piloted, based on the production of alcohols through fermentation of biomass followed by dehydration and oligomerisation steps. The latter endothermic steps require elevated temperatures (200-300°C) and considerable purification steps, significantly increasing the cost of production. ***SAFARI*** develops an alternative low-temperature electrified ATJ route, which can be performed in the aqueous phase at moderate temperatures, i.e., < 60°C. Therefore, ***SAFARI*** omits the energy-intensive distillation step. This gives ***SAFARI*** a strong competitive edge over other ATJ processes. This is important for a logistic hub such as Flanders/Belgium, which has an estimated annual jet fuel consumption of approximately 1.5 Mtonnes.

Further (co-)development of the technology could be done in collaboration with conventional fuel producers/refineries or with bio-ethanol producers which see their conventional target market, i.e., car fuels, diminish due to the rise of EVs.

***SAFARI*** brings together experts from multiple disciplines. Profs. Kuhn and Leblebici will develop electro-flow reactors for the conversion of aqueous ethanol and test their robustness for bio-ethanol. Furthermore, they will develop an integrated process flow sheet to couple the electro-flow reactor to the thermo-catalytic process in the third year of ***SAFARI*** to achieve a first proof-of-concept as a step towards an LSI proposal. Profs. Cazin and Grimaud will develop improved electrocatalysts. The latter holds a unique combination of expertise in the organic electrochemistry of alcohol oxidation combined with the electrode (catalyst@electrode) and flow echem-reactor design. These novel electrocatalysts will be integrated into electro-flow reactors. Prof. Saeys and Dr. Ordomsky will optimize the thermo-catalytic process for the conversion to long-chain alcohols and the hydrodeoxygenation step to upgrade the branched mono-alcohols to C8-C16 SAF molecules.

*For substantive questions about this project proposal, please contact* [*moonshot@catalisti.be*](mailto:moonshot@catalisti.be)*.*

## Abstract SUSPLASM

**Sustainable low-carbon thermal plasma processing platform for valorisation of challenging waste**

**A diagram of sludge treatment

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Flanders is strong in bio-based sectors (agri, food, others) but along the bio-based value chain that runs from production to post-consumer waste processing, there is a wide range of challenging waste streams that defy simple and economic processing. More precisely, mixed waste containing a combination of organic bio-based materials with synthetic materials is proving to be increasingly problematic. The best available techniques for such problematic mixed organic-synthetic waste are incineration or landfill, which has strong negative environmental impact and is associated with high greenhouse gases emission. In the context of SUSPLASM, the consortium will investigate the (i) technical, (ii) economic, (iii) energetic and (iv) environmental characteristics of waste processing based on thermal plasma for 4 different waste streams in small-scale practical tests of targeted waste streams: a. sewage sludge, b. PFAS contaminated organic sludge and sediment, c. mixed waste of plastic binders, d. problematic mixed organic-synthetic municipal waste. In SUSPLASM, thermal plasma treatment of waste will be further developed as a key-enabling technology which converts difficult waste streams into syngas and non-leachable slag for various applications (such as hydrogen production and recovery of phosphorus) ). In addition to benchmarking over indicated dimensions (i-iv) for syngas produced from these waste materials, the consortium will also develop the design & built blueprint for a small-scale thermal plasma platform in Flanders . This will herald the start of a broader platform across universities for joint activities on plasma science, thermal chemistry, waste economy and serve as an access point for the companies to enter the field of thermal prossessing. The project will position Flanders as a front-running region in green technology of high potential towards climate change abatement and circular economy.

**Plasma gasification**

Plasma gasification of organic waste streams is an endothermic process where the essential energy for the process is supplied by electricity (electrification of the gasification process); plasma torches convert electrical energy into thermal energy without direct CO2 emissions.

**Unique Selling Proposition (USP) of plasma-based waste processing**

Technologies for the treatment of various types of waste mainly include incineration technologies, where energy from waste is preferred. However, during incineration, the organic matter of the waste is burned, releasing enormous amount of CO2 and heat that can be converted to electricity in a steam cycle with limited efficiency (usually less than 20%). On the other hand, in plasma gasification, the energy required to drive the gasification process (or pyrolysis process) is provided by an external source (electricity); this allows the waste to be completely converted into syngas. If the electricity is generated from renewable sources, there are no CO2 emissions associated with it. With CO2 used as a gasification agent, the process can even become carbon negative. In addition, in the plasma treatment the syngas produced is tar-free and the inorganic part of the waste can be converted in a solidified, non-leachable slag with a considerably smaller. Within the framework of SUSPLASM, attention will be paid to recovery of valuable minerals prior to the plasma gasification process for which several strategies will be explored.

