Foresight

Smart Policy Series

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INCENTIVIZING LOW CARBON PATHWAYS FOR ADVANCED MATERIALS

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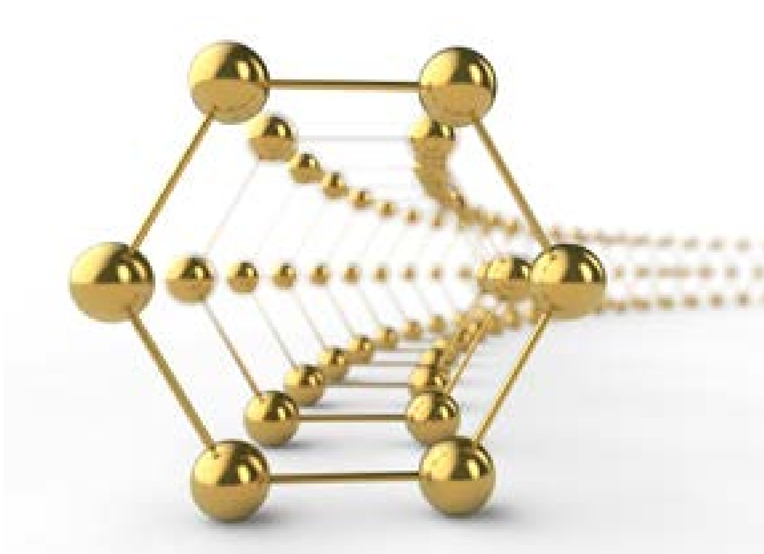
Materials discovery is a key element in the innovation cycle of energy conversion, transmission, and storage technologies, as well as energy use. So far, material science efforts combined with process and functional expertise has led to the creation of many simple materials with exceptional functionality, such as silicon-based materials that, after 60 years of R&D, have led to solar cells on roofs and billions of transistors in hand-held electronics. Of course, advanced materials is not specific to clean energy, its applicable to all sectors including the everyday products we use today.

However, given the imperative to meet our climate change targets fast, we need to accelerate the pace of development of new, high-performance, low-cost materials that are resilient, safe, recyclable and use abundant elements so that they can be deployed globally. But we don't have another 60 years to wait. This challenge is not merely an engineering problem; it requires fundamental new scientific advances to design and organize matter from the atomic scale to the systems scale. Underpinning this challenge is international, national, federal and city policy. Canada has committed to reducing their GHG emissions aligning with their UNFCCC commitment.[1] As part of that, the government is investing in R&D across sectors and Federal and City governments are investing time and effort to achieve low carbon outcomes across sectors such as energy, transport, buildings and waste.



With low carbon frameworks and increasing investment capability to solve problems, what are the barriers to deployment and scale in the advanced materials sector? And how we can realize opportunities to accelerate the clean energy transition much faster?

BARRIERS TO DEPLOYMENT & SCALE

The barriers highlighted here are not unique to advanced materials, in fact these regularly feature across the innovation landscape across sectors. However, it's important to note that advanced materials has a longer lead time for getting to market compared to other technology innovations. Typically, conventional materials R&D takes place in laboratories in companies, academic or government institutions. Government funded research is often published in academic papers and publicly open domains whereas private sector is more proprietary about the knowledge they share. Additionally, the scale of the process for the translation of new materials from conventional laboratories to market can take 15 - 20 years comparatively to private sector development, which is influenced by more pressing market drivers.

What's more, advanced materials represent about 50% of the manufacturing cost of clean energy products and are expected to increase to 80% in the near future, according to the Energy Materials Industrial Research Initiative.[2] This is because we are using materials that are becoming resource scarce or expensive to use. A significant consequence is that price of clean energy products could increase thus impeding wider adoption. We need to discover lower-cost new solutions faster.

Change is nigh. Today, a new accelerated alternative approach for advanced material discovery is being pioneered. It's called the 'High Throughput Experimentation (HTE) combinatorial approach'. This is a self-driving laboratory using smart robotics that are AI informed or supervised to guide the system of experimentation. In terms of material discovery this is 10x more efficient. What used to take months, can now take weeks or even days. For example, a researcher from MIT who runs a photovoltaic research lab is keen to use HTE to get the 15 - 20-year time frame down to 2 - 5 years by addressing various bottlenecks in the lab and automating processes as much as possible, thus allowing researchers to find dead-ends in hours rather than months.[3]

So far, we've learned that accelerating the process in discovery of new material is fundamental. Once a material is formulated and tested, the next challenge is to scale the process to yield enough for production volumes leading to a commercialization pathway. International collaborative R&D across academic, private and public sector laboratories is one method to achieve this experimentation and scale much faster, particularly if collaborators are working towards achieving a common vision such as the clean energy transition.

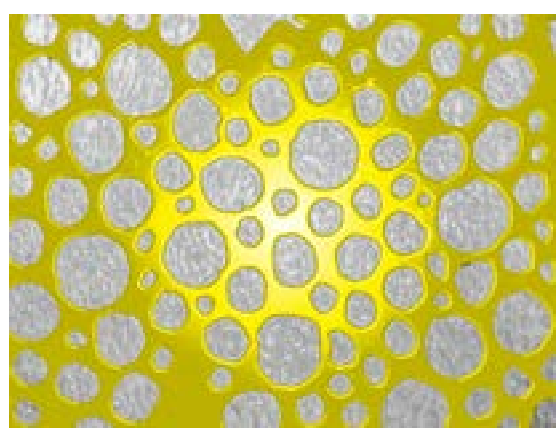
INNOVATION ECOSYSTEM FOR ADVANCED MATERIALS

There are numerous efforts underway to scale clean energy advanced materials development ranging from intergovernmental collaboration, national research initiatives developing centers of excellence to companies working on pioneering materials.

