A Sustainable Global Society

How Can Materials Chemistry Help?

A summary report from the Chemical Sciences and Society Summit (CS3) 2010
March 2011

www.rsc.org/sustainablematerials

ABOUT THE CHEMICAL SCIENCES AND SOCIETY SUMMIT (CS3)

The annual Chemical Sciences and Society Summit (CS3) brings together the best minds in chemical research from around the world and challenges them to propose innovative solutions for society's most pressing needs in the areas of health, food, energy, and the environment. This unique event boasts an innovative format, aiming to set the course of international science, and rotates each year among the participating nations.

A Sustainable Global Society summarises the outcomes of the second annual CS3, which focused this time on sustainable materials. Thirty top materials chemists from the five participating countries assembled in London to identify the scientific research required to address key global challenges, and to provide recommendations to policy makers. The full white paper presents an international view on how materials chemistry can contribute positively to creating a sustainable world. This is a summary of that paper.

The CS3 initiative is a collaboration between the Chinese Chemical Society (CCS), the German Chemical Society (GDCh), the Chemical Society of Japan (CSJ), the Royal Society of Chemistry (RSC) and the American Chemical Society (ACS). The symposia are supported by the National Science Foundation of China (NSFC), the German Research Foundation (DFG), the Japan Society for the Promotion of Science (JSPS), the UK Engineering and Physical Sciences Research Council (EPSRC), and the USA National Science Foundation (NSF).

CHALLENGES AND OPPORTUNITIES

With the aid of materials chemistry we can create a world in which energy use need not be limited, where we can decrease carbon dioxide (CO_2) emissions, reduce our dependency on fossil fuels and minimise the impact we are having on our environment. We can prevent further depletion of our scarce natural resources, and create new consumer products that can enable new low-carbon and resource-efficient industries to flourish, driving economic growth.

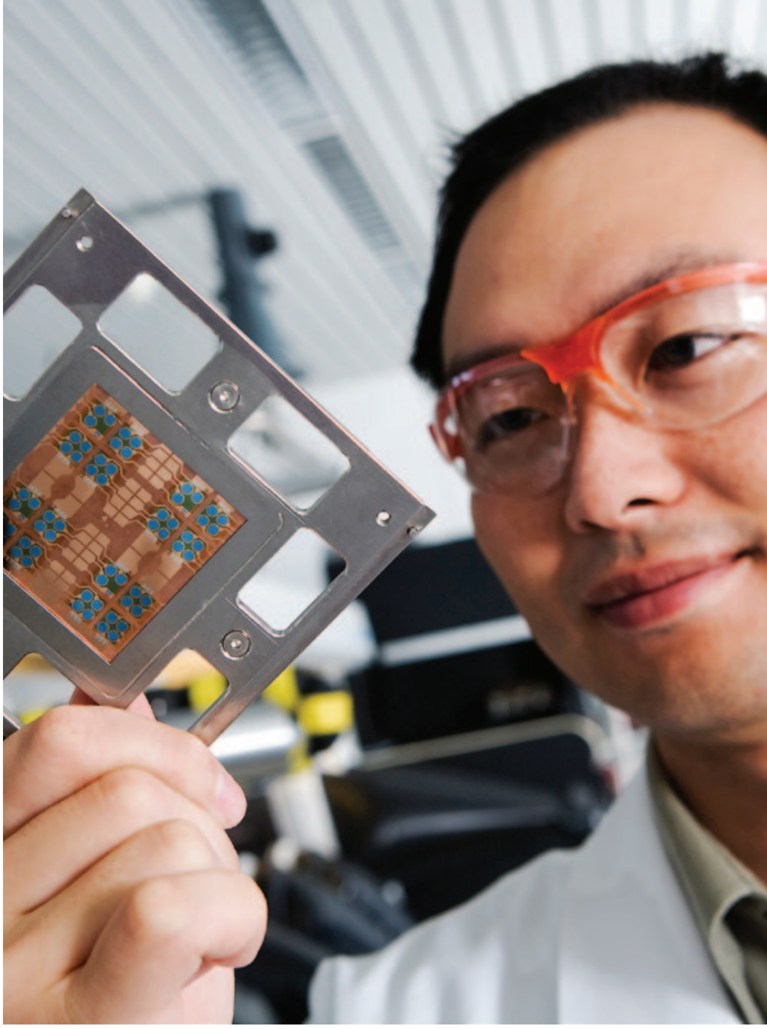
The world's population continues to increase and is expected to have increased by 1.7 billion to over eight billion by 2030, with the majority of people living in cities. Cities place huge pressures on the supply of energy and resources, and create emissions at a rate that is unsustainable.[1]

