A Low Carbon Economy

The Contribution of Nanotechnology

Benefits and Risks

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NANOTECHNOLOGY

- What is nanotechnology?

What is Nanotechnology?

The manipulation of matter on the nanoscale:

1 nanometre (nm) =1 **billionth** of a metre

Compare: DNA Alpha helix is about 2 nm in diameter; a large **virus** is about 100 nm, a small bacterium is about 500 nm; Human red blood cell is about 9,000 nm (9 microns).

New properties: more for less

Surprising novelty: Below about 200nm (i.e. nanoparticle) a substance changes properties; the familiar may become unfamiliar:

> **Stronger; different colour; more reactive; more toxic; lighter; more or less water-mobile; more heat-resistant; higher translucence; better electrical conduction or insulation; special magnetic, optical, catalytic and electronic properties, easier trans-barrier movement in living tissue; quantum effects; specific functionalities; etc. - all depending on size, structure, and shape.**

Benefits and risks: These novel properties provide potential new benefits and new hazards/risks

Manufactured nanomaterials:

Top-down or bottom-up; new instruments and techniques (AFM, STM); may be functionalised; from simple nano-additives to complex nano-devices

Nanoparticles of what?

- Metals e.g. gold, titanium, iron, copper, aluminium, silver
- Metal oxides e.g. titanium oxide, iron oxide, zinc oxide, aluminium oxide
- Polymers e.g. matrix for nanocomposites
- Ceramics (i.e.nanocrystals, clays) e.g. talc, mica, asbestos, vermiculite
- Carbon e.g. fullerenes, nanotubes, fibres
- Silicon e.g. sols and colloids
- Modified biomolecules e.g. proteins, enzymes, DNA
- Etc..

Application areas

Applications

- **Electronics, Information, Sensors, Communications**
- **Agriculture, Food, Drinks, Packaging**
- **Cosmetics, Sports, Clothing and other consumer goods**
- **Materials, Industrial processes, Energy, Catalysis**
- **Housing, transport**
- **Environmental remediation**
- **Security and Military**
- **Medical, Imaging, Diagnostics, Neural-cognitive**

Convergence

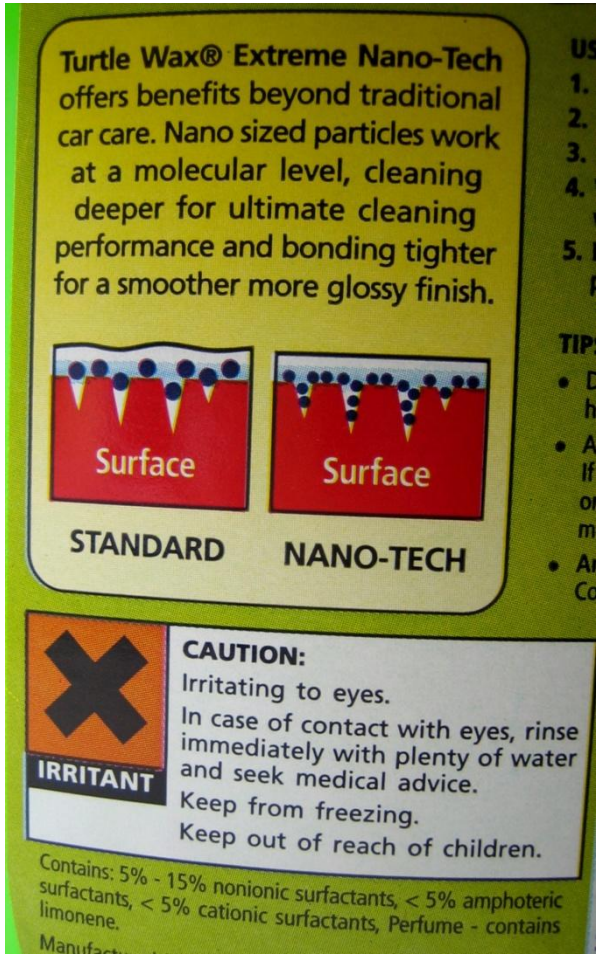
USA has launched NBIC Project, combing nanotech (N), biotech (B), information/communications technology (I) and cognitive/neural sciences (C).

