Alternative Materials and Processes for a Low-Carbon Economy

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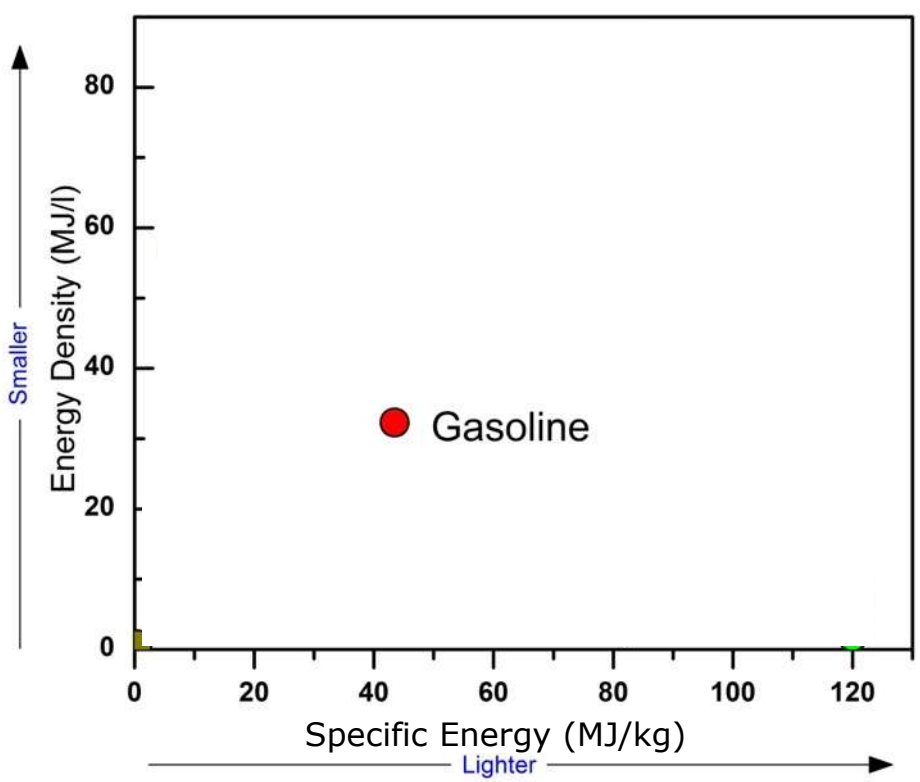
George Demopoulos, Raynald Gauvin, Jan Kopyscinski

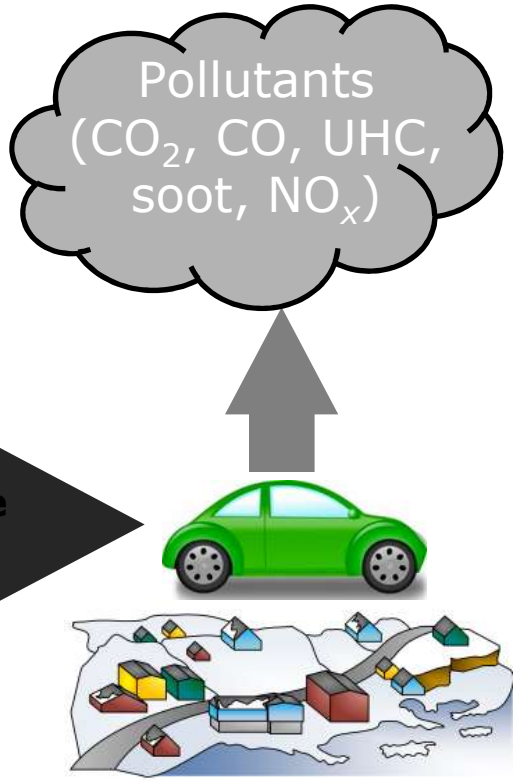
Visit by Senate Committee on Energy

Feb. 8, 2017

McGill

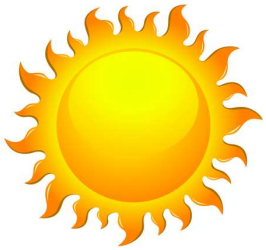
We need alternatives to fossil fuels

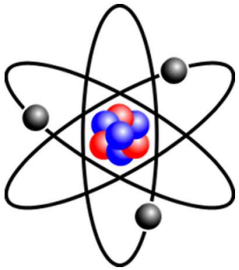




- Gasoline and diesel are excellent fuels
  - Convenient (liquids) and high energy density and specific energy
- But, there are problems with such organic fuels
  - Limited fuel supplies and air pollution, including climate change

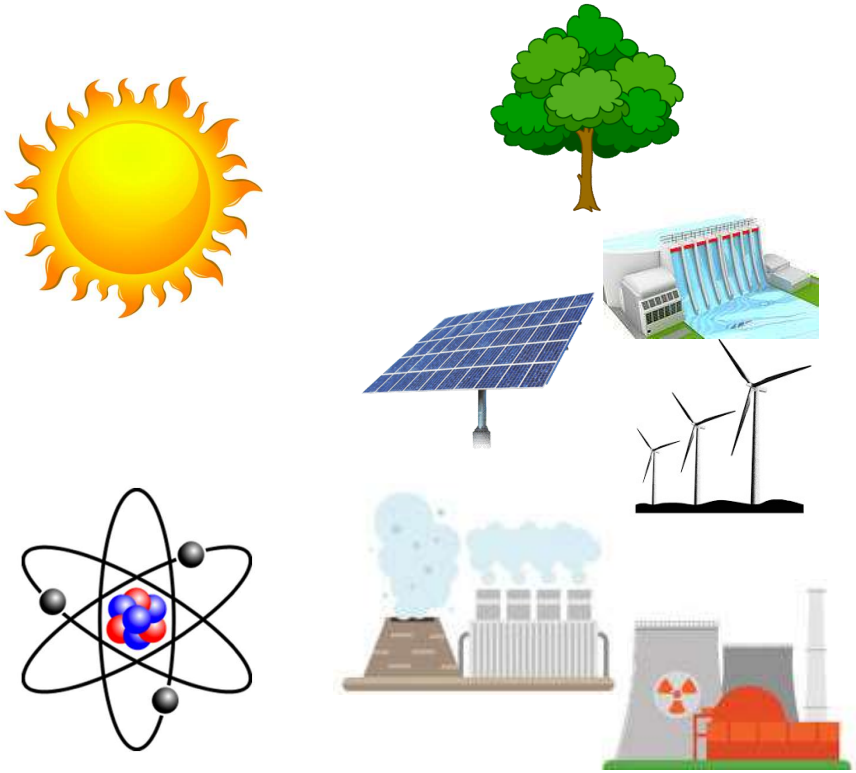
Energy production, storage, distribution, & use