Living standards are improving in many parts of the world.[2] If everyone today had living standards equivalent to those prevalent in North America, between two and three times the Earth's natural resources would be needed.[3]

The coupled effects of population growth and improved standards of living put great strain on the planet and on our remaining accessible resources. We are rapidly approaching the maximum rate at which we can extract oil from the planet. Our appetite for energy is producing increasing quantities of CO_2, a pollutant that contributes to the warming of the planet and which currently cannot be removed or stored in any efficient way. Supplies of other natural resources are also a concern. Current assessments suggest that we will soon need to identify alternative sources of a number of strategic minerals.

We are damaging our planet in an irreparable and sometimes unquantifiable fashion. It is clear that our current use of natural resources is not sustainable. Although chemistry has sometimes been rightly or wrongly blamed for damaging the environment, it has also provided many of the material benefits without which we could not survive today such as pharmaceuticals, plastics and fuels.

With the aid of materials chemistry, we can create a world in which our energy requirements are delivered sustainably, where usable energy can be produced, stored and then supplied wherever it is needed. We can minimise and remove pollutants from our environment as we create new consumer products which place less of a burden upon our natural resources.



A researcher examines solar cells made using novel semi-conducting materials; new materials will be vital in meeting world energy needs

"Chemistry provides the wisdom we need to achieve sustainability, to solve, in other words, the issues that threaten humanity's continued existence. The chemist has a mandate to counsel society on the possible solutions that can be achieved through chemistry."

Ryoji Noyori HonFRSC ForMemRS
President, RIKEN Research Institute
Professor, Nagoya University
2001 Nobel Laureate

A Sustainable Global Society outlines five key areas in which materials chemists, through collaboration with other scientists, industry and policy makers, can seize exciting opportunities to address global challenges. Materials chemistry will underpin many of the required solutions to some of the most important energy and environmental problems in today's society.

1. ENERGY CONVERSION AND STORAGE

A growing population and rising living standards are increasing world demand for energy. This demand may soon outstrip the amount of usable energy that can be obtained using currently-available methods.

Materials chemists will help to develop new, sustainable energy conversion and storage technologies that can meet future energy demands without increasing harmful emissions of CO_2.