Investment

In 2000, Bill Clinton, announced the National Nanotechnology Initiative to support budding nanotech industries. Publicly-funded investment, private investment and patents now accelerating worldwide. Major firms include BASF, Boeing and Mitsubishi.

Consumer products

Made in UK by the USA company TurtleWax



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- Nano for LCE?

Enabling

- Nanotechnology is an enabling technology, with significant potential for a Low Carbon Economy (LCE)
- Novel nanoscale properties are both the source of new technologies and products and the source of new hazards and risks, mostly unknown and unpredictable.
- The needs of nanotech development and the benefits of nanotech are not specific to one country (or one business) alone, but for a globalized economy in a situation of converging global crises.

Sustainability applications of nanotech

1. Pollution prevention
2. Recycling and remediation
3. Energy input reduction
4. Lightweight materials
5. Packaging and self-cleaning
6. Insulation
7. Alternative energy production
8. Smart, intelligent products
9. Bio-mimesis

1 Pollution prevention

- Molecular sensing of pollutants, acidity and chemical (inc. warfare) agents.
- Ultra-violet light (UV) activated catalysis for treatment of contaminants.
- Purification of water without use of chlorine.
- A nanoporous ceramic has been invented to absorb waste mercury efficiently as well as possibly lead, radionuclides etc.

2 Recycling & Remediation

Nanostructures for filtration, catalysis, separation devices, absorbents, adsorbents…

- Nanoporous absorbents and adsorbents etc. for remediation of water and other media (containing pesticides, PCBs, trichloroethylene etc).
- Oil-water separation. Iron nanoparticles coated with palladium being developed to break down organochlorines in groundwater.
- Spillage response: NanoScale Materials Inc. has produced a nanomaterial to render harmless a range of toxic substances – 25g has surface area of almost 3 football fields!
- Super-paramagnetic nanoparticles designed to bind to any molecular targets and then magnetised to remove from medium.

3 Energy input reduction

Using nanotech to reduce energy needs in production of industrial & consumer goods

- Production efficiency e.g. nanocatalysts (high surface-to-volume ratio), facilitating reactions more efficiently and selectively
- Reduction of material resource inputs, nanoscale versions of stock inputs
- Nano-catalysts
- Nano-sensors for process efficiency and quality
- Nano-filtration for purity and efficiency

4 Lightweights

- Very strong, very light materials (nanocomposites) Reduces energy inputs for any moving parts e.g. machines, turbines, transport, aeronautics.
- Improves durability (lasts longer, so reduces replacement inputs).

5 Packaging and self-cleaning

- Polymer nanomaterials e.g. For food and drink packaging
- Surfaces that need less cleaning (to remove toxins, pathogens, dirt) require less toxic cleaning materials.

6 Insulation

- Buildings: Nano and other advanced technologies enable a variety of new applications such solar, wind and kinetic energy harvesting, self-cleaning glass and other building components, pollution reduction, energy storage, insulation, energy conservation. Sensor and networking technologies enable buildings to respond to the environment…

7 Alternative energy production:

- Nanotech innovations in all alternatives - wind energy, hydropower, geothermal, bio-mass, solar energy (photovoltaics), hydrogen, tidal energy generators.
- Estimates of reduction of present electrical consumption by 75% in homes and industry.
- In fuel cells C nanotubes improve performance while reducing amount of platinum catalyst required.
- New thermal devices – surfaces and glass that generates warmth.