Primary Energy

Energy production, storage, distribution, & use

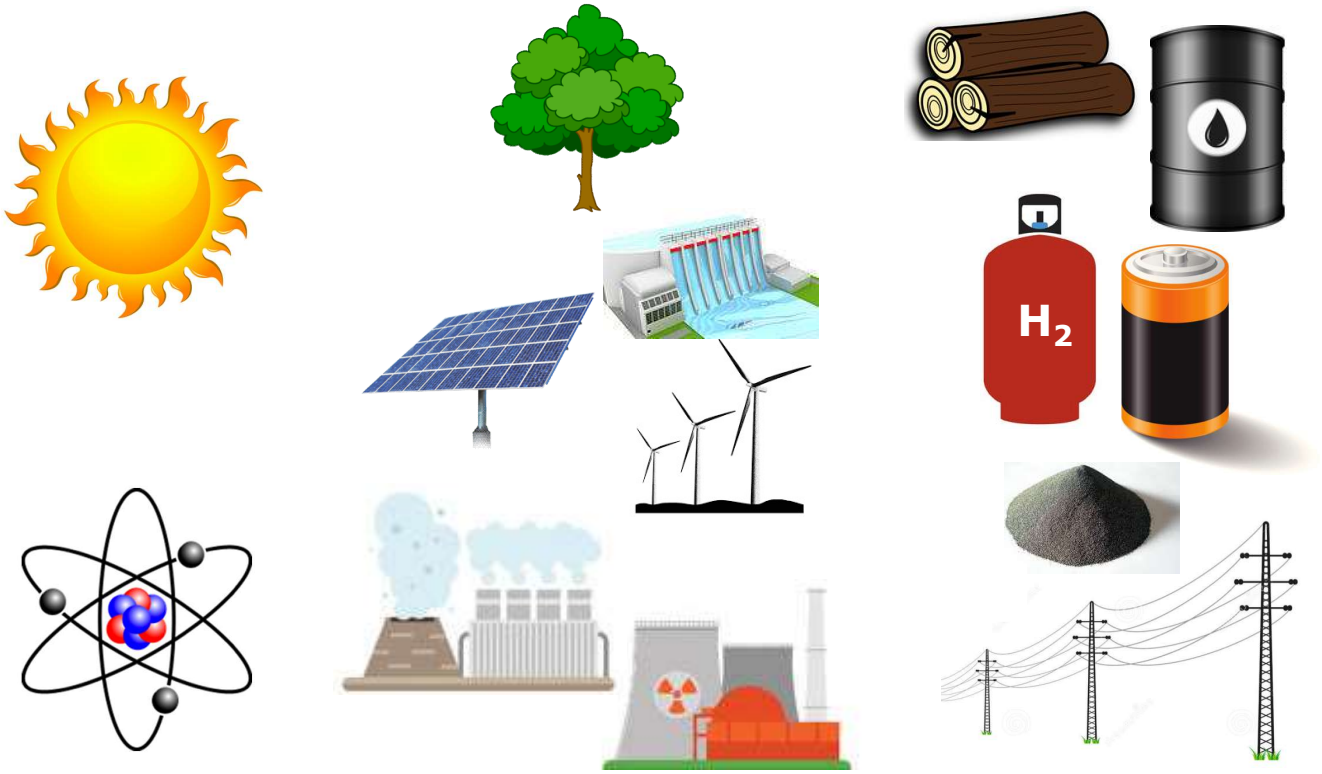


Energy Production

Primary Energy

Conversion losses

Energy production, storage, distribution, & use



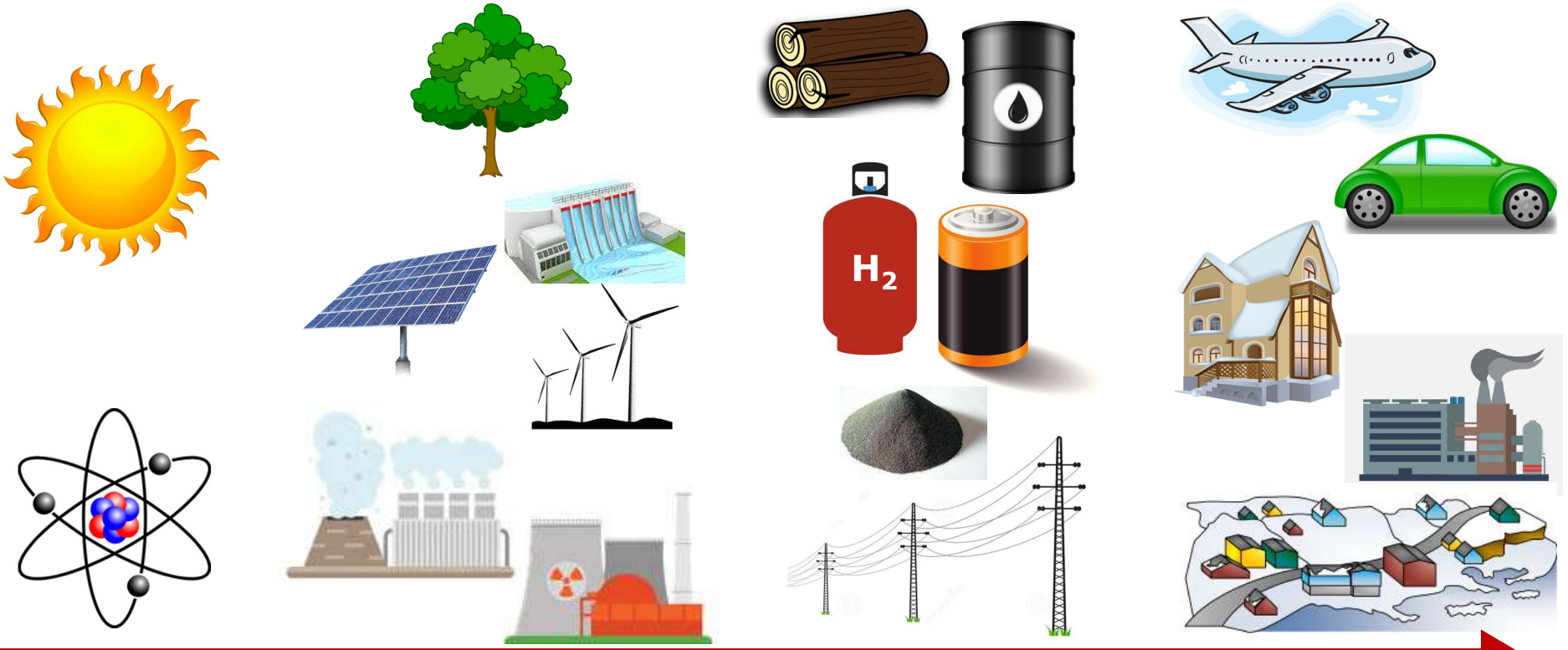