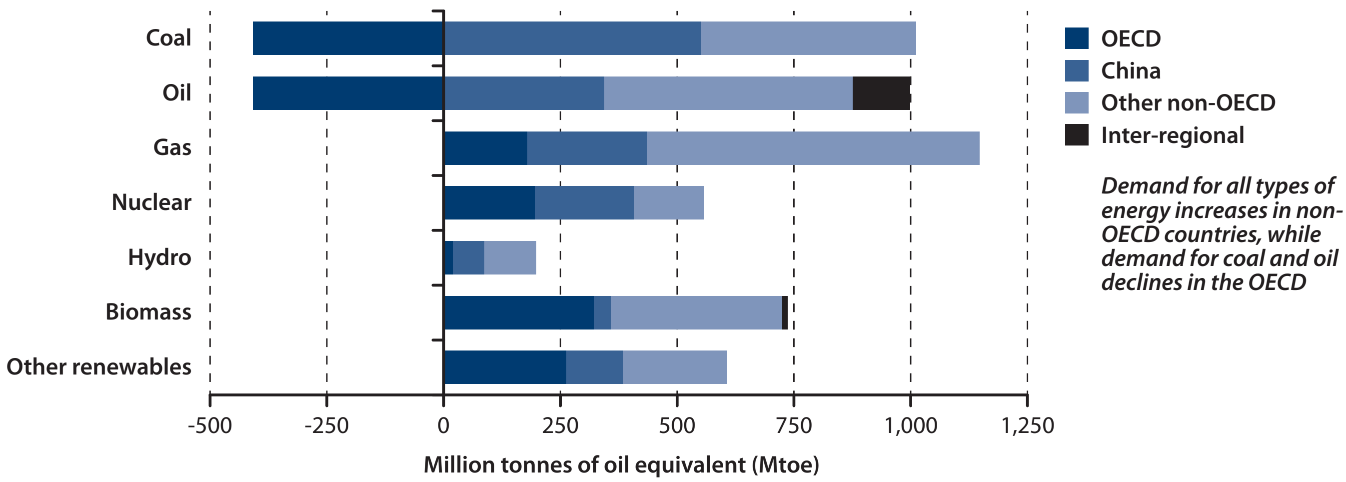
- Sustainable solar energy technologies can be developed that efficiently harvest energy from sunlight anywhere on the planet at lower costs.
- Innovative new fuel cells can efficiently exploit renewable sources of energy.
- Next-generation battery and chemical energy storage technologies will enable us to flexibly store and transport energy, and to fully utilise intermittent forms of energy such as solar and wind.

2. CO_2 CAPTURE, ACTIVATION AND USE

It is estimated that the Earth will likely warm by between 2 and 4.5 °C in the next 100 years, largely as a result of human-made CO_2 emissions. Although carbon capture and storage (CCS) systems may help to reduce CO_2 emissions, CO_2 cannot be commercially captured at present.

Materials chemists can help to improve CCS systems and to develop novel ways of treating CO_2 as a value product rather than waste.

- Sustainable methods can be developed to convert CO_2 into chemical products for fuel and feedstocks.
- Technologies to synthesise new polymers from CO_2 could be available within a few years, reducing our reliance on petrochemical feedstocks.
- Supercritical CO_2 can be used as a solvent in many industrial processes, as a sustainable alternative to those derived from fossil fuels.



Incremental primary energy demand by fuel and region 2008-2035[4]

3. FOSSIL FUEL AND FEEDSTOCK REPLACEMENT MATERIALS

Approximately 90% of oil extracted from the Earth is used to produce petroleum; the remainder is used to make everything from convenience plastics to life-saving pharmaceuticals, and the demand for all of these is set to rise.

Materials chemists can help to reduce our dependency on fossil fuels and feedstocks in a number of ways.

