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The paper is intended to Inform discussion and debate at the symposium, and should not be taken as representing the views or positions of the OECD or its member countries, or of the co-organisers or host organisation.

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FINANCE AND INVESTOR MODELS IN NANOTECHNOLOGY

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Introduction

1. This paper sets out to explain how industry, institutional investors and venture capitalists make investment decisions and the effect this has on investment patterns observed in nanotechnology. It will also address the extent to which there are specific challenges or opportunities which affect investment in nanotechnology, both at an overall level and in six specific sectors; Transportation and Aerospace, Nanomedicine, Electronics, Energy, Materials and Food and Food Packaging.

2. The information in this paper comes from published sources, and discussions with investors and representatives of industry, including those involved in both research and development and operational divisions. The investment figures are primarily drawn from Lux Research and Spinverse's own research, and reflect a global pool of investors, except where otherwise noted.

Challenges of Obtaining Investment Data

3. Due to the difficulties involved in developing accurate investment figures, the quantitative data in this paper should be regarded as indicative and used with caution. As an enabling technology, nanotechnology potentially affects almost all manufacturing sectors, but intensity of nanotechnology use varies within sectors and from company to company.

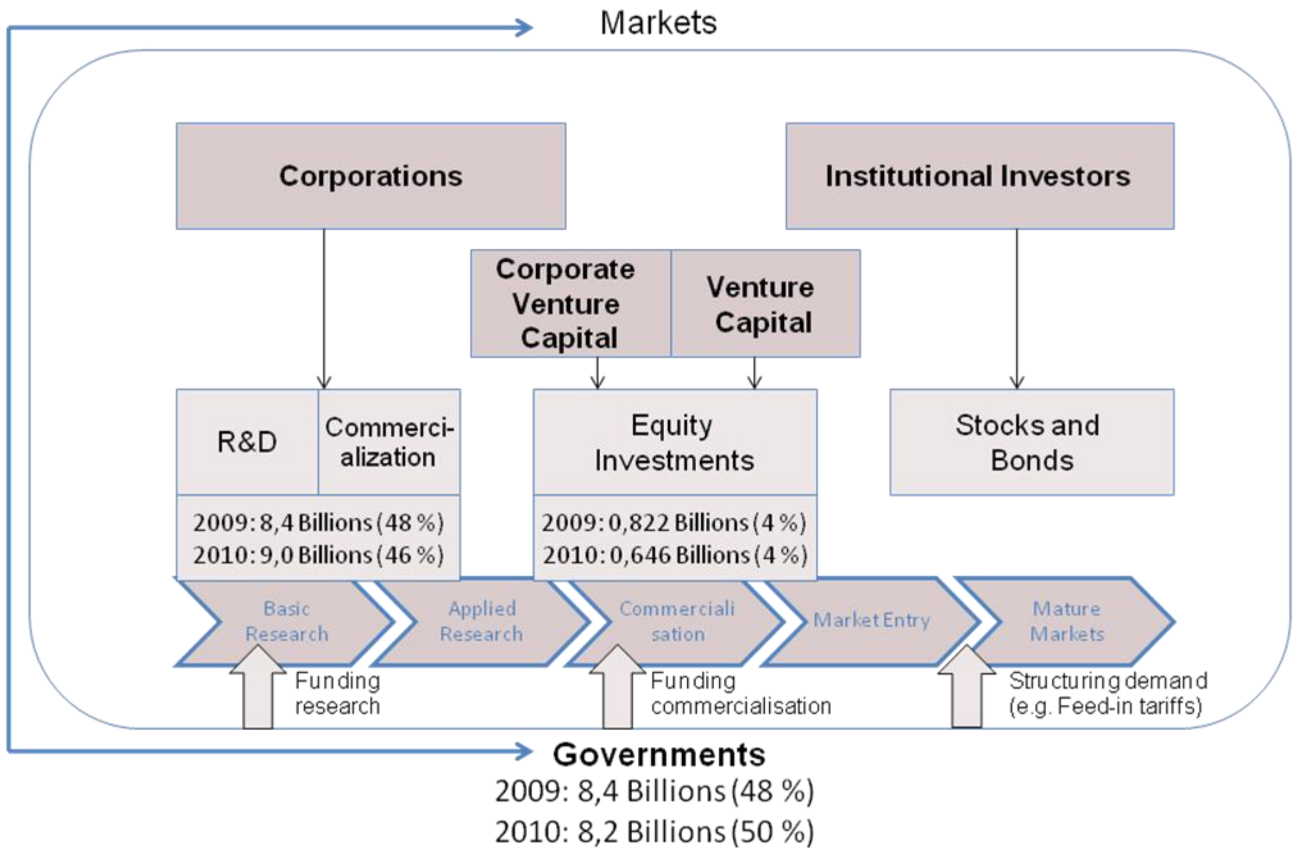
4. Estimates of corporate investment in research and development (R&D), typically obtained by surveying R&D managers, are often challenging to obtain for the managers themselves; both because research teams may work on multiple nano- and non-nano projects, and projects themselves have a mix of elements. In some cases, industrial investment in commercialisation of nanotechnology is more visible - building a plant to produce carbon nanotubes (CNTs) is clearly a nanotechnology investment - but in other cases, nanotechnology is an enabling, often process based technology. It is arguable whether an investment in a plant producing semiconductors should count as a 'nanotechnology investment' because one of the many processes used is Atomic Layer Deposition (ALD). It is also the case that companies in sectors that are more concerned about public acceptance of nanotechnology; particularly food and cosmetics, are less willing to disclose and publicise investments in nanotechnology.