8 Intelligent products

Nano-label tracking of products for liability for:

- recycling
- toxic and other harmful waste
- renting/leasing of consumables

9 Biomimesis

- Nanotribology (friction reduction) in indutrial production and transport
- Artificial photosynthesis

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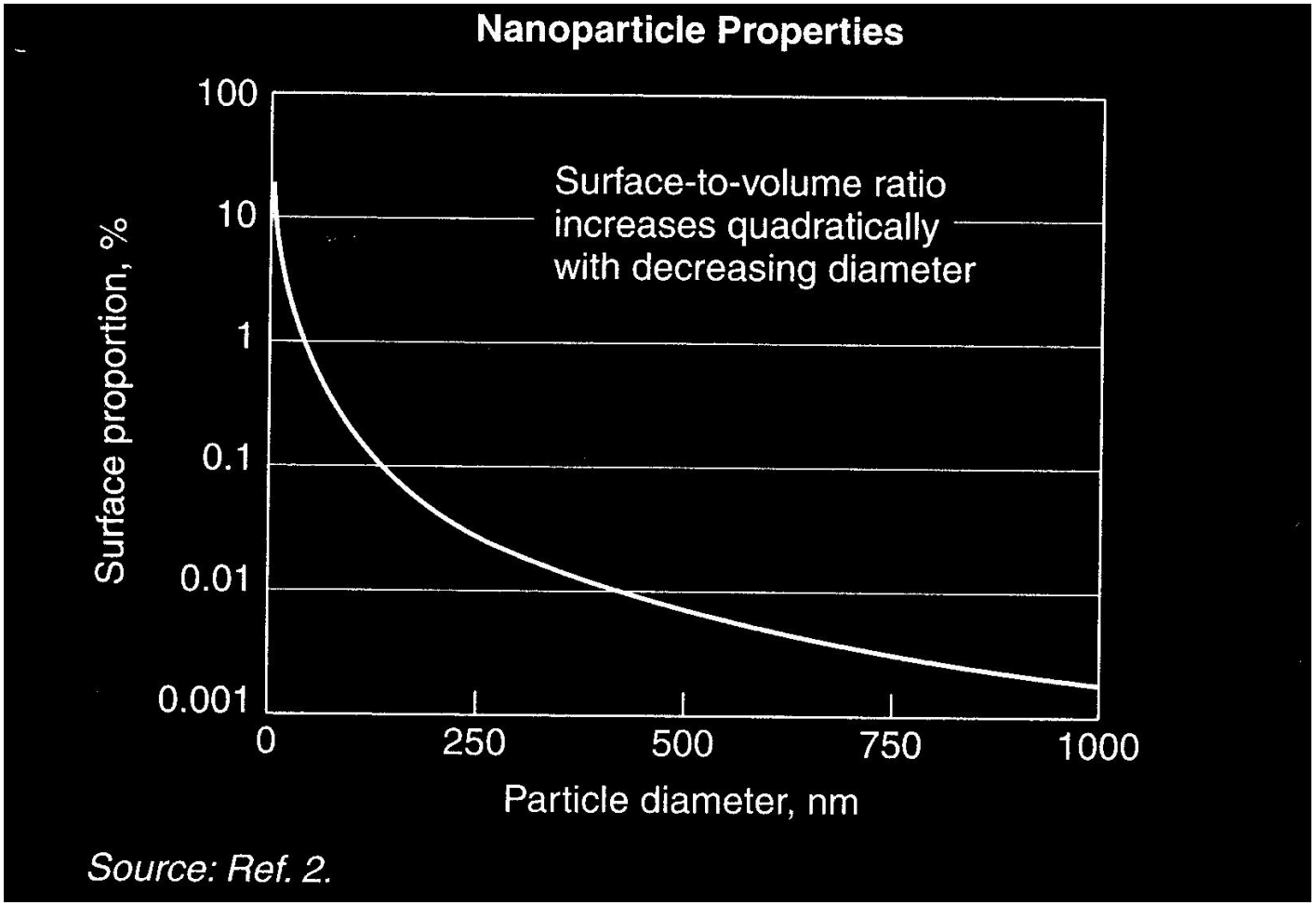
- Risk: toxicity?