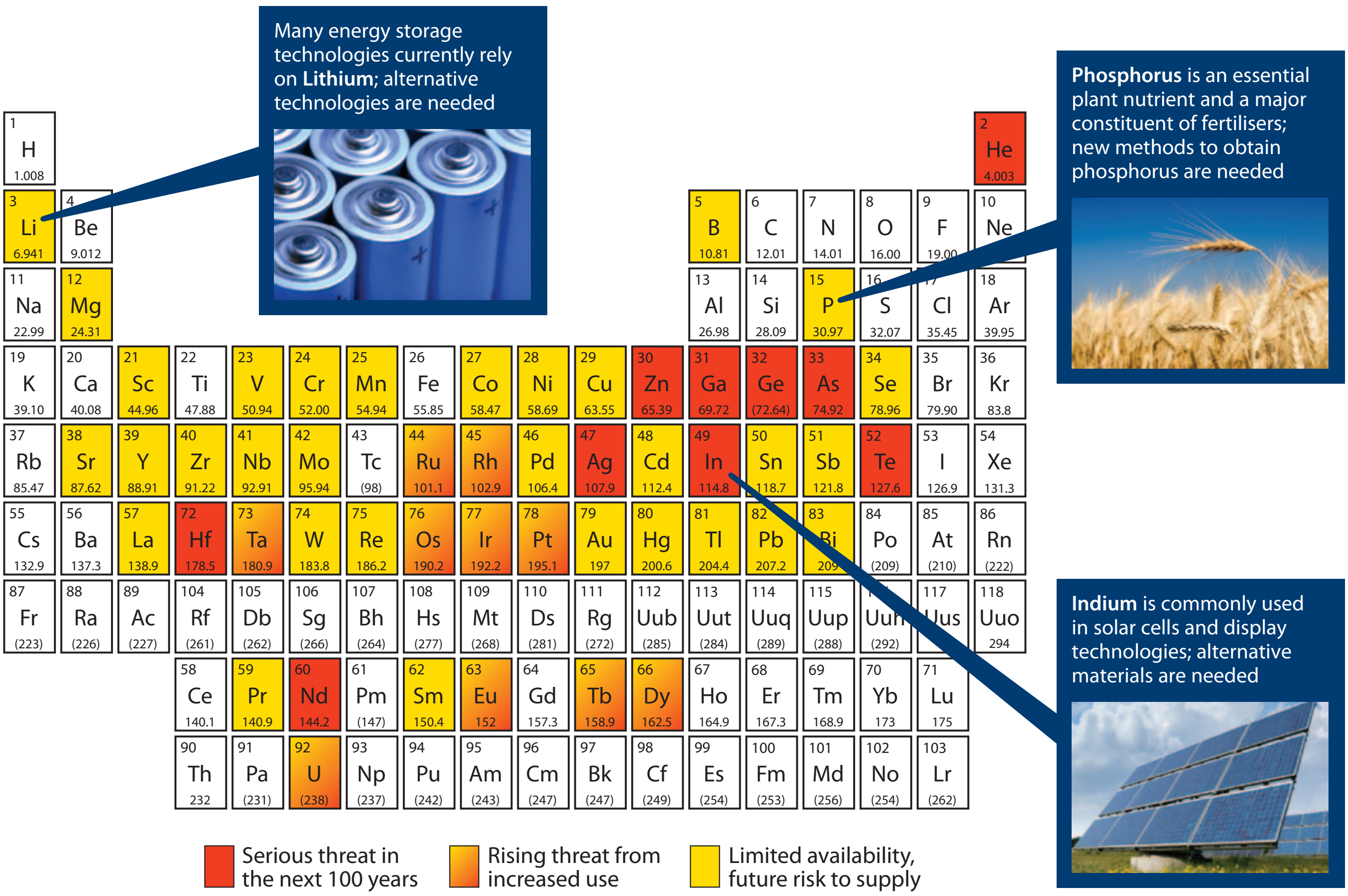
- Methods to efficiently extract petroleum from low-quality sources can be developed.
- Improved catalytic and separation processes can be designed and optimised that enable us to efficiently and sustainably utilise syngas, methane, biological feedstocks and even carbon dioxide as fossil fuel alternatives.
- Polymers made from new and unique biomass feedstocks may eventually overtake petrochemical-derived plastics in terms of superior properties and functionality.

4. CONSERVATION OF SCARCE NATURAL RESOURCES

Supplies of scarce natural resources are dwindling at an alarming rate and many vital, rare minerals are often obtained from politically turbulent countries. Shortages will hit within a generation.

Materials chemistry can help to reduce, replace and recycle the use of scarce natural resources.

- New methods to extract phosphorus from soil, rivers and oceans can be developed.
- Alternative energy storage technologies can be designed that do not rely on supplies of lithium.
- Materials chemists will design new catalytic processes that do not require platinum, together with new materials for appliances and solar cells that are free from indium. Alternatives to rare earth metals in a range of applications should also be considered.
- A concerted global strategy to optimise the supply of scarce natural resources is urgently required in the interim, until technological alternatives can be delivered.