Private Investors in Nanotechnology

5. Figure 1 shows the main entities involved in private funding of nanotechnology. The largest source of funding is corporations themselves, who invest in both R&D and commercialisation activities, typically using funding from their balance sheets. Many corporations have also established corporate venture arms which make equity investments in external companies. Institutional investors invest directly

into shares issued by publicly listed companies that use nanotechnology, as well as bonds and other instruments. Institutional investors are also responsible for investing into venture capital funds, which then channel funding to companies with high growth potential.

Figure 1: Private Funding of Nanotechnology. Investment figures in US$, source: Lux Research (2011)



6. Figure 1 shows the proportion of investment from corporate investors, venture capital and governments, using global figures in US dollars for 2009 and 2010 from Lux Research[1]. Several points emerge. Firstly, whilst 2009 appears to have a been a turning point at which corporate investment equalled and then exceeded public investments, the difference remains minor, and may not have persisted in 2011 due to the economic downturn having a greater effect on corporate investment.

7. The second notable point is that the amount of funding coming from venture capital is low; only 4% of total global funding. This indicates that the majority of nanotechnology development occurs at established firms. The level of venture capital funding is a product of supply – the number of investors willing and able to fund nanotechnology ventures – and demand – the amount of nanofirms with sufficiently high growth potential.

[1] Lux Research, Global Nanotech Spending, presented at EuroNanoForum 2011 conference, 30 May 2011

Role of Government

8. Figure 1 also refers to the important role played by public funding agencies in affecting investment decisions, both by providing public funding for R&D and commercialisation, and by policies which affect demand for innovative products (such as the impact on solar cell markets by establishing feed-in tariffs). These funding interventions also act to reduce the risk of investments in new technologies by directly reducing costs, as with public funding for R&D.

9. In part because of low levels of venture capital investment in Europe, public funding plays a critical role. In a sample of 100 European firms who reported using nanotechnology, the vast majority reported receiving public funding – 88% in nanomedicine, electronics, and materials (table 1). By contrast, the number of firms receiving external private investment was much lower.

Table 1: Sources of Funding for Companies Using Nanotechnology. Source: Spinverse analysis of ObservatoryNano company survey data[2]

Sector	Companies	% receiving external private investment	% receiving public funding
Transportation and Aerospace	24	21	75
Nanomedicine	16	13	88
Electronics	16	44	88
Energy	11	55	82
Materials	26	15	88
Food and Food Packaging	8	13	50
Other	30	7	67

Corporate Investment

Description

10. Corporate investments are typically the result of internal decision-making at firm level, and can take the form of investments in R&D and commercialisation activities. The former category typically includes applied research and experimental development, with fewer companies carrying out truly basic research (IBM is one company whose research activities do include fundamental science). Commercialisation includes those activities necessary to take an innovation to market, and could include building production facilities, hiring and training workers, and sales and marketing.

