2020 Cleantech to Market Application—due by Friday, February 21, at 6pm Pacific

Cleantech to Market (C2M) provides the following types of commercialization support: market research on customer needs & preferences, price points & competitors, potential new applications & niche markets, implementation strategies including key next steps, barriers to market entry, potential commercialization partners, fundraising suggestions, reports & presentation materials for grant applications and/or investor outreach.

Prior to completing the application, please review C2M’s FAQs for startups at https://haas.berkeley.edu/c2m/for-startups/.

Please note that ALL ITEMS in ALL SECTIONS MUST BE COMPLETED even though they are not marked as "required" to ease your navigation. Most of the "long answer text" questions are best addressed with a high-quality paragraph or two. Lengthy replies are not expected or ideal for applicants or reviewers.

If you have any difficulties with or questions about the application, please email c2m@berkeley.edu. Thank you.

HOW TO SAVE A DRAFT OF YOUR RESPONSE

AFTER you click "submit" on the final application screen, another screen will come up that provides the following instructions: "Your response has been recorded, you can edit your response until the due date."

"TO BE ABLE TO EDIT YOUR RESPONSE:
Click on the 'Edit Response' link and then save the unique URL that is generated (e.g., copy and paste into an e-mail or notepad). Using this unique URL, you will be able to come back and edit the link until February 21 at 6 pm Pacific.
Edit your response
Submit another response"

COMPANY INFORMATION

This section provides basic information about your startup or cleantech project.
FAQs
Please confirm that you have carefully reviewed C2M’s FAQs for startups at https://haas.berkeley.edu/c2m/startups/.

☑ Yes, we have reviewed them.

COMPANY NAME (or project title if not yet incorporated)

SiPure Membranes

WEBSITE (if any)

N/A

APPLICANT(s) NAME(s) & JOB TITLE(s)

Dr. Brendan Smith, Postdoctoral Associate, MIT

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AFFILIATION(s)

Please check all that apply—whether current or prior—and name any others (including universities) in "other" section

☐ ARPA-E
☐ DARPA
☐ OTHER DOE
☐ CALSEED
☐ CALCEF
☐ OTHER CEC
☐ CYCLOTRON ROAD
☐ CLEANTECH OPEN
☐ LOS ANGELES CLEANTECH INCUBATOR (LACI)
☐ FLOW
☐ I-CORPS
☐ BLUETECH VALLEY
☐ NSF
☐ UC BERKELEY
☐ STANFORD
☐ CALTECH

☑️ Other: MIT, also current finalist for Activate Boston
COMPANY or PROJECT STATUS
Please check all that apply.

☐ Company or LLC formed

☑ Founder(s) only

☐ Founder(s) plus 1-2 full-time equivalent employees

☐ Founder(s) plus >2 full-time equivalent employees

☑ Other: Incorporation planned within 3-8 months.

PARTNER(s)
In addition to the affiliations listed above, please list and explain the nature of any other key partner relationship(s), e.g., accelerators, incubators, and strategic partnerships (for materials, testing, trials, etc.).

In addition to participation in the NSF I-Corps program (April 2019), we have received generous support from the MIT Sandbox program, MIT IDEAS, and MIT Venture Mentoring Service. We are also developing strategic partnerships with contract manufacturers in the Boston area, and industrial partners in industries such as textiles, mining, and semiconductors.

FUNDING
Please summarize all funding received to date, including all debt, equity and/or grant amounts.

As our project is still within MIT, we have not received any dilutive funding to date. Project-specific funding received over the course of the project includes the following support:

MIT Tata Center: $200k
MIT Deshpande Center: $100k
MIT Materials Science and Engineering Kavanaugh Fellowship: $80k
MIT Sandbox Fellowship: $25k
Massachusetts Clean Energy Center Catalyst Grant: $65k

TECHNOLOGY
This section provides key information about your technology.

TECHNOLOGY

Describe the technology, including prototyping and testing history, as well as any related performance data.

