European Commission

Contribution of Nanotechnology & Nanomaterials to Sustainability of Industrial Products & Processes

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Joint Research Centre

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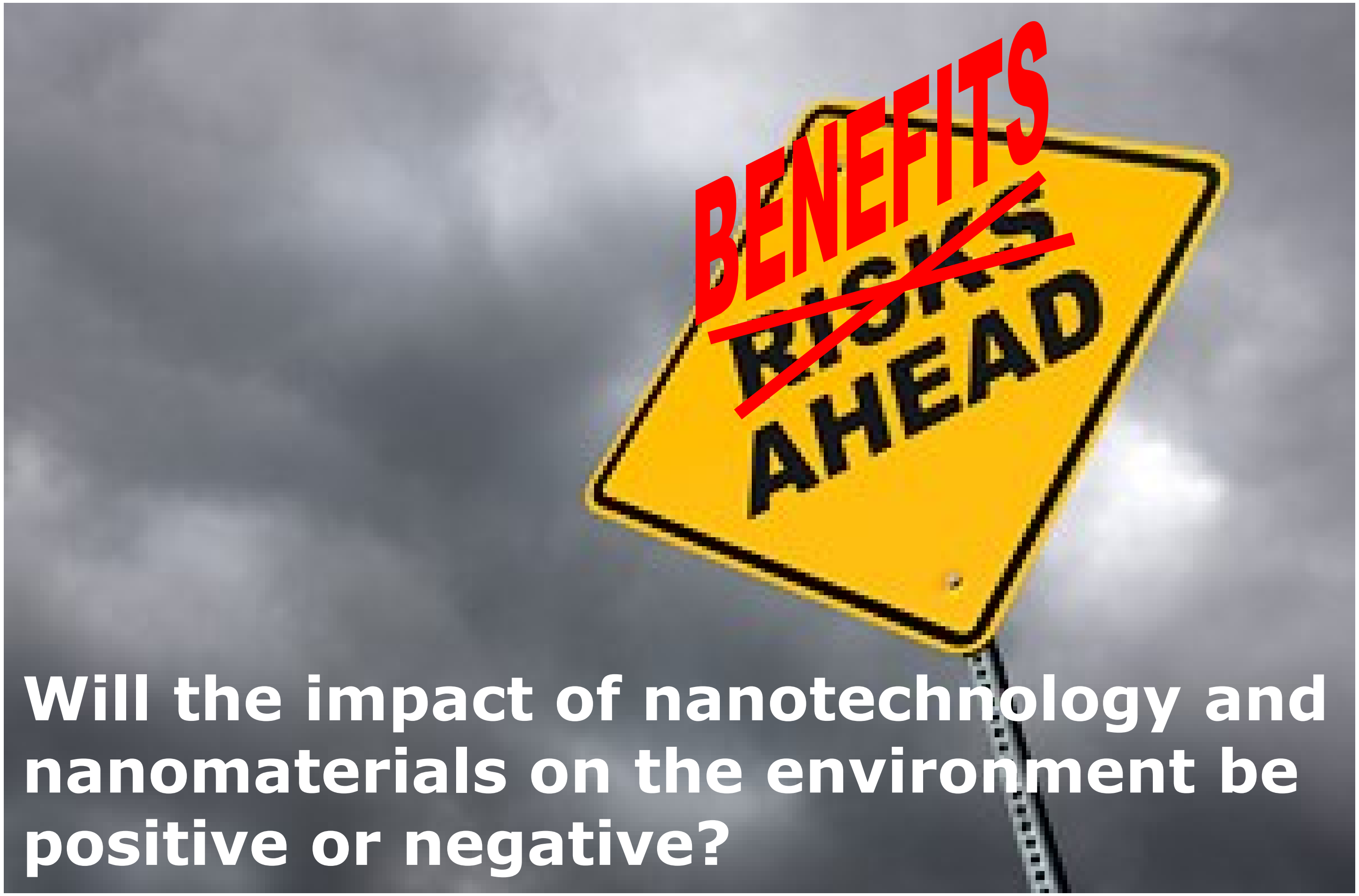
Stimulating innovation
Supporting legislation

European Commission

Key Question



Will the impact of nanotechnology and nanomaterials on the environment be positive or negative?