Investment Criteria

11. The investment criteria differ for R&D and commercialisation activities, although the fundamental rationale is the same; to provide increased revenue from new or improved products in new or current markets, and/or to improve profitability by reducing costs.

[2] European Nanotechnology Landscape Report, ObservatoryNano, http://www.observatorynano.eu/project/catalogue/3EN/

12. Many larger companies split R&D between central research centers and operational divisions. The German chemical firm BASF, for example, provides 22% of its €1.49 billion 2010 R&D budget from a corporate R&D center, with the rest from operating divisions[3]. In these cases the corporate R&D center is more likely to fund research which is further from the market, whereas the operating divisions fund incremental product and process developments.

13. In the former case, the company's Chief Technology Officer (CTO) is likely to identify a portfolio of technologies into which they invest, in order to mitigate the risk of focusing on one area. A decision to begin research in a particular area is triggered either by an external research breakthrough which could have an impact on the company's products and processes, or by the company's own strategic goals. Some organisations – 3M and Google are the most notable examples – also embrace bottom-up research, in which employees are able to spend a proportion of their time on research projects which interest them.

14. The metrics used to measure and justify R&D investments vary. CTOs may use output metrics such as number of patents and number of publications to assess the volume and quality of research output. Corporations typically also report their research intensity (R&D expenditure as a percentage of turnover), although only 40% measure the Return on Investment (ROI) of R&D activities[4]. Additional rationales for R&D investments can also include strategic considerations such as defensive patenting, and value may also be realized by licensing out technologies to other firms.

15. Investments in commercialisation have a more explicit focus on ROI. A company will take a decision to commercialise a technology based on the expected returns; increased sales through increased market share, entering a new market, and costs; building production facilities, marketing. Other factors in the investment decision include the expected payback time and cost of capital. The source of funding for these investments can be from either accumulated cash on the balance sheet, or through raising money on the capital markets.

Role in Nanotechnology

16. Corporate investments in R&D and commercialisation account for the largest single share of nanotechnology funding, at $9 billion in 2010[5]. There are a number of very visible examples of companies investing in R&D in nanotechnology, including companies like Nokia, Fiat, and BASF, who publish and patent extensively in nanotechnology-related areas.

17. Investments in commercialisation are typically much larger than those in R&D, as they often involve the construction of plant, purchase of equipment and hiring and training of staff. These have been amongst the most visible investments in nanotechnology; examples include Bayer MaterialScience's investment of €22 million in a pilot plant for the manufacture of CNTs.

18. Public funding plays an important role in investment decisions, by partially mitigating the risk of firms investing alone. Two large European investments in CNT commercialisation, the €90 million

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[3] Lux Research, Global Nanotech Spending, presented at EuroNanoForum 2011 conference, 30 May 2011

[3] BASF Facts and Figures, http://www.basf.com/group/corporate/en/innovations/research-verbund/organization/bvc, accessed 16 February 2012.

[4] Battelle-R&D Magazine Annual Global Funding Forecast Predicts R&D Spending Growth Will Continue While Globalization Accelerates, http://battelle.org/spotlight/12-16-11_forecast.aspx, accessed 16 February 2012

[5] Lux Research, Global Nanotech Spending, presented at EuroNanoForum 2011 conference, 30 May 2011

Inno.CNT project in Germany[6], and the Arkema-led €107 million Genesis project in France[7] have received funding from national governments of €45 million and €46 million respectively.

19. Global breakdowns of industrial investment by industry sector are rare, although some country-level surveys have been carried out. A study conducted by Spinverse in 2008 for Finland's national nanotechnology programme FinNano found firms investing a total of €56 million Euros in nanotechnology in that year, though the sectoral breakdown was heavily influenced by the county's existing industrial structure.