Toxic risks

Reactivity



At grain size less than 20nm as much as 30% of atoms can be present at grain boundaries, affecting mechanical, electrical and optical properties. The toxicity and inflammatory properties of ultrafine particles increase as the mean particle size becomes smaller.

Toxic risks

- Some nanoscale structures may disrupt, in unexpected ways, life systems at the sub-cellular level. They may interfere with DNA and mitochondria for example
- There is growing evidence that nanoparticles interfere in protein expression and gene expression *(Oberdörster et al, 2005, section 3.0)*
- Some nanoparticles will be persistent and bio-accumulative
- May cause oxidative stress
- Their high mobility also means that they can pass through physiological barriers such as the blood-brain, retinal and placental barriers
- It is likely that free nanoparticles can pass through the food chain in unexpected ways
- 70 nm particles pass through alveolar surfaces of the lung, 50 nm move through cells, 30 nm through CNS, and no comprehensive data on <20 nm particle movements

Unfortunately, many industries are going ahead with the production and marketing of nano-products without adequate information or safety precautions, e.g. nanoscale TiO_2 sun-block creams. Current regulations and risk assessments are inadequate.

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- Ethics and Regulation

Social and ethical Aspects

1. Technology policy: priorities?
2. Risk, esp. potential toxicity (EHS)
3. Public engagement, labelling
4. Intellectual property, patents
5. Regulation (chemicals?)
6. Privacy, surveillance
7. Military and policing applications
8. Educational, professional
9. Human identity (cyborgs?)
10. Nano-divide, governance

Royal Commission on Environmental Pollution

http://www.rcep.org.uk/reports/27-novel%20materials/27-novelmaterials.htm

- **RCEP Study of Novel Materials: Toxicology literature review, Final report, March 2008. Main Points:**

- A growing evidence base supports the potential for MNPs to cause biological effects. Paradigms incorporating oxidative stress, endocytotic intracellular trafficking and mitochondrial damage emerge as common themes.

- For the majority of published studies, a lack of detailed characterisation hinders full interpretation of the link between physical properties and biological effect

- Current predictions suggest that environmental concentrations are unlikely to cause significant ecotoxicological damage to biota. It is likely that this prediction will be influenced by modification of MNP properties within different environmental compartments and by the potential for particle:contaminant interactions.

- Exposure assessment and the need to integrate medical and environmental nano-research emerge as major research needs.

REACH

Registration, Evaluation, Authorisation & Restriction of Chemicals

- Although the European Commission has not yet argued for an amendment of the chemicals regulation REACH to take account of the *novelty* of nanomaterials, the European **Parliament** appears to be moving in another direction.
- In April 2009 the parliament's environment committee recommended that consumer products, including food-related items, be **withdrawn** until more adequate safety tests are performed.
- The parliament adopted a report calling for tighter controls and adherence to the REACH principle of **'no data, no market'**.
- This followed on a **parliamentary vote** on novel food regulations calling for adequate definition, labelling and targeted risks assessments for foods containing manufactured nanoscale entities.

REACH (32) European Commission. REACH in Brief. 2006. http://ec.europa.eu/environment/chemicals