Primary Energy

Energy Production

Energy Storage/Transport

Conversion losses

Energy production, storage, distribution, & use



Canada can produce more low-carbon energy than needed

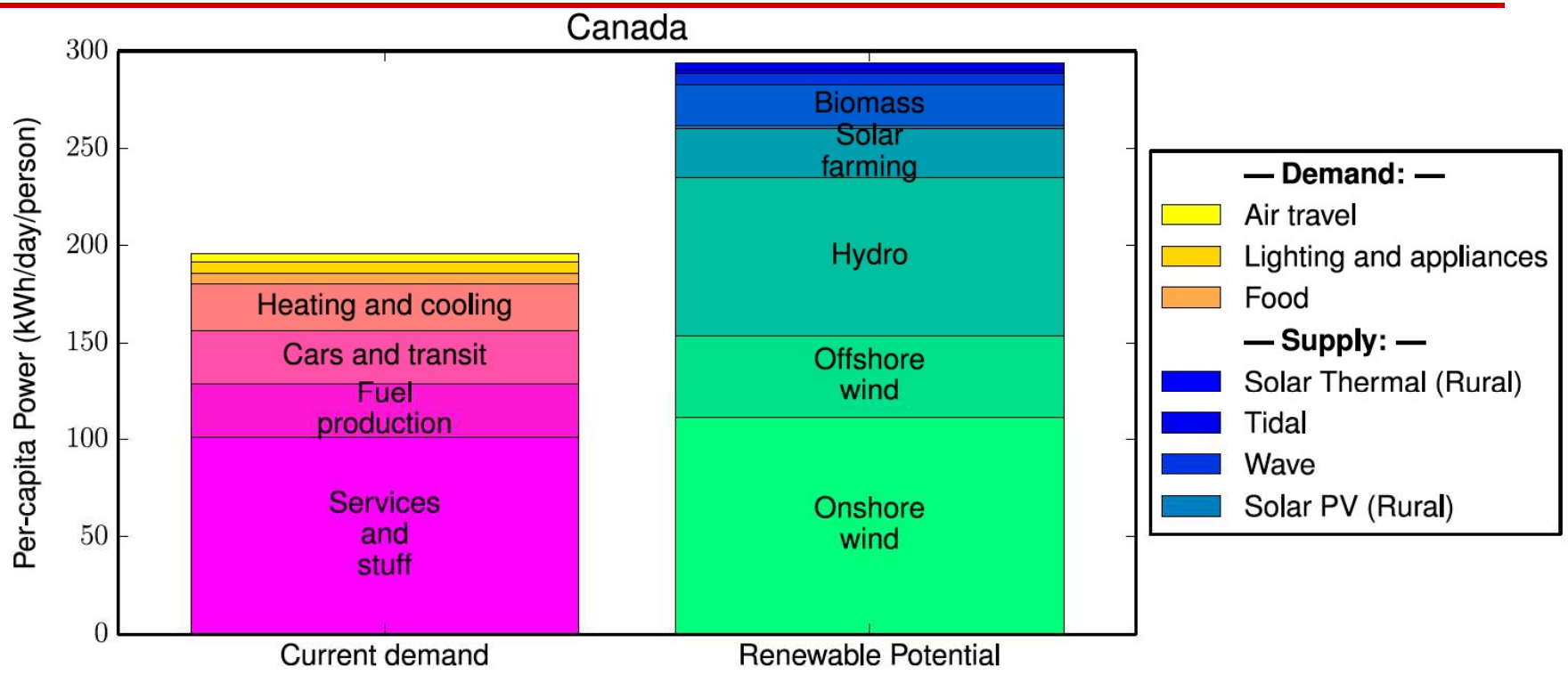
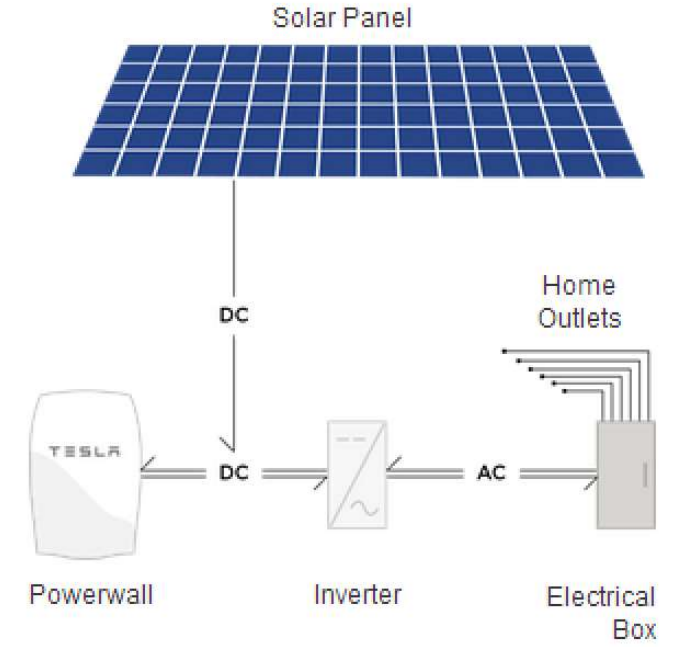