Table 2: 2008 Snapshot of Industrial Investment in Nanotechnology in Finland. Source: Nanotechnology in Finnish Industry, 2008 Survey[8]

Sector	Investment (€000s)	% of Total
Chemicals and Materials	14900	26,3
Forest Cluster	9700	17,1
ICT	9600	17,0
Health and Well-being	8300	14,7
Energy and Environment	6800	12,0
Tools and Instruments	3700	6,5
Metals and Mech. Eng.	2800	4,9
Construction	700	1,2

Venture Capital

Description

20. Venture capital figures include both independent venture capital funds and corporate venture funds which are controlled by a parent corporation. The typical investment mode is an equity investment in which the venture capitalist (VC) receives shares of ownership of the funded company, although other forms of investments such as convertible loans and senior debt are also used. VCs can be active or passive – active VCs bring in know-how and networks and invest mainly in familiar industries or technology fields, while passive VCs contribute money and general business acumen. The source of funding for VC funds is usually institutional investors, who commit a defined amount of funding for the lifetime of the fund.

Investment Criteria

21. VCs seek to invest in firms with the potential to take a significant share of large and growing markets, and mitigate risk by investing in a portfolio of companies. Working on the assumption that the majority of their investments will fail, VCs seek opportunities for 'home runs' which can generate returns of ten or more times the original investment.

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6 Inno.CNT, Questions and Answers, http://www.inno-cnt.de/en/faq.php, accessed 6 March 2012

7 State aid: Commission gives green light to €46 million in aid granted by France to GENESIS R&D programme http://europa.eu/rapid/pressReleasesAction.do?reference=IP/08/852, accessed 6 March 2012

8 Nanotechnology in Finnish Industry 2008, http://www.slideshare.net/spinverse/nanotechnology-in-finnish-industry-2008 accessed 6 March 2012

22. When evaluating investments, VCs consider the profile of the company's management, the market potential and business model, the development stage of the company and its technology, the exit plan and the valuation of the company. VCs typically claim that they invest in teams rather than business models or technologies, and the presence of experienced management is likely to reassure them that the company has the ability to achieve objectives and react positively to setbacks. It is important to demonstrate that large addressable markets exist, to reassure investors that there is sufficient potential to increase the value of the company enough to generate significant returns. The state of technological and market readiness also affects how quickly the company can start demonstrating value and generating returns. The exit plan is a critical factor, with VCs seeking opportunities to exit their investments through the company selling shares to the public in an Initial Public Offering (IPO) or via a trade sale of the company.

23. Corporate VCs have additional criteria, in that they seek to benefit their parent firm by providing information or access to potentially disruptive technologies, or by funding and creating an ecosystem of companies to drive demand for the parent firm's products. Corporate VCs can also bring more value to investments, by providing access to the parent firm's knowledge and resources.

Role in Nanotechnology

24. Venture capital accounts for just 4% of overall nanotechnology funding, according to the global figures from Lux Research. There are also significant geographical differences, with the amount of VC funding in Europe (at US $100 million) just a fifth of the North American level. This is accounted for both by broader systemic factors affecting venture capital investment, and some specific characteristics of nanotechnology (which will be covered in more detail in the next section).

25. Overall European venture capital investments have been declining substantially over the last five years, with European Venture Capital Association figures showing investments down 78% from their 2006 level.[9] This can be assumed to have had an impact on the low level of European venture capital investment in nanotechnology. The US situation is more favourable in terms of the availability of venture capital, with the amount dropping in 2009, but recovering quickly so that the 2011 level showed an overall increase of 7% from 2006.

26. There are at least two venture capital firms with an explicit focus on nanotechnology; Nanostart and Nanodimension. Nanostart, with offices in Germany and Singapore, currently has nine firms in its portfolio, spanning medical implants, cancer therapies, optical sensors, and coatings for sports equipment. Three of these firms are located in Singapore, two in the US, and four in Germany.[10] Nanodimension, based in the US and Switzerland, has invested in seven companies, including construction materials, electronics and targeted vaccines. All but one of Nanodimension's portfolio companies is based in the US.[11]

27. One of the major factors affecting the level of investment is the shortage of cases in which investments have been successfully exited. There have been very few IPOs in nanotechnology – the most important nanotechnology IPO of last five years was the floatation of battery manufacturer A123 Systems, though this failed to inspire other IPOs, and the subsequent poor performance of A123 Systems' stock is likely to dissuade other firms from going to market.