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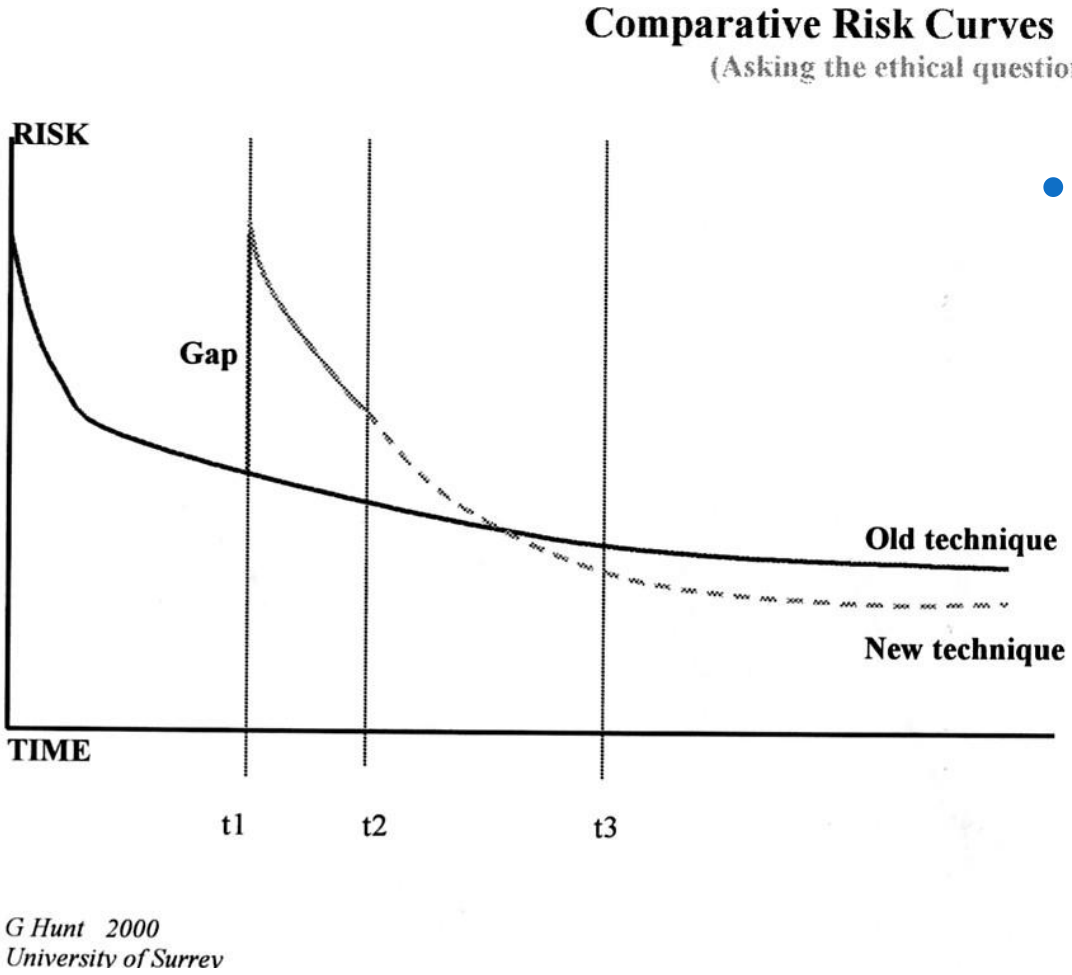
- Innovation and Investment

Innovation and investment - UK

NEEDS

- Government - Unified project approach
- Priority-setting (economic renewal through green-technology)
- Venture capital
- Public financial support
- Concentration of expertise and technical infrastructures (UK or EU?)