Nanotechnology

Medicine & Health

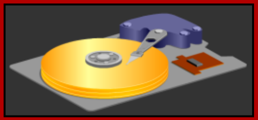
Electronics & Information Technology

Energy & Transport

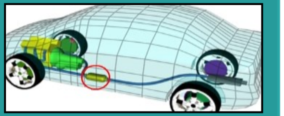
Innovative Materials

Environment & Agriculture

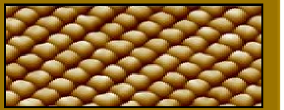
Drugs & Diagnostics



Lighting & Data Storage



Hydrogen & Solar

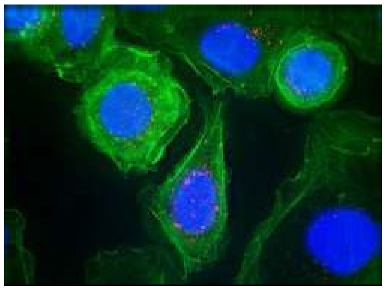


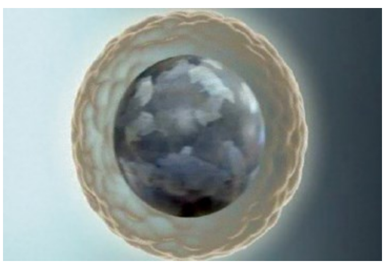
Resource Efficiency

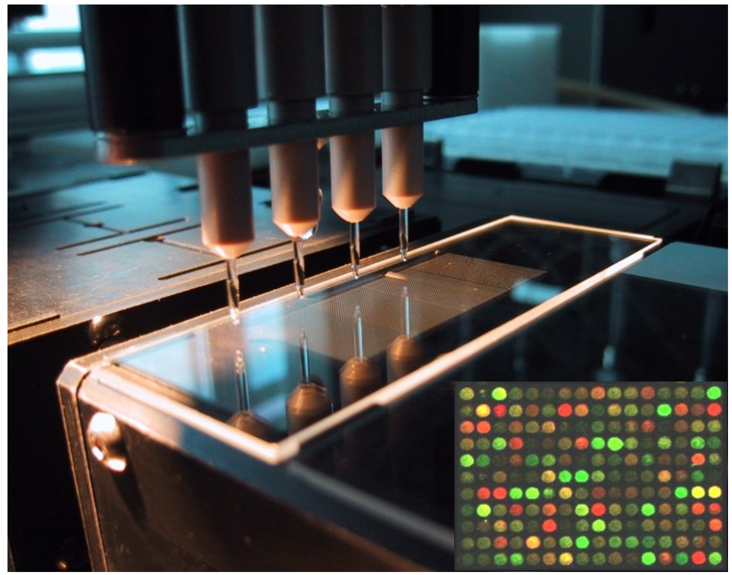
Water & Agrifood

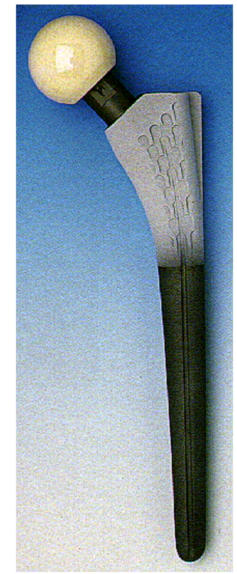
Reduce consumption of raw materials and energy over a range of sectors
Provide support to sustainable development and a cleaner environment

Healthcare







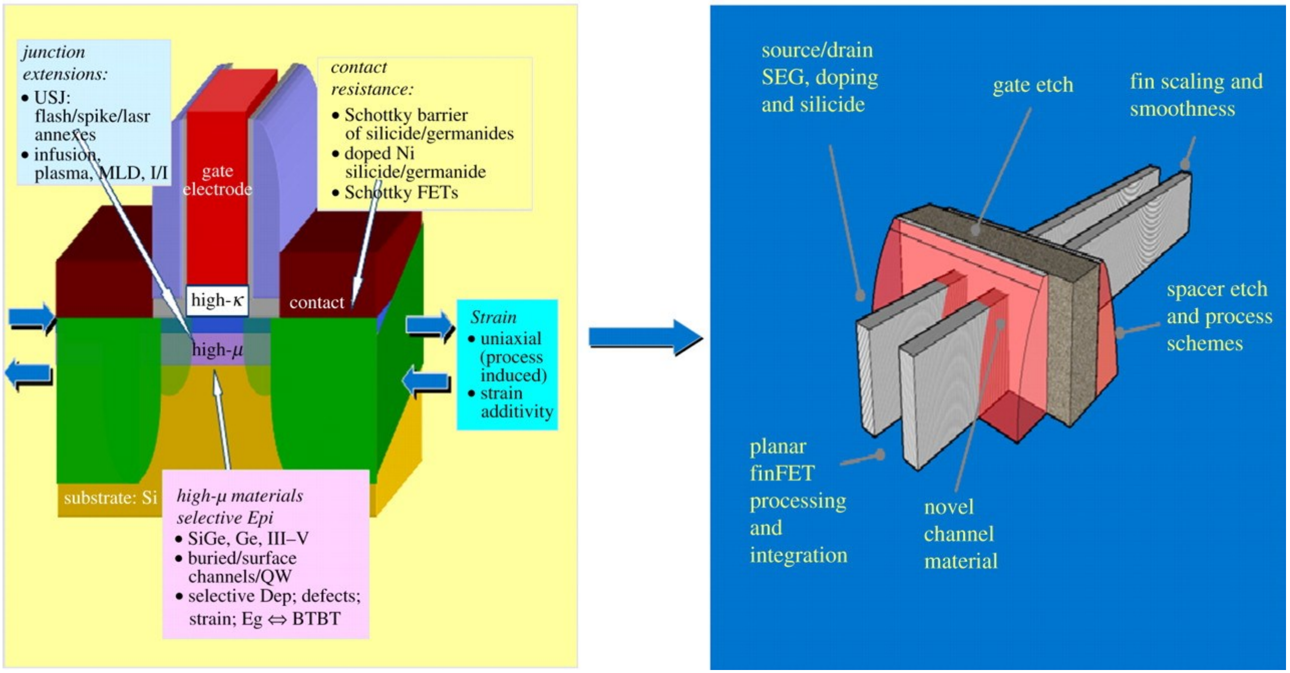


Pharmaceuticals: targeted drug delivery, advanced therapeutic systems
Diagnostics and Monitoring: genomics, proteomics, biosensors, imaging
Medical Devices: smart implants, biomaterials, tissue engineering
Reduction of pharmaceutical residues and use of chemical reagents