Produced from standard silicon via a patented two-step process, the SiPure membrane offers a novel combination of extreme durability and low-cost relative to competing membrane technologies. The manufacturing approach produces high-density nano-scale pores extending from one surface of the silicon tile to the other, allowing for water and other solvents to permeate, while excluding targeted species as small as divalent salts. Owing to the chemical and thermal resilience of silicon, the membrane has been proven capable of withstanding harsh conditions such as pH < 0, numerous organic solvents, oxidizers, and temperatures above 300 degrees celsius. A highly hydrophilic smooth surface minimizes fouling rate, and flux regeneration has been demonstrated via a variety of common cleaning protocols. The large-scale configuration of the membrane will involve a plate-and-frame geometry, allowing for treatment of highly concentrated waste streams. Production cost for the SiPure membrane is predicted by technoeconomic modeling to be over five times less expensive than competing ceramic nanofiltration membrane technologies.

The primary innovation behind the SiPure membrane technology is the ability to produce nanopores less than 5 nm in diameter which pass completely through a silicon tile. This capability surpasses both state-of-the-art silicon microfabrication techniques and ceramic membrane production processes with respect to pore size and length. The simplicity and streamlined nature of the patented manufacturing process allows for feasible scale-up of the technology at a reasonable cost.

The current stage of the venture is the production of multiple 150 square centimeter membrane tiles, which can be inserted in parallel into a housing module, allowing for the filtering of many liters of test liquid per day.
RISKS
Describe any known or expected technology risks, explain their potential impact, and discuss any current or pending plans to mitigate or resolve them.

We foresee two primary risks associated with the fundamental technology, and one with the system scale-up. Fundamentally, in order to achieve successful commercialization, the membrane must offer (1) significantly high flux to be practical and cost-competitive in a footprint and CapEx constrained industrial operation, and (2) sufficiently repeatable size cut-off to provide consistent excellent performance to the customer. These risks will be mitigated by (1) pursuing well-understood mechanisms for increasing pore density and therefore increasing flux through the membrane, and (2) working with contract manufacturers to transition from shared-use small-batch fabrication facilities to a more highly controlled manufacturing process.

De-risking scalability will primarily involve working with contract manufacturers with regard to both membrane and housing module fabrication. The fabrication process itself is simple and consists of already existing highly scalable processes, but the unique combination of these processes will require some process development in close collaboration with industry experts.

WHAT'S NEXT?
Describe (a) what you're working on now and (b) key activities/milestones expected over the remainder of 2020, with specific emphasis on August–December (which is when C2M students would be conducting market research for you).

(a) Current efforts are focused on continuing to develop relationships with contract manufacturers and industry partners, with a concerted focus on moving towards a small-scale industry pilot within the next year. In parallel, R&D is continuing with the goal of optimizing and scaling up membrane performance, as well as packaging membranes in a pilot-ready configuration and surrounding system.

(b) The following are milestones relevant to August-December of 2020:

Technical: Finalize optimization of membrane filtration technology for a selected beachhead market. This iteration should be a "product-ready" version.

Market Research: Attend at minimum three tradeshows in top beachhead markets of interest. Interview at minimum 30 stakeholders in these industries.

Business Development: Receive first test batch of membranes from contract manufacturer, Receive prototype housing module from contract manufacturer, agree with industry partner on a contract for an initial small-scale pilot project, initiate introductory pitches/meetings with angel and venture capital investors.
INTELLECTUAL PROPERTY

Currently, all IP associated with the SiPure technology belongs to MIT, and will be licensed upon incorporation.

One patent has been granted by the USPTO encompassing the production process for the SiPure membrane, and a further two patent applications are currently pending.

TECHNOLOGY READINESS LEVEL (TRL)

- TRL 2 - TECHNOLOGY FORMULATION: Technology concept or application formulated.
- TRL 3 - APPLIED RESEARCH: Early lab tests completed; proof of concept.
- TRL 4 - LAB PROTOTYPE: Component testing in a laboratory environment.
- TRL 5 - FIELD PROTOTYPE: Component testing in the intended field environment.
- TRL 6 - SYSTEM PROTOTYPE: More complete system demonstrated in intended field environment with close to expected performance.
- TRL 7 - DEMONSTRATION SYSTEM: System prototype demonstration in an operational environment at pre-commercial scale.
- TRL 8 - INITIAL COMMERCIAL SYSTEM: Actual system completed & demonstrated, manufacturing issues solved.