Fig. 8. National summary: per capita demand and potential supply.

- Canada can produce enough low-carbon primary energy to more than cover our current energy needs
- Solar energy farming could be much higher than shown if there was a market for this excess clean energy
- How can we export our abundant clean energy?

CP Barrington-Leigh & M Ouliaris
The renewable energy landscape in Canada: a spatial analysis

The case for solar energy and Li-ion batteries



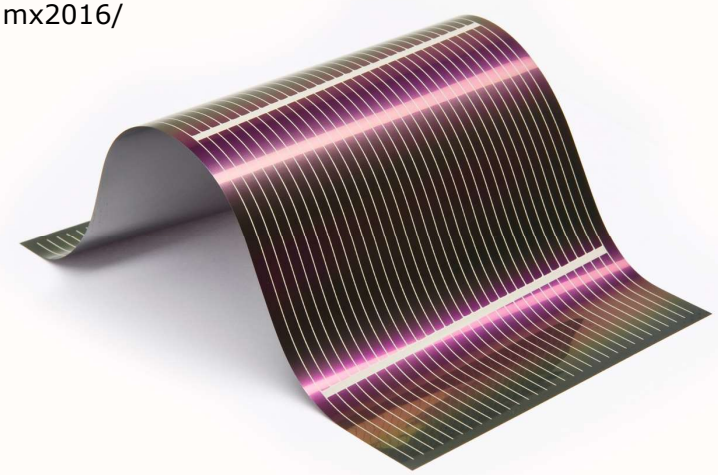
http://www.teslamotors.com/en_CA/POWERWALL

https://www.lecircuitelectrique.com/

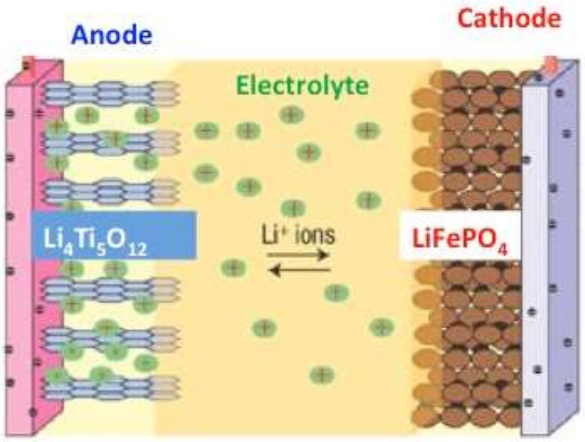
- **Solar energy** - make solar energy cost-competitive with fossil fuels
- **Battery-based energy storage** - for stationary (ESTALION-HQ-SONY Venture) and transportation applications: **reduce cost and increase capacity/driving range**
- **Lithium-ion batteries:** Strategic priority for Québec and **Hydro-Québec**
- **Big growth potential**: up to **one trillion $** by 2026*