Rickerby, J. Nanosci. Nanotechnol. 7 (2007) 1-8

Electronics

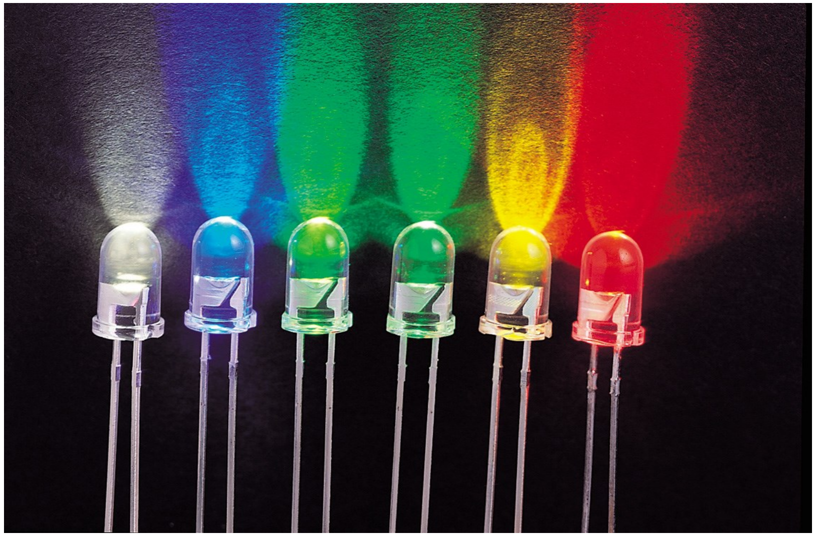
planar non-planar

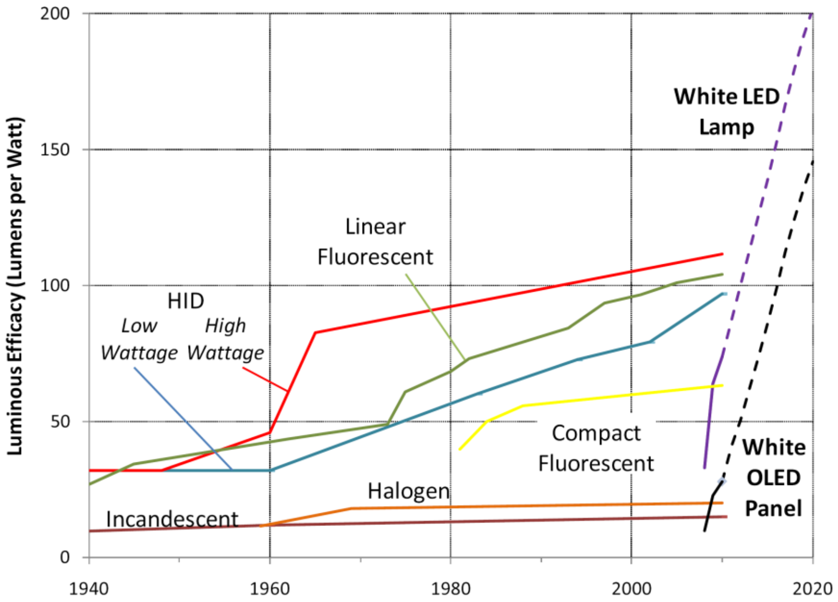


Non-planar FETS can be expected to achieve a 6 nm gate length by 2026
Scaling down enables lower power consumption and raw materials savings
Alternatives to silicon technology based on CNT and graphene

International Technology Roadmap for Semiconductors (2009)