9 European Venture Capital Association, http://www.evca.eu/

10 Nanostart portfolio, http://www.nanostart.de/index.php/en/portfolio-and-funds/portfolio, accessed 6 March 2012

11 Nanodimension portfolio, http://www.nanodimension.com/portfolio-content/index.php, accessed 6 March 2012

28. As would be expected, venture capital is unevenly distributed between firms, with certain high potential companies receiving repeated infusions of funding from investors. One European company, Oxford Nanopore, accounts for a significant share of European VC investment in nanotechnology, having received almost €50 million over three investment rounds from 2009-2011. This speaks to a lack of companies capable of 'home-run'-like performance, the high capital requirements of some companies and sectors, and to a certain extent the herd mentality of investors, who are conscious of safety in numbers.

29. Corporate venture capital has an important role within overall venture capital investment in nanotechnology. Corporate VCs are motivated to invest in firms producing nanotechnology-based innovations which could potentially be disruptive for the parent firm, or which could produce new markets for the parent's products. An €18 million investment round in 2009 in the German polymer photovoltaic company Heliatek is a good example, with three of the eight investors being corporations or corporate VCs (Bosch, RWE Innogy Ventures, and BASF Venture Capital).[12]

Institutional Investors

Description and Investment Criteria

30. Institutional investors include banks, insurance companies, pension funds and mutual funds. Depending on their risk profile, institutional investors seek to protect capital and receive above inflation returns by investing in a diverse range of instruments. Institutional investors channel investment to firms using nanotechnology by investing in shares of publicly listed companies, corporate bonds, and venture capital funds.

Role in Nanotechnology

31. The importance of institutional investors is primarily seen in their willingness or otherwise to invest in venture capital funds. The existence of very few venture capital firms with an explicit focus on nanotechnology indicates that institutional investors have little interest in this sector *per se*, because of the inconsistent but largely disappointing performance of publicly listed nanotechnology companies.

32. Investment firms have periodically established nanotechnology index funds in order to track performance and enable investors to invest in the sector. Table 3 shows the five-year performance of the five largest constituent companies of the longest running index, the Invesco PowerShares Lux Nanotech Portfolio[13]. Firms have lost significant amounts of value, including the highest profile nanotechnology IPO of recent years, the battery manufacturer A123 Systems. The one strong performer, Veeco Instruments, benefits in part from continued public investment in nanotechnology research being used to purchase its equipment.

[12] Heliatek receives US$ 27 million to continue development of organic solar cells, http://www.nanodimension.com/portfolio-content/index.php, published 26 November 2009

[13] PowerShares Lux Nanotech Portfolio (Fund), http://www.invescopowershares.com/products/overview.aspx?ticker=pxn, Accessed 16 February 2012

Table 3: Share Price performance of five largest constituents of the Invesco PowerShares Lux Nanotech Portfolio. Source: Lux Research (2011)

Company	Ticker Symbol	Sector	5 Year Share Price Change
Headwaters Inc	NYSE:HW	Energy	-86,6%
Flamel Technologies	NASDAQ:FLML	Nanomedicine	-79,9%
Valence Technology, Inc	NASDAQ:VLNC	Energy/Transportation	-39,05%
Veeco Instruments Inc	NASDAQ:VECO	Tools & Instruments	+41.36%
A123 Systems, Inc.	NASDAQ:AONE	Energy/Transportation	-89.11%

Specific Characteristics of Nanotechnology

33. A consistent message from both investors and corporations is that they do not have distinct approaches for evaluating nanotechnology investment cases as compared to other high-technology investments. However, there are several ways in which technological and market factors make nanotechnology investments somewhat more risky.

Risks of Nanotechnology

Product versus Process

34. An important concept when evaluating nanotechnology is to establish whether the use in question is a product innovation or a process innovation. Conceptually, product innovations are somewhat simpler; a tennis racket made from a composite material which includes CNTs to improve its mechanical properties is an attempt to create a differentiated and improved product to gain market share. By contrast, process innovations are more embedded, but potentially more radical; using ALD to produce components for semiconductors has created significant value for semiconductor manufactures by enabling them to continue downscaling feature sizes. It is often the case that product and process innovations go hand in hand; the use of ALD in a manufacturing process required a product innovation – an ALD reactor; whereas included CNTs in composites requires adapting the manufacturing process.