An important aspect of plasma technology is its potential to be used as a means of storing electricity from the distribution grid in the form of chemical energy of syngas or derived chemicals in the power-to-X concept. Since the operational power range of plasma torches is very flexible it can very quickly adjust its consumption of electricity according to the situation in the distribution grid. The project interacts – as an integral part from during the application development – with wastestream (problem) owners. Amongst others, growers and industrial partners involved in intensive greenhouse cropping as well as the intermunicipal association IVLA (and other waste collectors) as first contact end-users of technology and/or suppliers of biomass. In any case they provide us with the more ‘up-stream’ part of the stakeholder chain : the ones ‘owning’ the problem and the biomass. Thermal plasma technology allows the sustainable processing and valorization of challenging waste with zero or even negative CO2 footprint and recovery of minerals while storing electricity in the form of chemical energy of tar-free syngas or derived chemicals.

*For substantive questions about this project proposal, please contact* [*moonshot@catalisti.be*](mailto:moonshot@catalisti.be)*.*

## Exhibit 1 Moonshot SBO Advisory Board Accession Form

Certain Flemish research institutions (the “**Institutions**”) will submit through the Moonshot department of Catalisti a Moonshot SBO project proposal (the “**Project**”) for funding to *Vlaams Agentschap voor Innovatie en Ondernemen* (“**VLAIO**”) and will sign a *Samenwerkingsovereenkomst Moonshot Strategisch Basisonderzoek* upon approval of the Project by VLAIO (the “**Agreement**”).

Upon approval of the Project by VLAIO, an advisory board composed of companies with a particular interest in the research performed under the Project will be established (the “**Advisory Board**”, with each such company a “**Participant**” and jointly the “**Participants**”). The Advisory Board will act as an advisory group to the Institutions with respect to the performance of the Project and as a sounding board to explore the possibilities of economic implementation of the Foreground. “**Foreground**” means the results generated by the Institutions under the Project.

This Moonshot SBO Advisory Board Accession Form (the “**ABA Form**”) lays down the organization and objectives of the Advisory Board as well as the protection of confidential information disclosed by the Institutions and the Participants (each of those entities a “**Party**” and jointly the “**Parties**”) and will become effective upon approval of the Project by VLAIO.

Each Participant will be bound to this ABA Form through its signature of the Letter of Intent for the Project. The Institutions are bound by the Agreement to an obligation to protect confidential information disclosed by the Participants in the scope of the Advisory Board which is substantially the same as that set out in Section 3 below. For the purpose of the enforcement of its rights, each Party will be provided by Catalisti with a (redacted) copy of all Letters of Intent signed by all Participants and of the Agreement signed by the Institutions.

1. **APPOINTMENT AND Role of the Advisory Board**

1.1 In its Letter of Intent, the Participant appoints its representative in the Advisory Board (the “**Representative**”).

1.2 The Participant will ensure that its Representative will dedicate sufficient time and effort to the fulfillment of its role in the Advisory Board. In the event that a Representative becomes unavailable or the coordinator of the Project (the “**Coordinator**”) informs the Participant of such Representative’s failure to fulfill its role in the Advisory Board, the Participant will promptly inform the Coordinator of the contact details of a successor with comparable skills and expertise it has appointed.

1.3 The Participant may resign from the Advisory Board by giving one month prior written notice to the Coordinator.

1.4 The Representative will be regularly informed on the progress of the Project to the extent as necessary for the evaluation of the economic potential of the Project and be provided an insight in the Foreground obtained under the Project.

1.5 The Representative as part of the Advisory Board will (i) advise the Institutions with respect to the performance of the Project and formulate general recommendations on the execution of the Project in view of the expected valorisation potential of the Foreground, and (ii) act as a sounding board to explore the possibilities of economic implementation of the Foreground. The Representative will also monitor the valorisation plan of the Project (to the extent it has been disclosed to the Advisory Board).

1.6 The Participant may communicate to the other Parties any information which it considers useful for the Project or the valorization of the Foreground.

1. **Advisory Board MEETINGS**

2.1 The Coordinator will convene the Advisory Board at least once per year during the course of the Project. At least thirty (30) days prior to the meeting, each Party will receive an invitation including the agenda.

2.2 The following persons will attend the meetings of the Advisory Board:

1. Representatives of the Participants
2. Representatives of the Institutions
3. Representatives of Catalisti (including representatives of Catalisti’s scientific advisory board (WAR) and governance board) and VLAIO

2.3 The Project manager appointed by the Coordinator will chair all meetings of the Advisory Board and will produce written minutes of each meeting. Draft minutes will be sent to the other Parties within ten calendar days of the meeting. The minutes will be considered as accepted if, within fourteen calendar days from sending, no recipient has objected in writing to the Project manager with respect to the accuracy of the draft of the minutes.