Lighting

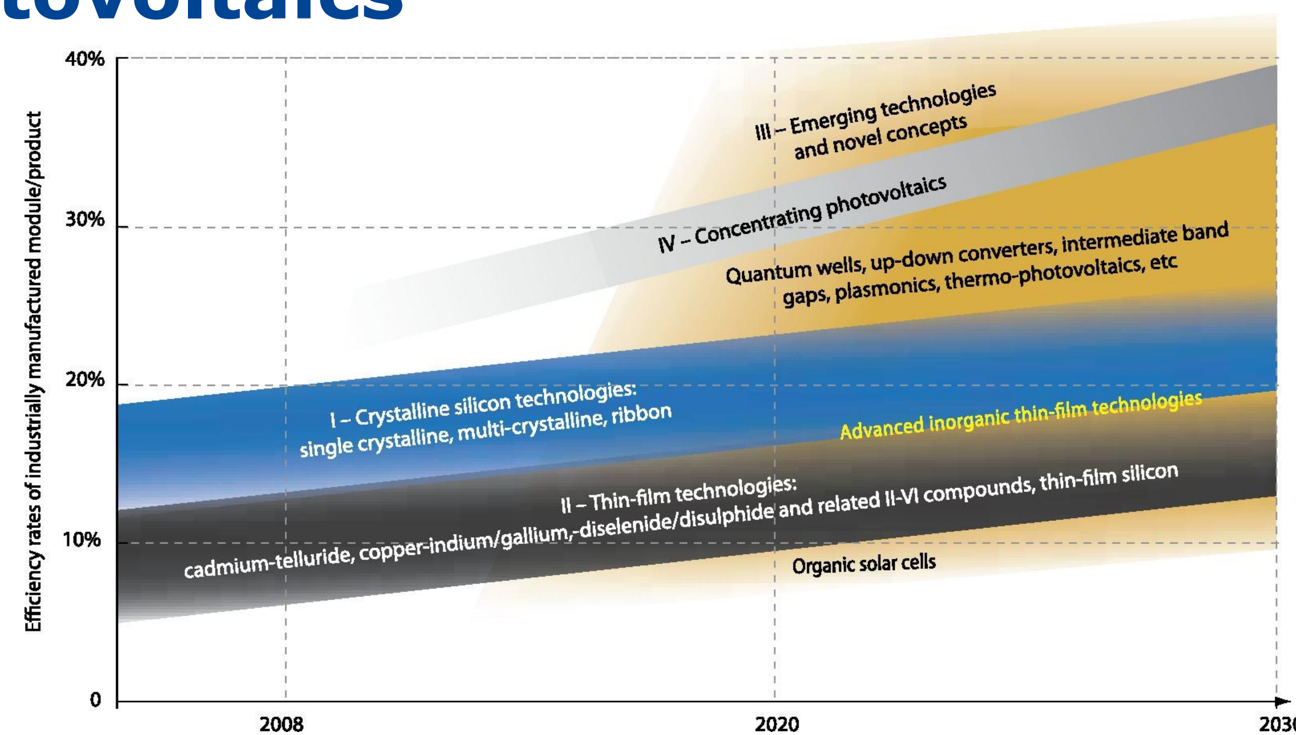




Lighting uses ~20% of electricity produced (1.5 Gtonnes of CO_2 per year)
LEDs & OLEDs have higher efficiency than conventional light sources
Smaller environmental impact due to longer life, less resource consumption
Contain no mercury and less phosphorus than fluorescent lights

Haitz and Tsao, Phys. Status Solidi A 208 (2011) 17-29

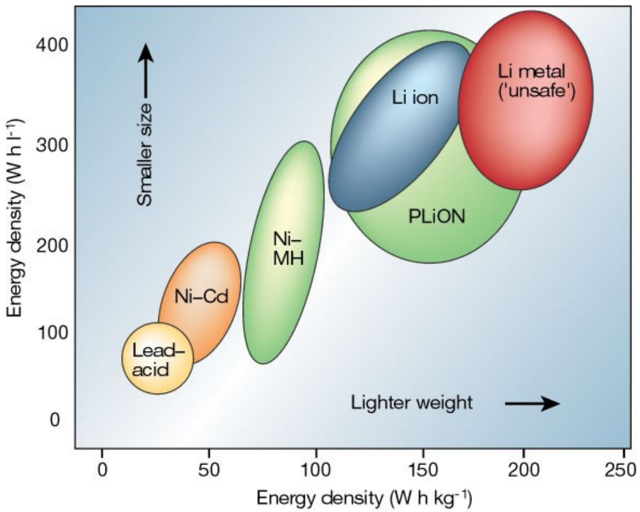
Photovoltaics

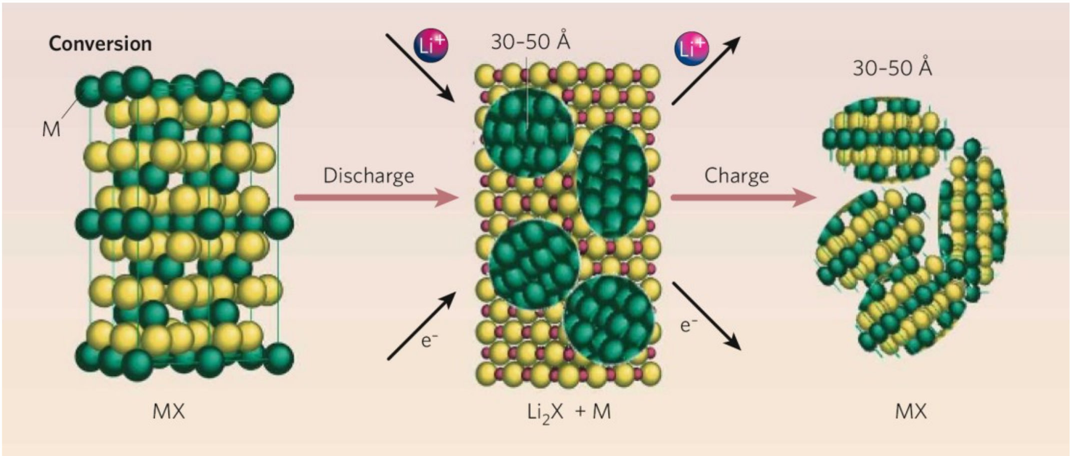


Increased efficiency due to use of nanotechnology in solar cell fabrication
Reduced energy pay back time from present 2 years to 0.75 years in 2030
Potential savings of 2.3 Gtonnes of CO_2 emissions annually by 2050

Solar Photovoltaic Energy Technology Roadmap, OECD/IEA (2010)