Solar cells and lithium-ion battery research

https://materia.nl/article/innovation-thin-film-solar-cells-a
mx2016/



Thin-film solar cell



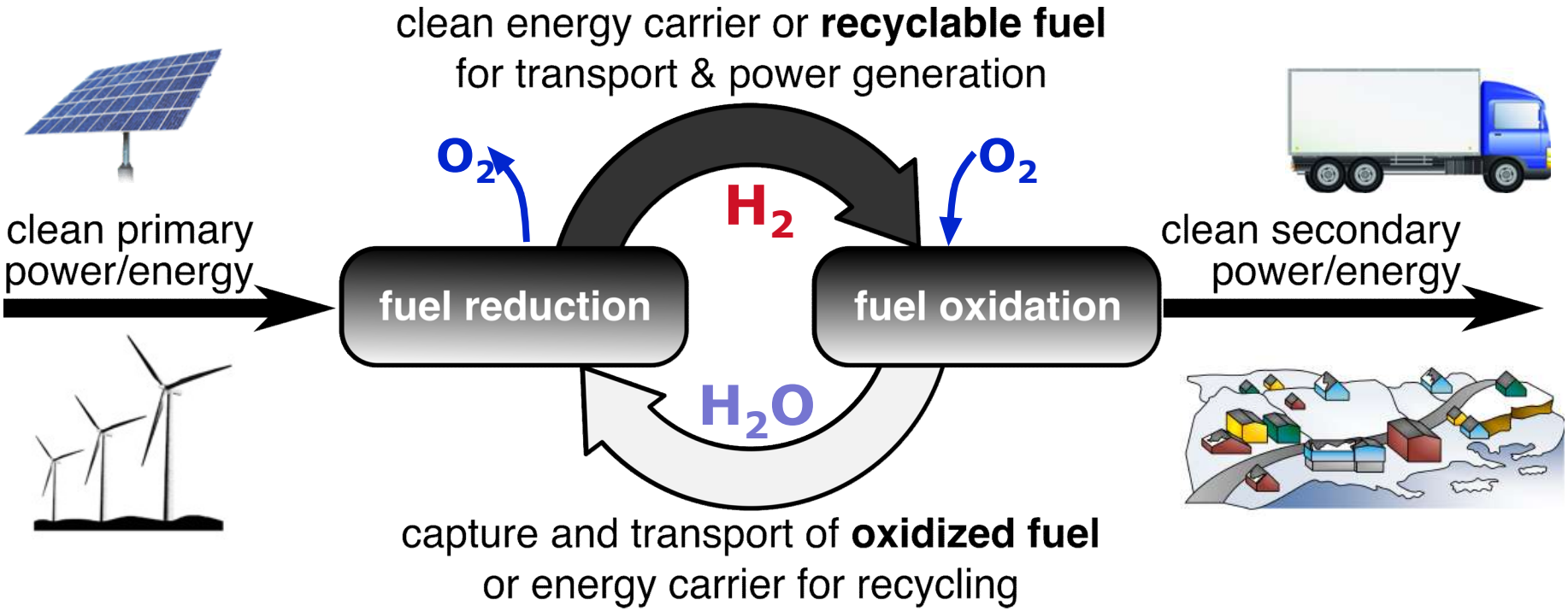
[Nat Nano **2**(2007), 598]

Novel cathode material for Li-ion batteries

Demopoulos group (Materials Engineering):

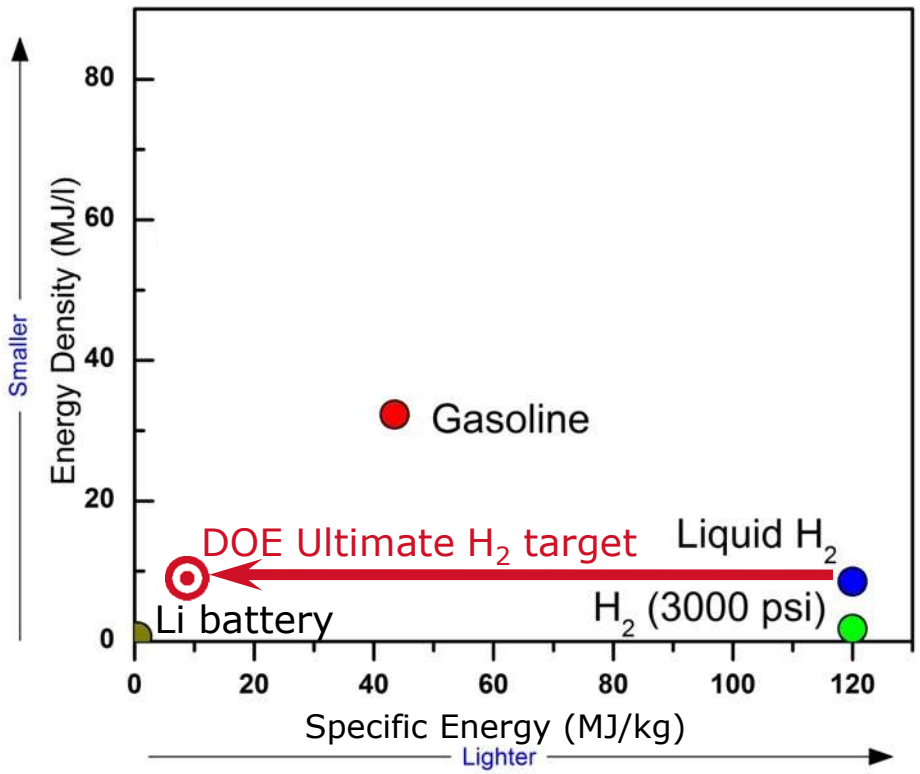
- Focus on **cost-effective, scalable and sustainable fabrication** of electrodes for:
    1. New thin-film solar cells (DSC, CZTS etc.) and
    2. Lithium-ion batteries
- Research in collaboration with Hydro Québec

Electricity ➔ Fuels



- Energy carriers are needed to allow for international energy trade
  - **Renewable energy commodities** and **strategic energy reserves**
- Fuels are the densest form of energy that is convenient to use
  - Can be oxidized by atmospheric oxygen
- Energy carriers should be recyclable with no carbon emissions
  - No carbon emissions at point of use or during recycling