35. Process innovations typically take longer to reach the market because they require adaptation along a value chain. CNTs could improve the performance of composite materials so that they become suitable for manufacturing automotive bodies. However this requires the automotive manufacturer to change significant elements of its manufacturing process to deal with the new material from assembly to painting and testing, as well as potentially finding new suppliers. This would also generate a response from incumbent suppliers of automotive steel, who would seek ways to compete with the new solution. A lighter vehicle would provide great value; fuel efficiency benefits for drivers, reduced shipping costs, less material usage, but only a portion of that value would be captured by the new material supplier. By contrast, the value created by product innovation is clearer and more quickly captured by a single firm.

36. This is reflected in the relationship between investment source and innovation type. Process innovations are more suitable for funding by corporate investment, both because expected payback times can be longer, but also because the value from process innovation can be captured in ways – such as reduced manufacturing costs leading to higher profits – which don't lend themselves to spectacular revenue growth. Many of the firms that have received venture capital investment can be considered to have made a product innovation; the use of nanostructured materials to build better battery products in the case of A123 Systems, for example.

Technological Risks

37. Nanotechnology is a broad term covering a range of scientific phenomena and research areas, but much of nanotechnology development still occurs close to the frontiers of research and to the limits of understanding of the properties of materials at the nanoscale. This presents a number of technological risks, starting in some cases from a fundamental question about whether the basic principles causing an observed behaviour - the electrical properties of CNTs, for example – are sufficiently well understood. A secondary challenge is to exert sufficient control over the properties of a material to ensure that desired behaviour can be replicated at larger volumes. These constitute a very significant risk that the technology may not do what is intended beyond laboratory scale.

38. Further technological risks include the integration of nanomaterials or components with larger systems. This extends from the risk that the subsystem cannot be made to integrate with the supra-system, to building this integration into manufacturing processes and ensuring that products can be manufactured economically and with acceptably low failure rates. The nature of nanotechnology is that many developments need to be integrated into manufacturing processes that are already highly optimized, such as semiconductor fabrication.

39. An uncertainty related to technology also exists around patents. Whilst we have not yet seen patent wars in nanotechnology, there is a widespread fear that overlapping intellectual property exists. The failure or inability of a single company to assure freedom to operate by controlling enough of the IP ‘stack’, from material synthesis to application to integration, also creates a risk of future legal battles.

40. Safety is a much-discussed topic in nanotechnology, and both the perception and reality present risks that must be considered and mitigated. From a technology viewpoint there is a requirement to ensure that production processes are safe for workers, and that products do not unnecessarily expose users to nanomaterials during their life-cycle. An investor would be concerned about financial liabilities that may be incurred as a result of tracing worker or user health problems to exposure to nanomaterials, particularly if appropriate insurance is not available.

Market Acceptance Risks

41. A fundamental challenge in any new technology or solution is to understand the value that is created for customers. This is a factor of the benefits the new solution will bring, set against innate inertia and the very real costs of adopting new materials, products and processes. This need to understand customers is complicated by the fact that nanotechnology developers are typically separated from the end-user of the technology by several value chain steps. Adaptation by intermediate suppliers –particularly for process innovations -may also be required at each stage, requiring a series of cost/benefit calculations. It may often be the case that new value chains or industrial structures and partner relationships are required, and that actions to build new value chains generate reactions from existing firms.

42. A further risk affecting market acceptance is the extent to which regulatory and societal factors are likely to impact acceptance of the technology, such as the impact of REACH legislation in European products incorporating nanomaterials, or fears of a GM-like public backlash against nanotechnology. This introduces an additional risk to investments in nanotechnology.

Sector-specific Investment Risks and Opportunities

43. Some risks and opportunities feature more heavily in the six sectors covered in this report. Table 4 provides a brief overview of these sector-specific factors.