Lithium Batteries

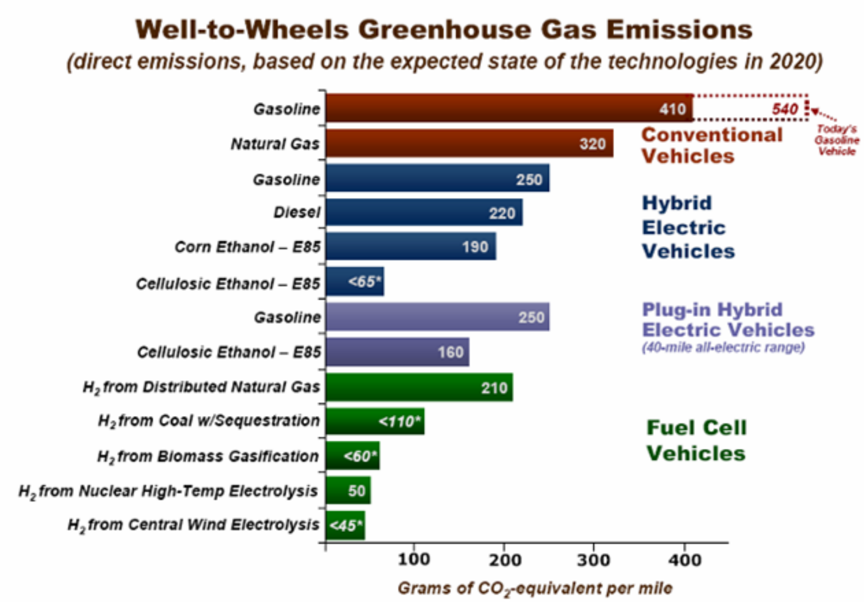


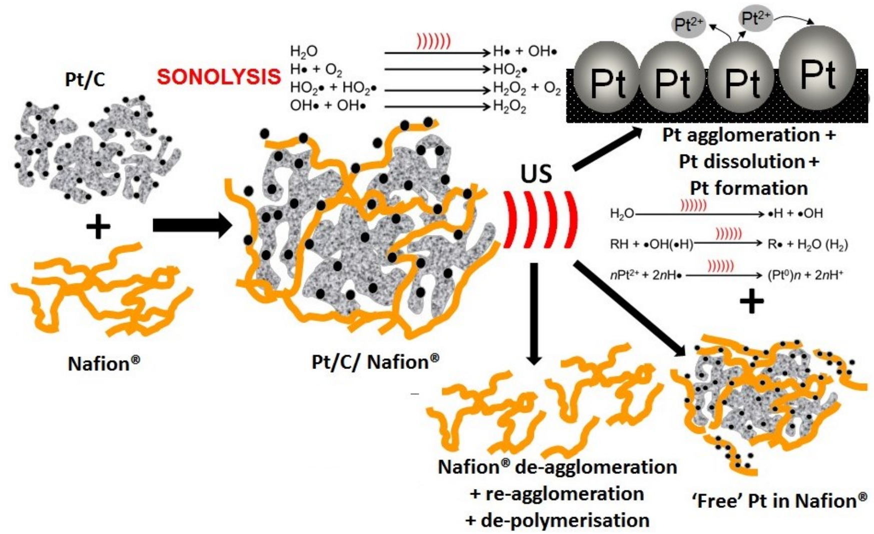


In-situ formation of transition metal nanoparticles embedded in Li_2O matrix
Potential increase in the energy density from ~200 to ~300 Wh/kg
Higher charge/discharge rates due to shorter diffusion paths for Li^+ and e^-
Better accommodation of Li^+: extended battery life and intrinsically safer

Armand and Tarascon, Nature 451 (2008) 652-657

Fuel Cells

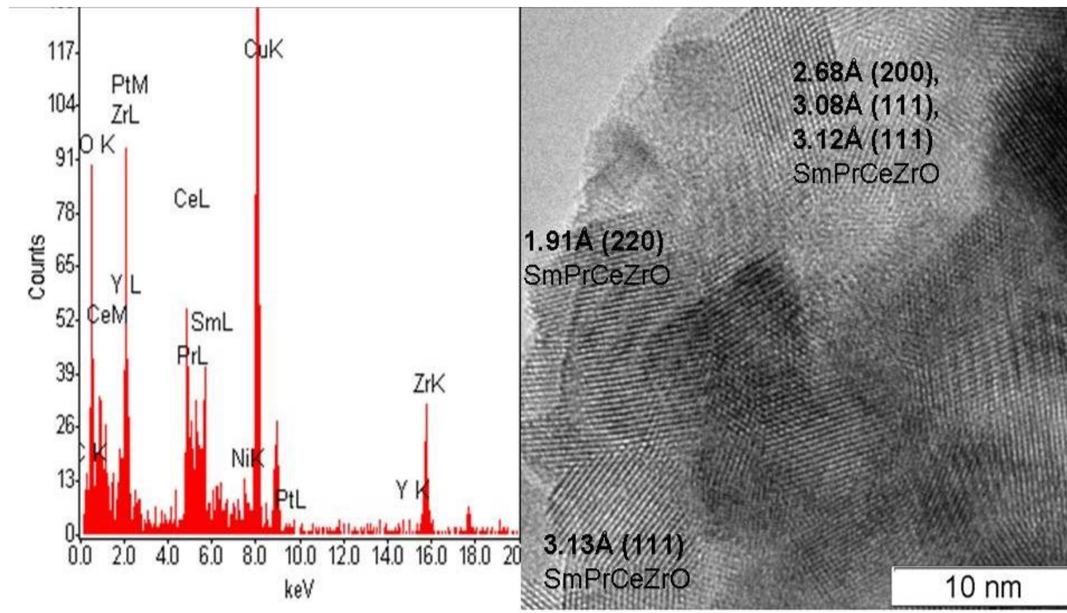




Reduction of CO_2 emissions by use of hydrogen fuel cell powered vehicles
Limited by cost and efficiency of Pt catalysts for PEM fuel cell electrodes
Current research focused on low cost, high performance nanocatalysts

Pollet, Electrocatalysis 5 (2014) 330-343
DOE Hydrogen and Fuel Cell Program Plan (2011)

Catalysts



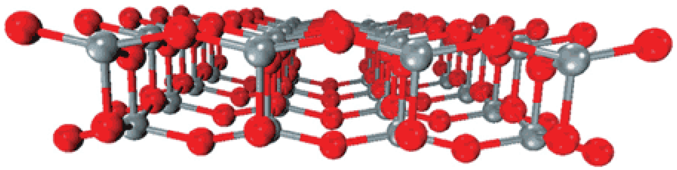
Nanocomposite catalysts for conversion of methane to produce hydrogen