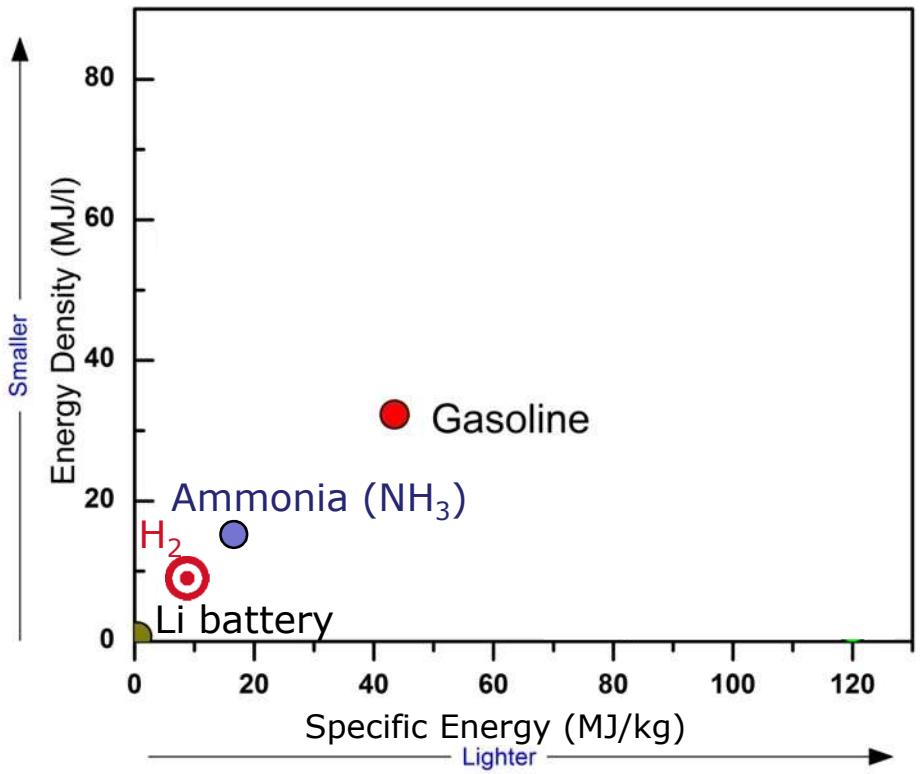
Batteries and hydrogen are great, but not enough

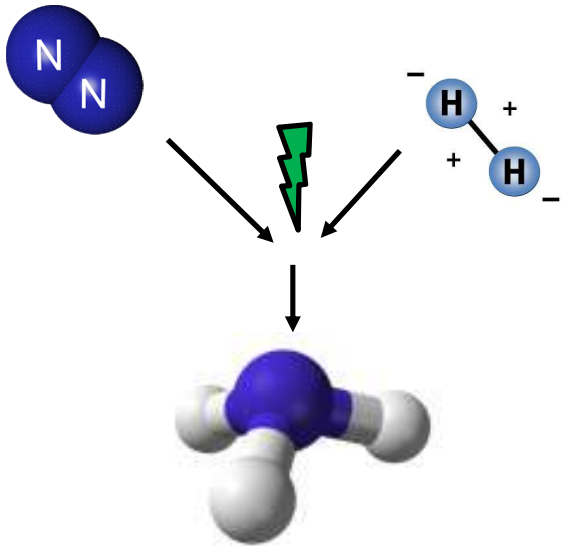


http://de.toonpool.com/user/651/files/fuel_cell_63455.jpg

- Hydrogen has low energy density
- Hydrogen storage systems have low specific energy
  (50kg of hydrides for 1kg of hydrogen)
- Hydrogen is very explosive for wide range of fuel-air concentrations
- Batteries have low energy density and specific energy