Broad recommendations for business



- In the long term it pays to support new 'green' technologies

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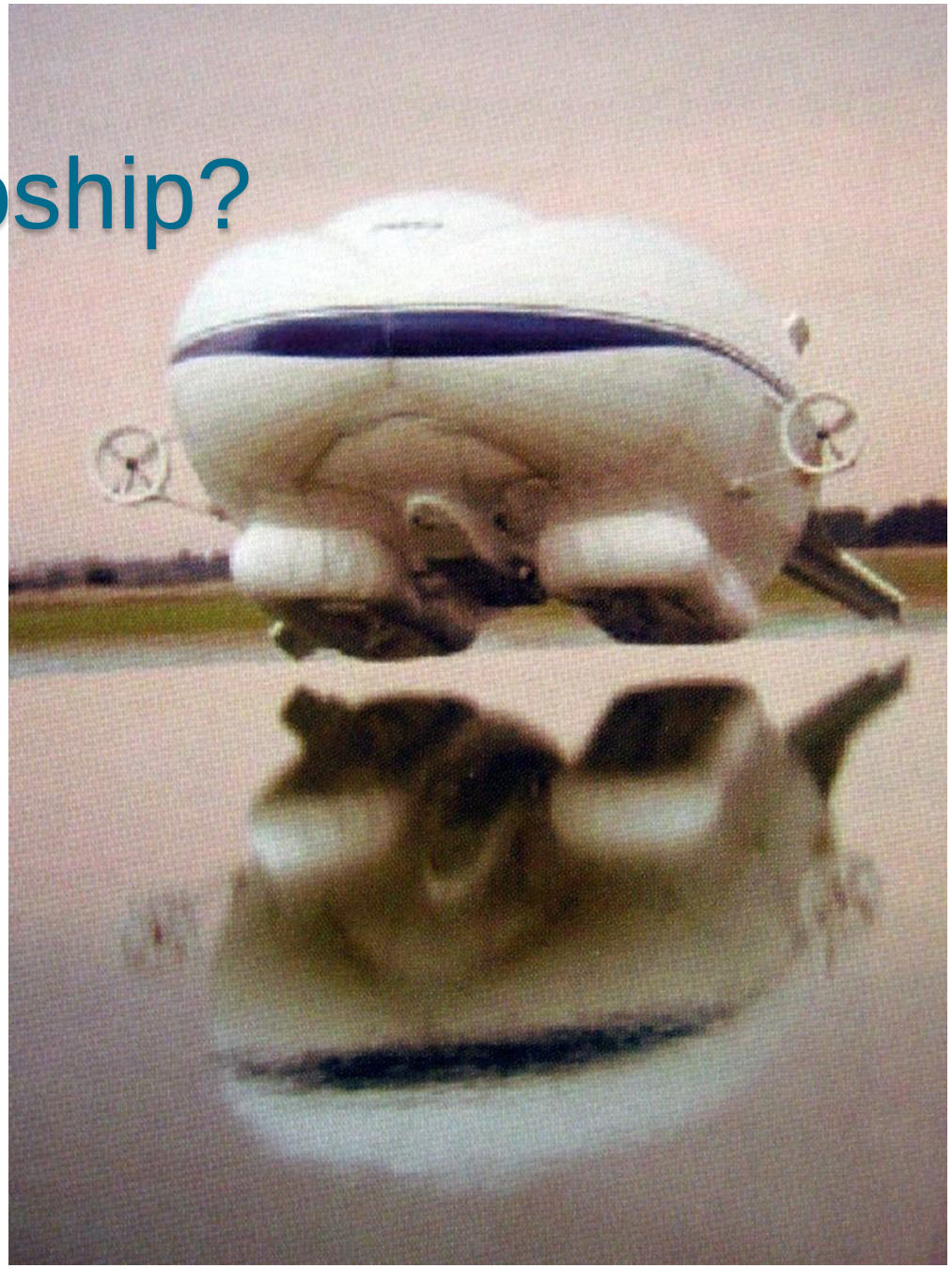
Broad recommendations for business (2)

- Wait for hazard and risk assessments now being undertaken on specifics
- Seek out and support solutions to ecological/climate problems created by your/related business
- Think longer term
- Take account of impact of global concerns on consumer wants
- Direct your investments to whatever will mitigate ecological /climate damage
- Direct investments to whatever goods contribute to a ‘cyclical’, globally sustainable society
- Do not follow corporate dinosaur mentality but innovate, initiate
- Lobby and support government & international policies for enlightened competition and support

- And to conclude…..

… a nano-future?

The Nanoship?



Carbon-neutral Airfreight?

Nano in VSLW materials, solar skin, sensors, advanced avionics…

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Thank you

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