Endangered elements: the periodic table in short supply[5]

5. GREEN MATERIALS AND PROCESSES

The pressures created by a growing world population are damaging the environment. We must meet our energy, material and water needs in ways that are non-harmful and sustainable, using the principles of green chemistry.

Materials chemistry will help to develop new processes and technologies which are more efficient and which minimise the long- and short-term impact on the environment.

- Materials chemists can develop new catalysts that do not rely on scarce or toxic chemical elements while delivering high yields of product and generating minimal waste.
- New large-scale industrial processes can be designed that are energy- and water-efficient and avoid fouling the environment.
- New technologies to better monitor and remove air, soil and water pollutants from the environment can be designed for both developing and developed countries.
- New generations of plastics can be designed that are safe, easily recyclable or fully biodegradable, to have a minimal impact on the environment.

MAKING IT HAPPEN

Fundamental advances in science underpin many of these proposals – support for curiosity-driven (blue-skies) research must be in place to maintain the flow of future scientific breakthroughs.[6] *Chemistry for Tomorrow's World: a roadmap for the chemical sciences*, provides recommendations to create and maintain a supportive framework to address global challenges.[7]

A sustainable and long-term strategy for investment in science will be vital for the continued well-being, comfort and wealth of modern society.[8,9] While the challenges in each geographical and political arena may vary, it is important that national thinking not be limited to the challenges of that country alone.

Many of the goals outlined here should be achievable within a relatively short timescale, and will help to improve the world for this generation and the succeeding ones. Although financial investment is

required, in the mid-to-longer term this investment can be economically beneficial,[10] will create new, greener industries that create sustainable jobs, and will ensure global security. We must act now if we are to reap the benefits materials chemistry can offer.

> ***"The focus on global warming sometimes blinds us to the other consequences of an increasing world population and the depletion of many resources needed to sustain and develop the advanced lifestyles we crave. This report warns us of the fact that resources are finite, and in some instances are already in very short supply, but also gives the positive message that chemists can and will provide some of the solutions needed to move to a sustainable world."***

David Phillips OBE CSci CChem FRSC
Professor, Imperial College London
President of the Royal Society of Chemistry

REFERENCES

1 *State of the world's cities 2008/2009: Harmonious Cities*, UN–HABITAT, 2008, http://www.unhabitat.org/pmss/listItemDetails.aspx?publicationID=2562

2 *Human Development Report 2010*, United Nations Development Programme, 2010, http://hdr.undp.org/en/reports/global/hdr2010

3 *Growth isn't possible: why we need a new economic direction*, New Economics Foundation, January 2010, http://www.neweconomics.org/publications/growth-isnt-possible

4 *World Energy Outlook*, International Energy Agency, 2010, http://www.worldenergyoutlook.org/docs/weo2010/WEO2010_es_english.pdf

5 *Sustainable Technologies Roadmap*, Chemistry Innovation Knowledge Transfer Network (CIKTN) http://www.chemistryinnovation.co.uk/roadmap/sustainable/roadmap.asp?previd=425&id=426

6 *The Scientific Century: securing our future prosperity*, Royal Society, March 2010, http://royalsociety.org/The-scientific-century

7 *Chemistry for Tomorrow's World: a roadmap for the chemical sciences*, Royal Society of Chemistry, July 2009, http://www.rsc.org/roadmap

8 *Workshop Report: Chemistry for a Sustainable Future*, National Science Foundation Workshop on Sustainability and Chemistry, June 2006, http://www.chem.uiowa.edu/research/sustainability/2009_reprint_chemistry_sustainable_future.pdf

9 *Innovation for a Better Future: Putting Sustainable Chemistry into Action*, SusChem Implementation Action Plan, 2006, http://www.suschem.org/upl/3/default/doc/SusChem_IAP_final(1).pdf

10 *The economic benefits of chemistry research to the UK*, Oxford Economics, September 2010, http://www.rsc.org/ScienceAndTechnology/Policy/Documents/ecobenchem.asp

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