COMMERCIAL OUTLOOK

This section is for you to provide any information YOU may have on the commercial outlook for your technology. If your company/technology is selected for the C2M program, YOUR C2M TEAM will conduct 15 weeks of market research (using a minimum of 80 sources) to provide you with a 100-page report comprising a detailed technology-assessment and market-based information and related recommendations.
ESTIMATED TIME TO MARKET
Estimated time to initial paying customer(s)

☐ Within the next 12 months
☐ 1 - 3 Years
☐ 3 - 5 Years
☐ More than 5 years

TIME TO MARKET BACKGROUND
Please explain reasoning/support for time to market estimate above.

While the membrane filtration technology is not yet at a "product-ready" stage, both the performance at the large bench-top scale and the road-map to scalability intrinsic to the process design fosters confidence that the venture can grow rapidly and effectively with sufficient resources and support. By leveraging relationships with contract manufacturers and OEMs, we anticipate the ability to rapidly accelerate production of the technology once the product-ready stage is reached. By forming commercial partnerships with these entities, we anticipate a sales pipeline which involves the sale of our membrane to an OEM or similar entity, for incorporation into a larger system which is then sold to the industrial end-user.
IMPACT

Describe market opportunities and customer pain points that your technology may address.

Significant market research across many industries has yielded two distinct types of use-case, the first being the integration of the SiPure membrane into an industrial production process to enhance production efficiency, and the second involving effluent treatment and recycling to reduce waste of energy and water, and to lower CapEx and OpEx.

Industrial production processes of interest include pharmaceuticals and biopharmaceuticals, as well as petrochemicals such as ethylene, phenol, and methanol. In pharma, an example pain point is the inefficiency of current batch production techniques, which could be significantly improved by implementing a resilient anti-clogging membrane such as the SiPure technology to move towards a semi-continuous process. In chemical production, replacement of current cryo- and thermal-distillation processes with a chemically and thermally durable membrane could reduce energy usage by as much as 90%, and annual CO2 emissions by hundreds of megatons.

Pain points focused around massive waste of energy and water are also central to effluent treatment in industries such as textiles and oil & gas. In textiles, adoption of the silicon membrane technology is projected to reduce effluent treatment OpEx by over 50%, as well as drastically increasing the energy efficiency of the process, reducing annual CO2 emissions by as much as half a gigaton.
ADVANTAGES
Describe the expected and/or potential advantages your technology has over existing alternatives and emerging competitors.

In many high-volume industries, the method of choice for liquid separations is the boiling-off and condensing of components one by one. Filtration membranes, though 10X more efficient from an energy usage standpoint, have largely failed to gain ground due to either their chemical and thermal fragility or prohibitive capital and operational costs. State-of-the-art membrane technologies can be categorized into two types: polymeric and ceramic. While polymeric membranes are low-cost and able to remove most chemicals, they clog rapidly and lack cleanability based on their fragility. Ceramic membranes are composed of much more durable materials, but can be orders of magnitude more expensive, and cannot isolate species at the small end of the spectrum. The lack of alternative between these two membrane types has prevented the widespread adoption in many industries and for water treatment in the developing world.

The SiPure membrane offers a combination of the benefits provided by polymer and ceramic membranes, while minimizing the negatives. It has been shown through extensive testing to reject contaminants as small as arsenic from water, while resisting clogging and withstanding harsh chemical and thermal environments, performance which has not been achieved by either ceramic or polymeric membranes. Importantly, techno-economic modeling estimates the production cost of the membrane at below $100 per square meter, a figure over 5X lower than the closest competing ceramic membrane.

BARRIERS
Describe expected barriers to commercialization and potential mitigation strategies.