1. **CONFIDENTIALITY**

3.1 For the purpose hereof, “**Confidential Information**” means any information that is disclosed or made available by a Party to another Party in connection with the Project (i) which, when communicated in written form, is clearly marked as ‘confidential information’, or (ii) which is confirmed in writing to be confidential information within fourteen (14) calendar days following its oral communication; or (iii) that is clearly to be considered confidential in view of the nature of the information. The minutes of the Advisory Board meetings may reflect Confidential Information of several Parties and will be treated accordingly. Without prejudice to the foregoing, Foreground will always qualify as Confidential Information, even if it would not have been marked as ‘confidential information’.

3.2 The Participant accepts the other Parties’ Confidential Information only to perform its role in the Advisory Board (the “**Purpose**”) and shall keep such Confidential Information strictly confidential. Without the disclosing Party’s prior written approval, the Participant shall not

(a) use such Party’s Confidential Information for any purpose other than the Purpose; or

(b) publish or otherwise disclose or transfer to any third party in any form whatsoever such Party’s Confidential Information.

3.3 The Participant may disclose another Party’s Confidential Information to its representatives, employees, staff members and consultants and those of its Affiliates (jointly “**Staff**”) only for the Purpose and on a strict need to know basis. “**Affiliate**” means any undertaking which is, on or after the date hereof from time to time, an affiliate as this term is defined in section 1:20 of the Belgian Companies and Associations Code. The Participant shall fully inform all such Staff of the terms and conditions contained herein and will ensure they are bound by confidentiality terms which are at least as stringent as those contained herein.

3.4 Notwithstanding the above, the Participant shall have no obligation hereunder to refrain from disclosing or using Confidential Information for which it can reasonably prove that:

a) it is generally available to the public at the time of its disclosure by the disclosing Party;

b) it became publicly known not due to any unauthorized act or omission on the part of the Participant;

c) it was disclosed to the Participant by a third party as a matter of right;

d) it was at the time of first disclosure by the disclosing Party already known to the Participant;

e) it is subsequently developed by the Participant completely independent from any of disclosing Party’s Confidential Information; or

(f) disclosure is imposed by a court order or legal provision.

3.5 The Participant may disclose another Party’s Confidential Information to the extent required by any applicable federal, state or local law or regulation or an order, rule or decree of any court, government or regulatory body of competent jurisdiction (including any securities commission or stock exchange on which the securities of the Participant or its Affiliates are listed), provided the Participant has, to the extent it is legally not prohibited to do, given that other Party prior written notice of such required disclosure and, to the extent reasonably possible, has given that other Party an opportunity to contest such required disclosure, including (but not limited) by seeking a protective order or other appropriate remedy to prevent or limit such disclosure, at that other Party’s direction and expense.

3.6 The Participant agrees that all Confidential Information is provided by the other Parties “as is” and no warranties are given with respect to such Confidential Information, including, but not limited to, accuracy, correctness or non-infringement. The Participant shall be solely responsible for its use of Confidential Information hereunder and the other Parties shall not be liable to the Participant for any damages incurred by it in connection therewith.

3.7 The receipt of Confidential Information shall not be construed as granting, or as an undertaking to subsequently grant, to any Party any license, right, title or interest in or to that Confidential Information or any present or future intellectual proprietary rights a Party may have with respect to that Confidential Information.

3.8 Within thirty calendar days after a disclosing Party’s written request, the Participant will return to the disclosing Party all originals, reproductions and summaries of the disclosing Party’s Confidential Information or, at the disclosing Party’s sole option, destroy the same and provide written certification thereof. The Participant shall not be obligated to erase Confidential Information that is contained in an archived computer system backup that was made in accordance with the Participant's security and/or disaster recovery procedures. Notwithstanding the foregoing to the contrary, the Participant may retain one archival copy of the Confidential Information for its own records to determine its obligation hereunder, internal auditing or legal purposes on a confidential basis in accordance with this ABA Form.

3.9 The Participant shall respect the obligations of confidentiality and non-use set forth herein during the entire term of the Agreement and until **five years** after its end.

1. **INTELLECTUAL PROPERTY**

4.1 Except as may otherwise be set forth in a separate agreement between the relevant Parties, the Participant will not obtain any ownership or (option to) license rights to Foreground or background of the Institutions. The Institutions will own the Foreground in accordance with the provisions of the Agreement and may pursue intellectual property rights or publish such Foreground.

4.2 If the Participant wishes to implement certain Foreground in its business, it must initiate bilateral negotiations with the Institution(s) owning that Foreground. Rights to Foreground will only be granted to such Participant under a formal written agreement between the Parties concerned.

**5. MISCELLANEOUS**

5.1 The Participant agrees that each other Party is a third party beneficiary of this ABA Form with full rights to enforce their terms and seek remedies against any breach of this ABA Form.

5.2 In the event that a Party pursues legal action against the Participant to enforce the terms and conditions of this ABA Form, the Dutch speaking courts of Brussels shall have sole and exclusive jurisdiction over the matter. This ABA Form shall be governed by the laws of Belgium, without giving effect to its conflict of laws provisions.