Electricity ➔ Hydrogen ➔ Ammonia

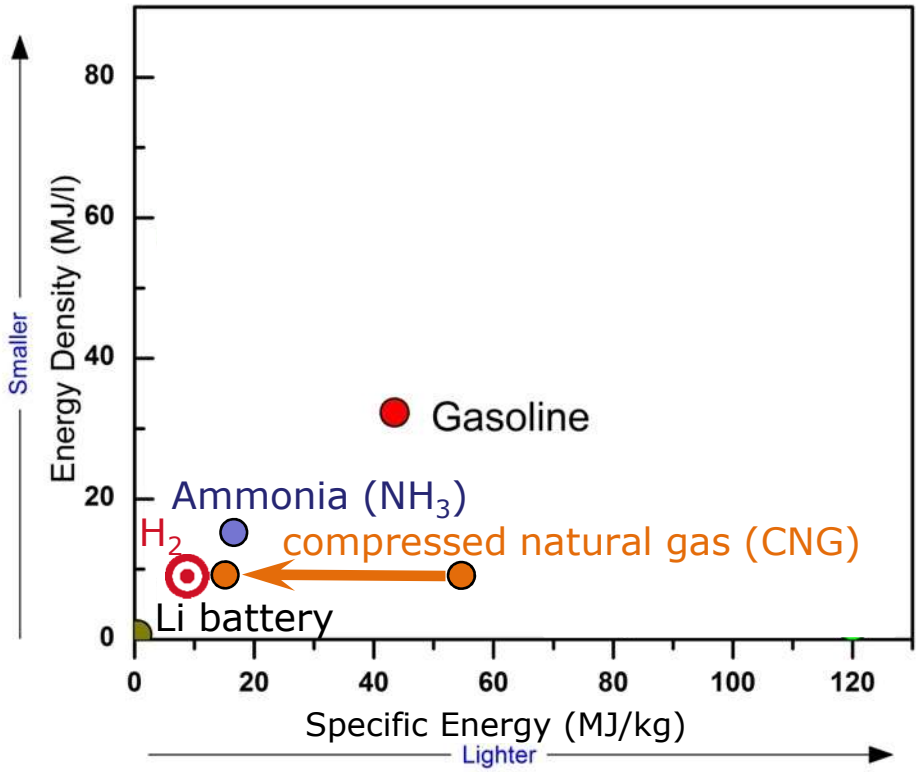


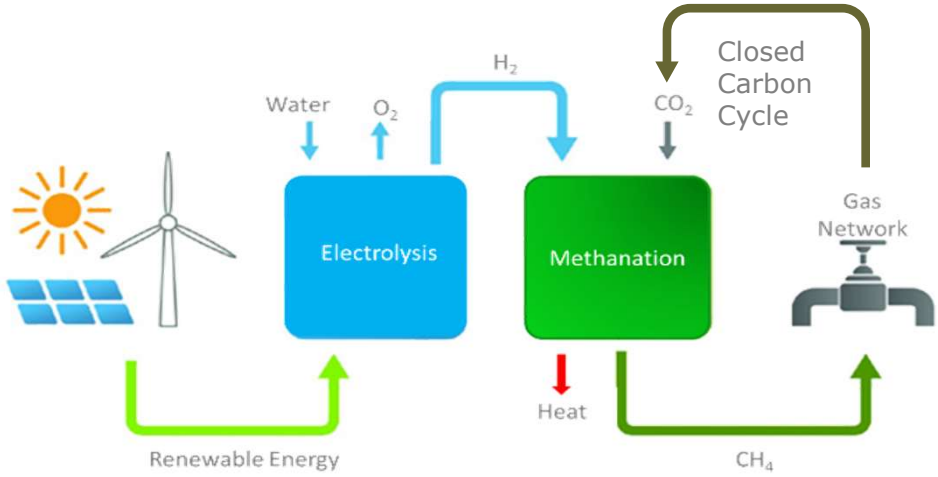


Plasma Processing Laboratory (Coulombe, Chemical Eng.)

- Hydrogen can be stored in chemicals, including ammonia
- Ammonia is also an important commodity and fertilizer input
- Ammonia can be used directly as a fuel or to produce hydrogen on demand
- Research at McGill targets improved electro-catalysts to improve both hydrogen and ammonia synthesis

Electricity ➔ Gas (Methane)



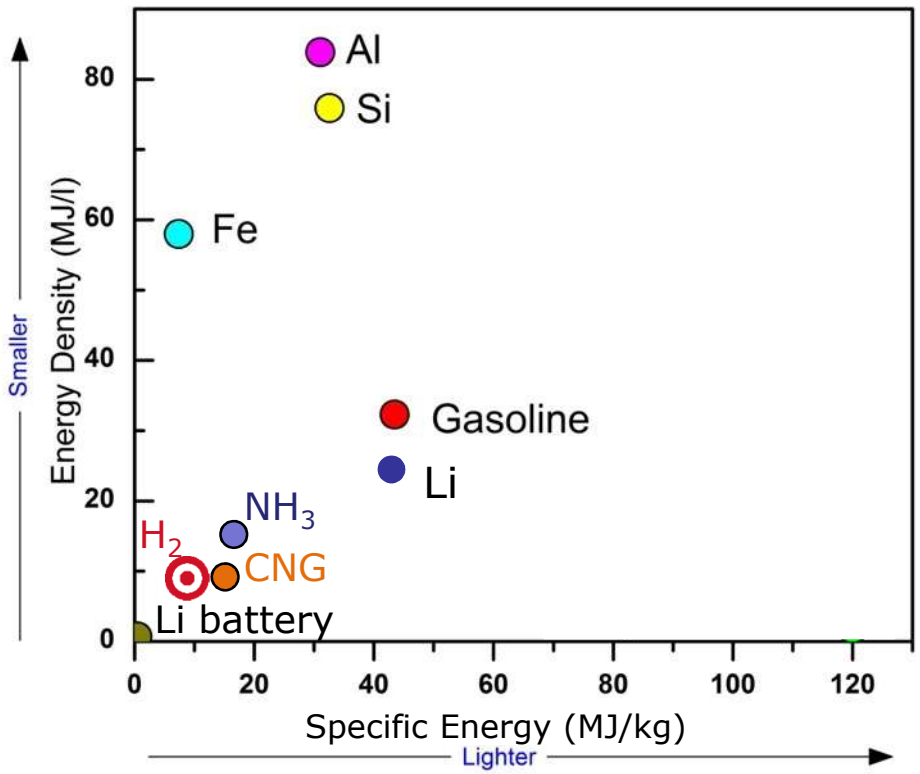


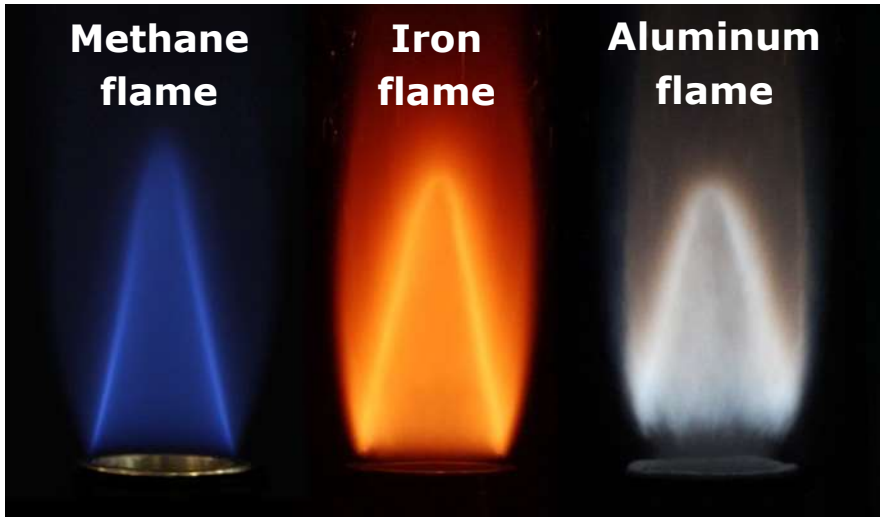
Electricity ➔ Methane (Power2gas)

Catalytic Process Engineering Laboratory (Kopyscinski, Chemical Eng.)