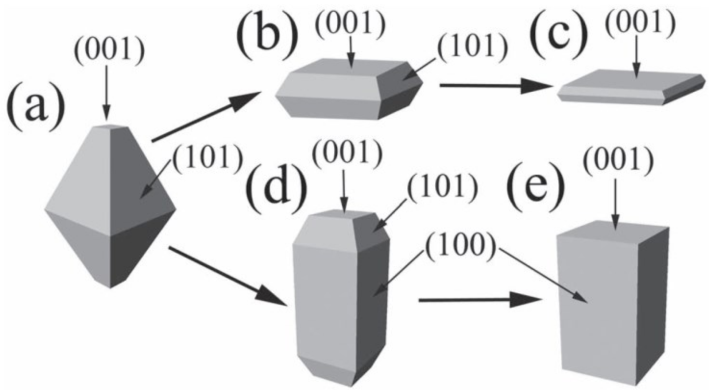
Reduction of CO_2 emissions compared to direct combustion of fossil fuels

Point source instead of diffuse emission enables CO_2 capture

Sadykov et al. Adv. Nanocomposites (2011) 909-946

Photocatalysis





Chemical free solar disinfection for decentralised drinking water treatment
TiO_2 (001) surface is reactive due to coordinative unsaturation at Ti sites
Modification of nanocrystal shape to increase the photocatalytic efficiency

Byrne et al. Int. J. Photoenergy (2011) doi:10.1155/2011/798051
Rickerby, in Nanomaterials for Environmental Protection, Wiley (2014) 169-182

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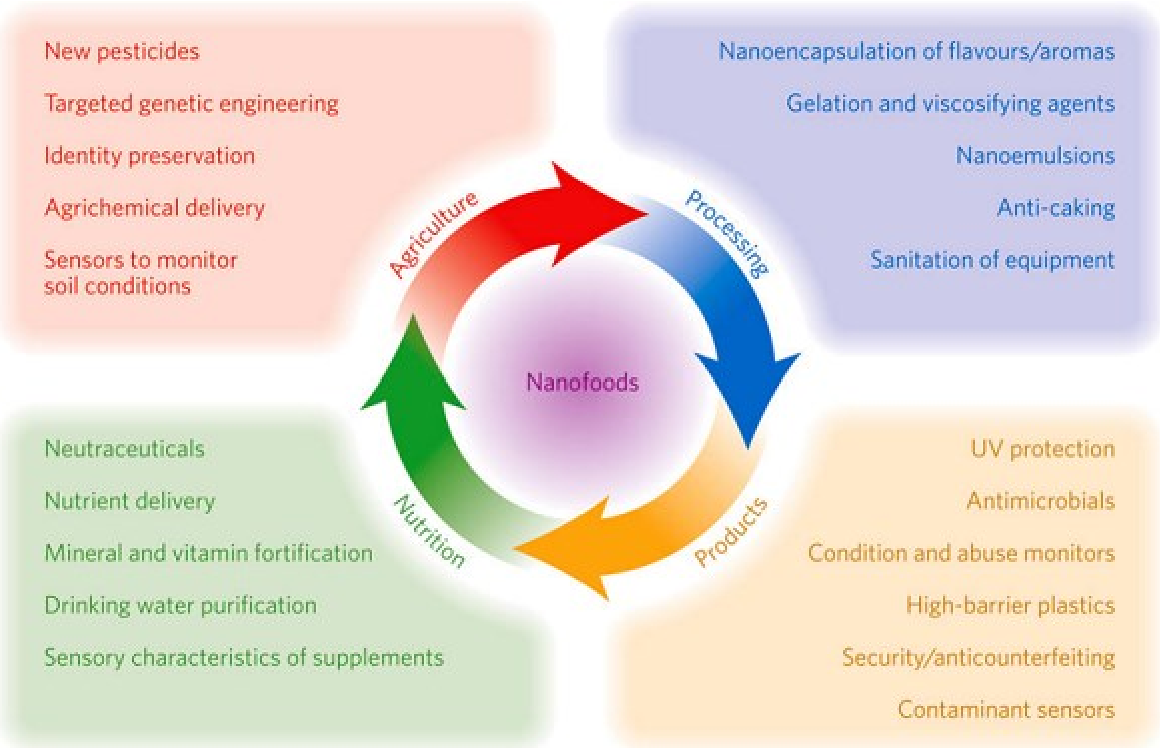
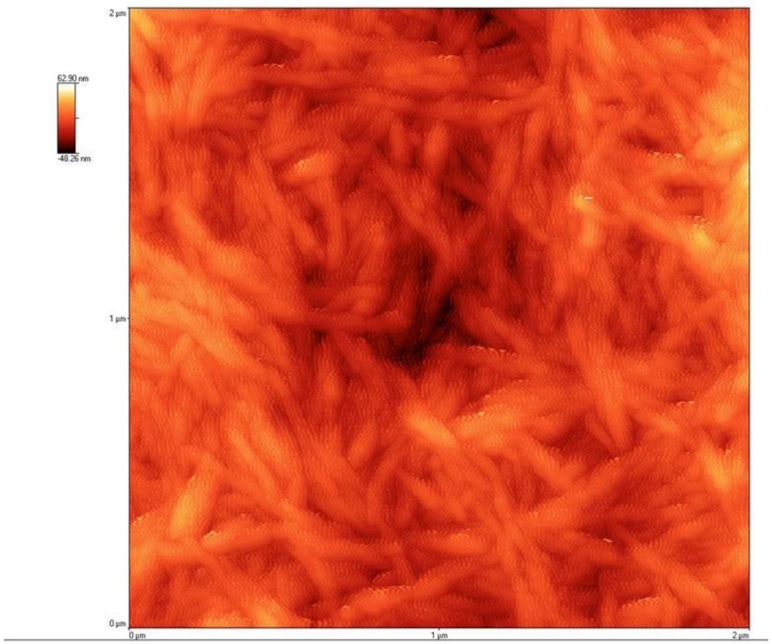
Agrifood