Table 4: Overview of Sector-Specific Risks and Opportunities

	Risks	Opportunities
Transportation & Aerospace	The automotive energy storage market has been much hyped, but companies in Europe and US have faced strong competition from Chinese manufacturers. Other applications in nanotechnology in transportation are process-like, often requiring adaptation from users and thereby reducing customer acceptance. A shift away from steel to nanoenhanced composites would require extensive changes to production machinery, for example.	The major opportunity in transportation is improved batteries for electric vehicles; a clear meeting of market need, government support and a technology where advanced materials science plays an important role. Other opportunities include new materials for vehicle manufacturing, exemplified by Boeing's shift to composite materials for the 787 Dreamliner.
Nanomedicine	The well-established but time-consuming and costly regulatory approval process increases level of investment required.	Needle free vaccines, earlier cancer detection and improved treatments, biodegradable and biocompatible implants, and proactive wound dressings all present opportunities for nanotechnology to contribute to innovative products. The phenomena of pharmaceutical firms filling their development pipelines by acquiring other firms (often described as R&D by M&A -Mergers & Acquisitions) creates an exit market through trade sales for companies in this field.
Electronics	Technologies must fit with existing processes that are well optimised and reflect substantial sunk costs. New approaches must demonstrate significant performance improvement to be able to compete with existing solutions, with few examples of bottom-up nanoelectronics gaining market traction.	Nanotechnology's impacts range from techniques to continue downscaling feature sizes of integrated circuits, to 'More than Moore' applications for improved components, and eventual bottom-up methods of transistor manufacture. Several corporate VCs and an active trade sale market.
Energy	As with energy storage, issues of cost competitiveness –particularly from Asian manufacturers – have impacted photovoltaics.	Aside from energy storage, opportunities for nanotechnology include new or improved photovoltaics (from optimised thin film to flexible solar cells), and catalysts for use in bio- and fossil fuels. Energy/'Cleantech' has been very attractive to investors, though with some recent evidence that this is declining.
Materials	Materials as such are difficult to evaluate as an investment class, and are likely to interest VCs only when targeted to specific	Nanomaterial manufacturing and integration still has potential to transform other sectors, from automotive to

	applications (as with nanostructured materials for energy storage). Typically process innovations with long development times and the customer acceptance risks.	electronics, and retains the power to generate hype – as the recent surge in interest in graphene attests.
Food & Food Packaging	Public image of "nano" – c.f. gene-manipulated food – means that investors may regard companies using nanotechnology as food and food packaging as presenting a higher market acceptance risk.	Nanotech in processing and packaging offers have more degrees of freedom for nanotechnology based innovations Strong incumbent players – tech start-ups aiming for partnering with the large players or prepare for exit through trade sale

Conclusions and Recommendations

44. There is room for collective action, supported or initiated by public bodies, to mitigate risk and therefore increase investment in nanotechnology. This can already be seen in several places, such the formation of industry associations in the US and Europe (the NanoBusiness Alliance and the Nanotechnology Industries Association) to contribute to public debate about nanotechnology, and ultimately to impact regulation.

45. At the R&D and early commercialisation stage, more innovative approaches to pool risk and knowledge are being seen. The Inno.CNT alliance mentioned earlier in this paper is a good example. The project, which includes a number of potentially competing CNT manufacturers, brings together 80 partners to develop markets for CNTs, with a focus on building links along the value chain from material supplier to end user. Collaborative projects also provide opportunities to build a common technology platform, from which individual firms can then develop business from specific applications.

46. As a process innovation, it is also important that collective action and public funding be used to reduce manufacturing risk and thus encourage investment. For nanotechnology to address major societal challenges, it will be necessary for products using nanotechnology to be manufactured and used in large volumes. In practise this often means extending funding to prototype and pilot manufacturing, as this is a point at which costs and risk are at their highest, dissuading corporations and institutional investors from funding these activities. This was recognised in the recent report from the European Commission's High Level Group on Key Enabling Technologies, which urged more funding for these types of activities.

47. A final area where collective action could reduce investment uncertainty would be in the formation of patent pools, in which intellectual property is cross licensed to a number of firms. This mitigates the risk of individual firms blocking developments whilst being able to fully exploit technologies themselves, and would resolve some of the uncertainty around overlapping patents and freedom to operate which is currently affecting investment. A current patent pool example is that of radio frequency identification devices, in which critical patents have been pooled in order to encourage the widespread adoption of the technology, and resulting in simple and transparent pricing for licensees.