International

The International Energy Agency has been convening Technology Collaboration Programmes for the last 40 years with experts from IEA member countries, including Canada. The collaboration groups for advanced materials are mostly concentrated in the Energy End Use Working Group in transport and renewable development.[4]

Mission Innovation is a global initiative of 23 countries (including Canada)[5] plus the European Commission working on eight challenge areas, one of which is Clean Energy Materials, otherwise known as IC6. They developed the Materials Acceleration Platform,[6] or MAP, which aims to reduce the materials and devices development cycle from the aforementioned 15-20 years to 1-2 years. National teams are looking at developing or improving materials for applications ranging from advanced batteries and solar cells, to low energy semiconductors, thermal storage, coatings for various applications, structural materials, and catalysts for the conversion and capture of CO2. The governments of Mexico and Canada are the current responsible national teams, though the USA was instrumental in initially establishment of the program with Mexico.



Canada

A number of progressive academic departments and companies are working on pioneering and commercialization of advanced material technology across Canada.

A first-of-its-kind academic project funded by NRCan Energy Innovation Program at UBC, called project ADA,[7] will demonstrate the acceleration potential of artificial intelligence driven and autonomous laboratories as mentioned earlier in this article (see image).

In addition, National Research Canada recently launched a clean energy materials challenge to support the development of affordable and cost-competitive alternative solutions that aim to help the country meet its greenhouse gas emission reduction targets.[8] Canada's Research Chair in Advanced Materials for Clean Energy is Dr. Zhongwei Chen.[9] He is designing and developing new nanostructured energy materials that will support the development of clean energy technologies, including fuel cells, rechargeable metal-air batteries, and lithium-ion batteries. His research group based at University of Waterloo focuses on the development of unique, high performance nanostructured materials for use in clean, sustainable energy technologies.

Canadian companies offering solutions on the market are:

- Switch Materials, a Vancouver company, focus on synthetic and polymer chemistry research and applications. Their glazing product can be applied to transportation, aerospace and building sectors with the latter application helping to reduce total building energy consumption.[10]
- Intermetallica is an advanced material startup introducing a new class of intermetallic compounds in the form of coatings to protect steel from corrosion. Using a novel low-cost, scalable and environmentally neutral manufacturing method, they intend to displace traditional metal manufacturing methods which have remained unchanged for decades.[11]
- CarbonCure, based in Nova Scotia, improves the compressive strength of ready-mix concrete, which enables concrete producers to optimize their mix designs, while reducing the carbon footprint of their concrete.[12]
- Enerkem, a Montreal headquartered company, has proprietary technology that converts non-recyclable municipal solid waste into methanol, ethanol and other widely used chemical intermediates.[13]

Credit: Berlinguette Research Group, University of British Columbia

- Metamaterial Technologies Inc from Nova Scotia have developed a new patented platform technology using a variety of smart materials that are capable of manipulating light. The company's smart material products are made from precisely designed nanostructures which effect light in different ways—blocking, absorbing, and enhancing as required. One application, among many, is solar enhancement.[14]

WHERE ARE FUTURE OPPORTUNITIES FOR CLEAN ENERGY MATERIALS?

Mission Innovation released a report in January 2018, including a table citing opportunities and gaps for material innovation in batteries, solar fuels, wind power, thermal energy conversion, gas separation and storage and power transmission (visit pg. 13 of the Materials Acceleration Platform IC6 report).[15]

Below is a summary from the Photovoltaics section where you can see current status and scientific advancement required to make the technology more productive and efficient, including work on organic solar cells.

ENERGY TECHNOLOGY	CURRENT STATUS	MATERIALS OPPORTUNITIES
Photovoltaics	· PV module production is dominated by a small number of materials: polycrystalline and single crystalline Si and CdTe. · Reducing capital and manufacturing costs could lower full levelized cost of solar electricity to 0.03 US$/kWh (i.e., US DOE 2030 target).	Further reductions in cost of solar electricity require improved efficiency, longer module/ electronics lifetimes, and reduced efficiency degradation. · New materials and new mechanisms for solar energy harvesting are required. · Hybrid perovskites are one of the most promising classes of new materials, with power conversion efficiencies >22%, but suffer from low long-term stability and presence of toxic elements. · New mechanisms for boosting efficiency (e.g., photon up-conversion, carrier multiplication, luminescence concentrators) require new materials, but performance of current materials is lacking.

When looking at opportunities in advanced materials, we've learned it's important to look more closely at where in the value chain can a solution best work to extract profit, productivity and reduction in GHG emissions.

Endnotes

[1] nrcan.gc.ca/environment/10760

[2] mission-innovation.net/wp-content/uploads/2018/01/Mission-Innovation-IC6-Report-Materials-Acceleration-Platform-Jan-2018.pdf

[3] technologyreview.com/s/612898/ai-is-reinventing-the-way-we-invent/

[4] iea.org/about/structure/cert/euwp/#d.en.35058

[5] nrcan.gc.ca/energy/resources/mission-innovation/18612

[6] mission-innovation.net/wp-content/uploads/2019/01/6.1.22-Materials-IC-Jan-2018-workshop-report.pdf

[7] projectada.ca

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