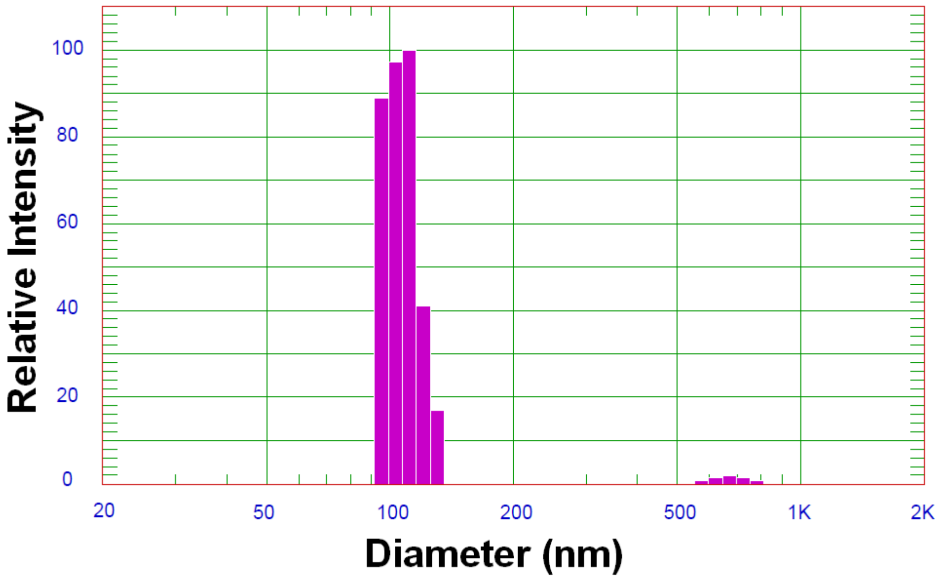


Reduced use of pesticides & fertilizers, improved food processing methods
Less waste due to spoiling or contamination, enhanced nutrition properties

Duncan, Nature Nanotechnol. 6 (2011) 683-688

Forest Products

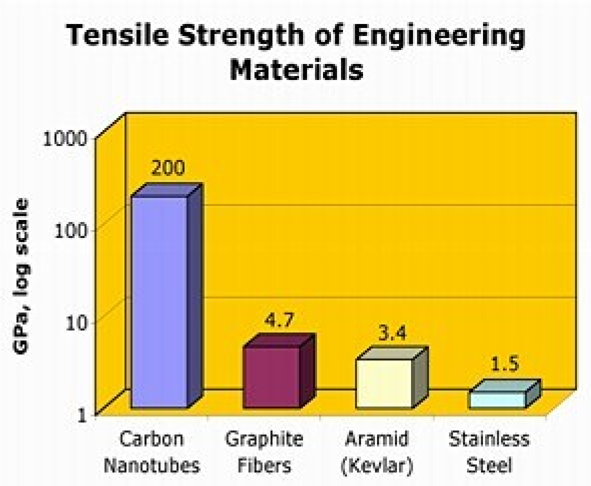




Production of nanocystalline cellulose by controlled microbial hydrolysis
Environmentally friendly, cost-effective, energy-efficient production method
Biodegradable material with applications in paper and packaging industry

Prasad et al. Carbohydr. Polym. 83 (2011) 122-129

Aerospace



Carbon nanotube composites offer high strength and weight savings
Additional advantage because of a reduction in the use of strategic metals
Need to develop consistent and inexpensive manufacturing processes

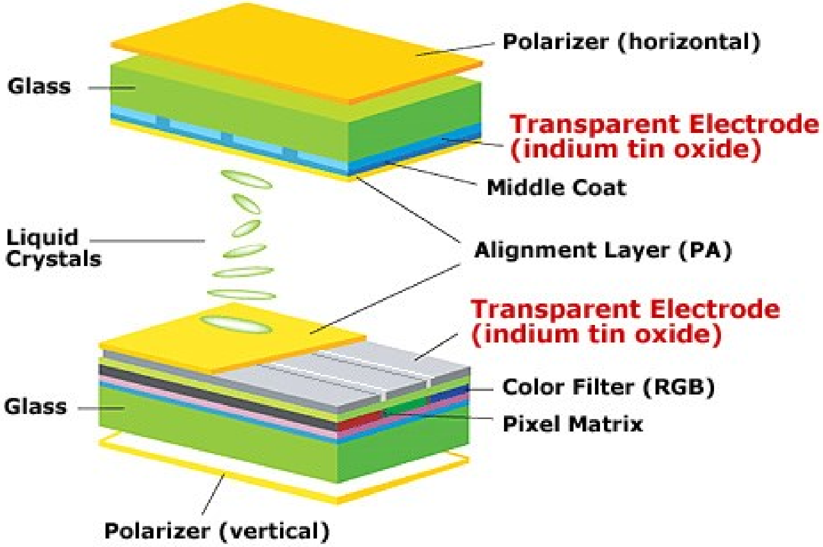
http://www.nasa.gov/vision/space/gettingtospace/16sep_rightstuff.html