- Hydrogen is difficult to transport and store but can be stored in chemicals, such as being upgraded to methane (natural gas)
- This gas can be fed into existing gas network to distribute this energy
- McGill research focuses on improved catalysts for methane production

Electricity ➔ Metal Fuels





Alternative Fuels Laboratory
(Bergthorson, Mechanical Eng.)

- Metal fuels burn in air producing heat
- Metal fuels burn in water producing hot H_2
- Combustion product is solid metal oxide
- Heat (and H_2) can be converted to power

Aluminum-water propellant

McGill Alternative Fuels Laboratory

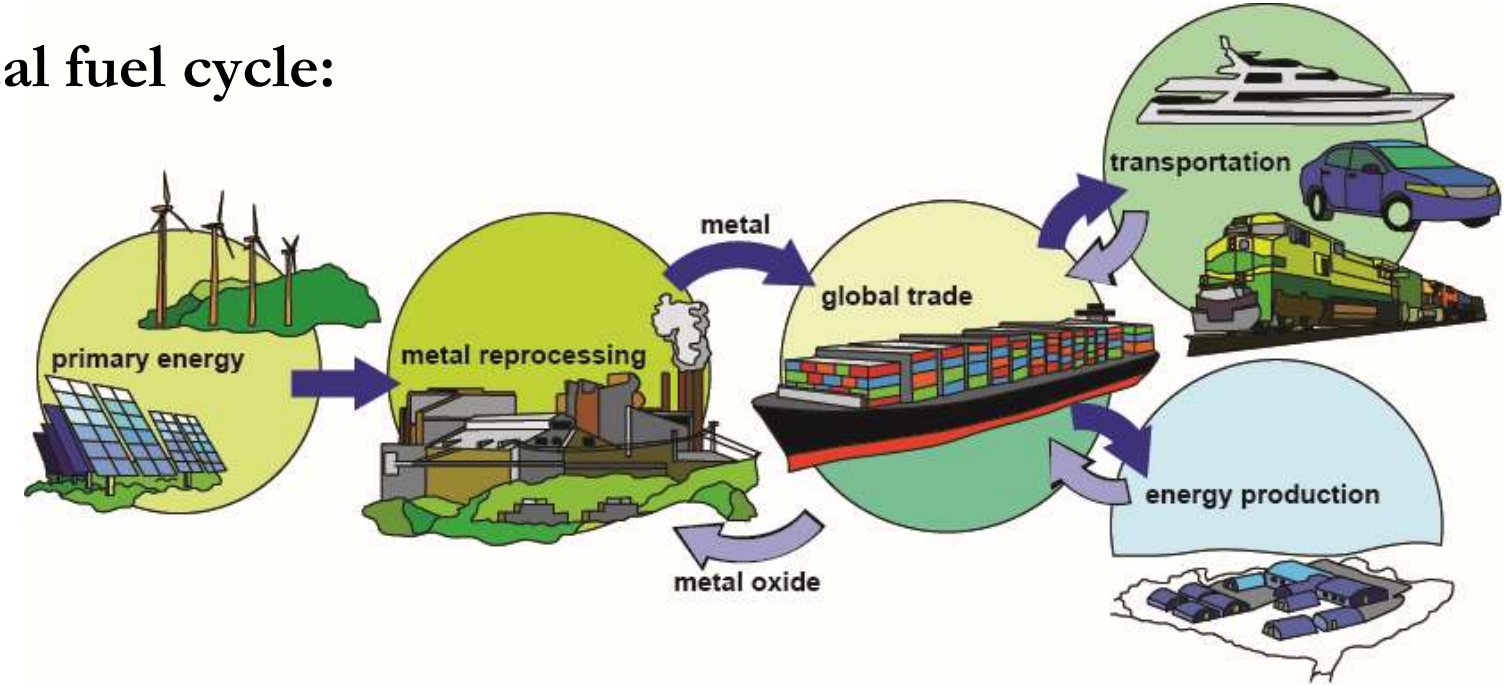
ALICE rocket (aluminum-ice)

Purdue University

JM Bergthorson et al. *Applied Energy* (2015, 2016, 2017)

Metal fuels – zero-carbon recyclable energy carriers

Metal fuel cycle:



Alternative Fuels Laboratory (Bergthorson, Mechanical Eng.)

- Clean primary energy (solar, wind) can be used to recycle metal oxides (combustion products) into reactive metal fuels with no carbon emissions.
- Metal fuels can be shipped globally, like oil, coal or natural gas are today.
- Energy in metal fuels can be released to generate electrical or motive power for stationary or transportation applications.

JM Bergthorson et al. *Applied Energy* (2015)

Alternative Low-Carbon Materials & Processes

- Canada can produce more clean energy than we currently consume.
- To export this excess clean energy, we need to store it in a **renewable energy commodity** through **electricity ➔ fuel** technologies.
- McGill researchers are studying a whole host of clean technology options:
  - Low-cost solar cells
  - Improved battery technologies
  - Recyclable fuels (hydrogen, ammonia, renewable gas/liquid fuels, metal fuels)
- A whole range of options are needed to serve different markets.
- The potential economic returns on such fundamental research are huge and strategic investment is urgently needed in this area.
  - Current programs require universities to "give away" the intellectual property during the transition of the technology from the lab to prototype or pilot scale.
  - Low-carbon energy is not currently a Strategic Target Area for NSERC research proposals
- We need to recognize that investments in clean technology bring a return on that investment, in energy and money, and are not a "cost" to society.

Thank You

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