The largest commercialization barrier is existing inertia as a barrier to entry in the traditional industries where our research shows a good product-market fit, to which high changeover cost and risk from the perspective of early adopters are major contributors. This risk must be mitigated through convincing demonstrations of significant value on a scale which increasingly approaches realistic operating conditions, culminating in on-site piloting.
SCALING
Describe the opportunities and issues you see with scaling this technology.

The developed fabrication process for the membrane was designed largely with scalability in mind. Therefore there exists a clear road-map towards reaching the large scale required by most of the target markets investigated to date. The ability to scale efficiently will depend mostly on the formation of a strong relationship with a contract manufacturer capable of producing the SiPure membrane with existing equipment and processes. One such manufacturer has already been engaged in the Boston area, and additional connections are also being developed.

The largest challenge with scaling the technology is not the production of the membranes themselves, but rather of large-scale housing modules. While similar module configurations exist for other membrane technologies (known as plate-and-frame configuration), there are distinct differences that will need to be accounted for in the design and operation of modules for our technology. Ultimately, the metrics which must be maximized are the amount of membrane surface area that can be packed into a specific module volume, and the robustness of the module with expect to chemical and thermal durability, as well as tolerance to applied pressure.

FEEDBACK
Summarize any feedback you have received so far from industry, entrepreneurs or potential investors.

Industrial stakeholders and investors generally seem interested by the idea of a filtration membrane that combines harsh environment resiliency, low-cost, and rejection performance capable of separating nanoscale chemicals. In the many specific industrial applications where this type of performance is highly relevant, initial interest can be followed by healthy skepticism, and a questioning of whether the technology can be produced at a large scale in a cost-competitive manner. To prove this, we have performed multiple in-house validations of the technology pertaining to several different industrial applications, and are in the process of moving towards the next stages of engagement, namely small scale on-site pilots, with several of our industrial partners.

In general, potential investors would like to see the technology at a more advanced stage, namely in the hands of customers, prior to considering investment. There are however some earlier stage investors with whom we are in ongoing contact.
We have not yet undergone any major pivots in our strategy, though with respect to markets we are still considering a number of different potential industrial applications as potential beachheads. These include industries such as textiles, oil & gas, pharmaceuticals, semiconductors, food & beverage, and chemical production.

**OBJECTIVES & QUESTIONS**

Please describe why you would like to be selected for the C2M program and ask any questions you may have.

**OBJECTIVES**

What do you most hope to get out of your participation in the C2M program?

I would most hope to engage with students of diverse backgrounds and expertise who are passionate about cleantech technologies and applications, and are eager to engage with industry stakeholders to develop a detailed understanding of how our technology fits into the landscape of a given market. My expectation is to work with the student team to develop a detailed set of goals and questions that we would like to answer over the course of the term, and to be involved in the process to whatever extent possible, within the parameters of the program.

**QUESTIONS**

What questions (if any) do you have about the C2M program?

I am curious about the typical level of detail posed to the student teams with respect to the central questions that we would like answered. For instance, is a more appropriate question: "we would like to know how much value our technology can provide to the pharmaceutical manufacturing space", or: "we would like to develop a business plan for the implementation of our membrane in the manufacturing of a specific pharmaceutical molecule, particularly in the drug purification and concentration stage as a replacement for a specific status quo process".

Thank you for the opportunity to apply to the C2M program!
SUPPORTING MATERIALS

Please upload the following to inform C2M’s selection process (selection committees & graduate student teams).

C2M technology ...

DETAILED TECHNOLOGY DESCRIPTION

Please upload up to three (3) pages of detailed supporting materials to further explain your technology.

C2M summary sl...

SUMMARY POWER POINT SLIDE

Please upload one (1) summary Power Point (.pptx) slide to serve as an overview of your company/project.

90-SECOND PITCH VIDEO

Please upload one (1) 90-second video to serve as a virtual "elevator pitch." This is meant to be easy and informal, i.e., feel free to use any existing materials you may have an/or create a new video on your smartphone.

C2M video_Bren...

This form was created inside of UC Berkeley.

Google Forms