Construction Materials

Spectrally selective glass coatings and nanosilver antibacterial surfaces
Energy savings for air conditioning and reduced need for cleaning products

Cortie et al. Mater. Aust. 38 (2005) 10-11

Resource Efficiency



Contribution to resource savings through reduced use of scarce materials
Typical examples include indium in liquid crystal displays and solar panels
Recycling is complex and may release nanomaterials in the environment

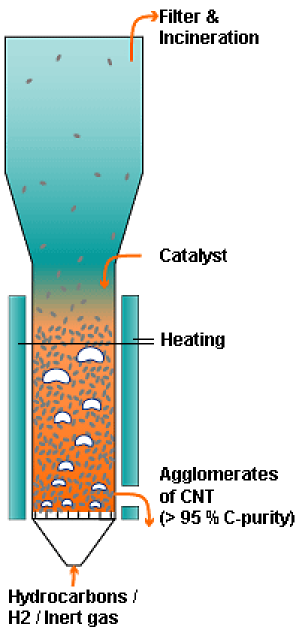
Rickerby and Morrison, Sci. Technol. Adv. Mater. 8 (2007) 19-24

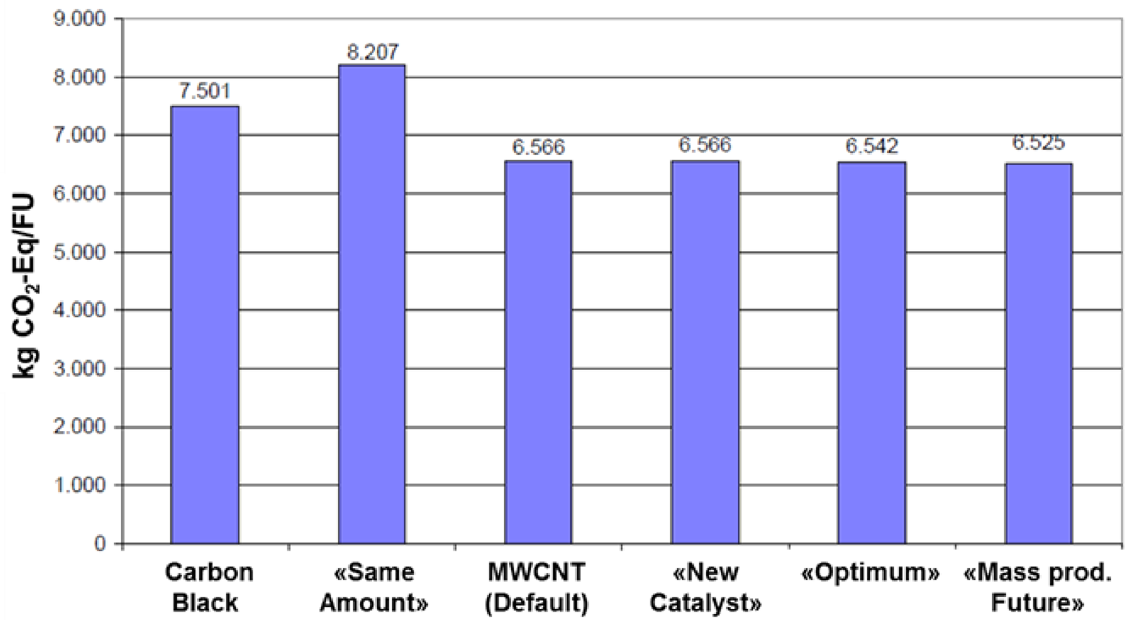
Life Cycle Analysis

Use of LCA to explore environmental impact scenarios for nanotechnologies

Wender and Seager, IEEE Intl. Symp. Sustainable Systems and Technologies (2011)

Environmental Impact





Case study of an industrial CVD process for production of carbon nanotubes

CO_2 emissions in comparison to using carbon black in plastic composites

OECD Guidance Manual on RA and LCA of nano-enabled applications

Steinfeldt et al. UBA Report No. 001317 Texte 33/2010

Conclusion

Nanotechnologies offer potential for more efficient use of natural resources and energy

Nanomaterials can contribute to sustainability through clean, less wasteful production processes, energy and transport systems

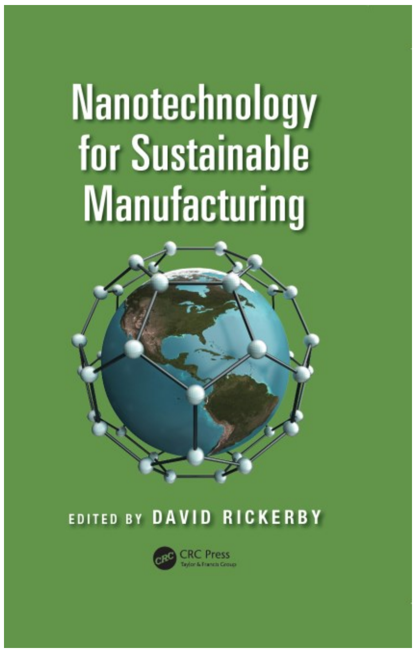
Application areas include healthcare, electronics, lighting, solar power, fuel cells, batteries, catalyts, agrifood, forest products, aerospace, construction

Consequent reductions in energy consumption, materials use and emissions should benefit the environment

Effective recycling and recovery strategies are needed to limit dispersion of scarce and/or toxic nanomaterials in the environment

LCA is a useful tool to assess the environmental impact of nanomaterials at each stage of the product life cycle

Acknowledgements



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SEVENTH FRAMEWORK PROGRAMME

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