

## **Global Research & Development (R&D) Expenditure on Nanotechnology**

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#### **Overview**

- 1) Funding for nanotechnology R&D in the developed world has accelerated rapidly within a very short time; spending by governments world-wide has increased approximately seven-fold in the last six years i.e. from \$0.43 billion in 1997 to \$3.0 billion in 2003 (1). At least thirty-five countries have initiated R&D activities in nanosciences (2). At the present time, the most visible backers of nanotechnology have been governments whilst funding by private corporate bodies has been much more difficult to ascertain. Nevertheless, public and private funding of this technology has been estimated to amount to \$4.0 billion in 2002 (3). It has been reported that more than 100 venture capital groups have invested \$0.5 to \$1.0 billion into nanotechnology R&D projects in 2002 (3). However, comparisons of nanotechnology expenditure on a global basis is somewhat complicated by variations in the funding mechanisms employed throughout the world and even the absence of a clear agreement on what constitutes this new technology. The need to fund R&D to establish a leading position in nanotechnology is viewed by authorities globally, particularly in the USA, Japan and EU, as essential for a strong economic platform for the future. To put this into a perspective the world-wide annual industrial production in nanotechnology sectors has been estimated to exceed \$1.0 trillion in 10 to 15 years from now and could require about two million workers with the appropriate skills (4).

#### **National Nanotechnology Funding Activities**

- 2) The R&D spending of the major players in the area of nanotechnology are outlined below and summarised in Table 1.

#### **USA**

- 3) Since January 2000 the US government has initiated a multidisciplinary strategy for development of science and engineering fundamentals through the National Nanotechnology Initiative (NNI). This programme provided funds for ten federal departments and independent agencies that support long-term fundamental research, the establishment of facilities/networks and the setting up of education/training programmes (1). The actual funding for the NNI in 2003 amounted to \$770 million and the proposed spend in 2004 is \$849 million; whilst the senate has already approved \$3.7 billion over the next four years. It has been estimated that the central government funding in 2002 (\$697 million) has been matched by the industry/private sector whilst state and local authorities (including

universities & foundations) have additionally contributed an amount for nanotechnology R&D approximately half that of the NNI (5).

- 4) At a recent senate hearing (6) it was claimed that most of the manufacturing companies of the Fortune 500 now have some nanotechnology effort; corporate leaders such as IBM (\$100 million committed to R&D on nanoelectronics).
- 5) ExxonMobil, Dupont, Hewlett Packard, etc., have had major programmes in place for many years. Over sixty US venture capital firms, in addition to corporate venturing operations, have invested in nanotechnology related companies. For the reasons indicated above, it is difficult to measure the total private equity investment figure however Venture One has tracked \$500 million in nanotechnology funding to start-ups in 2002. More than half the world nanotechnology start-ups are in the USA.
- 6) In addition to the federal government funding, there are a number of states that have major nanotechnology initiatives (7)(8). Some of the more notable are: the setting up of the Californian Nanosystem Institute (\$100 million over 4 years), Californian CISI programme (\$300 million over 4 years), New York Center of Excellence in Nanoelectronics - Albany Center (\$50 million facility and a programme funding of £212 million over five years), Pennsylvania Nanotechnology Center (\$37 million), Illinois Nanotechnology Center (\$34 million), etc.

## **Japan**

- 7) Japan has had for some time a fully coordinated initiative for nanotechnology funding and R&D. Government spending in 2003 amounted to approximately \$800 million (5). Most of the nation's largest companies have entered the nanotechnology field including NEC, Hitachi, Sony, Mitsubishi, etc., and have spent an estimated \$830 million in 2002 on R&D (9)(10). The Japanese view the development of nanotechnology as the key to restoring their economy.

## **EU**

- 8) The funding of nanotechnology R&D within the EU is an involved process which is further complicated by the separate national initiatives of the members. The Sixth Framework Programme (6FP) has devoted \$1.44 billion for the period 2002-2006 to the theme that includes nanosciences (11). The proportion directly allotted to nanotechnology R&D being \$780 million (c. \$200 million per year). However, the figure is viewed as a serious underestimate. Nanotechnology projects are expected to benefit significantly from other thematic areas and optimistic analyses suggest a total 6FP funding of \$3.8 to \$7.8 billion (\$0.95 to \$1.95 billion per year) may result. The EU is using 6FP to encourage large-scale collaboration between research centres, universities, regions and countries, as well as

between academia and industry; a main emphasis is networking on a large scale with an integrated more focused approach.

- 9) A perceived weakness in Europe's nanotechnology position, compared with the US and Japan, is the subsequent translation of its research base into building viable high-tech industries. By and large, industry fails to match public-funded research adequately (12). A recent Institute of Nanotechnology report indicates that private funding to EU initiatives presently run at about \$100 million per year (13). For the present EU funding appears to be adequate to match the US and Japanese nanotechnology initiatives. Given that EU 6FP funding represents only 4% of Europe's total R&D expenditure, the efforts of member states are likely to be the deciding factor in the eventual competitiveness of European nanotechnology initiatives (11).

### **South Korea**

- 10) The South Korean government in March 2002 announced the Nanotechnology Action Plan 2002 with a budget allocation of \$154 million; of this sum 79% was allotted to R&D projects, 17% for new facilities and 4% for engineer training/education programmes (14). A further \$1.1 to \$1.2 billion will be invested in nanotechnology over a period of ten years and will be funded on a 2:1 basis by public and private means respectively. The government's intentions are to develop a highly skilled workforce and secure the country a high position in the top 10 nanotechnology economies.

### **Taiwan**

- 11) In September 2002 the government of Taiwan launched a six year \$667 million investment to promote nanotechnology (15)(11). Taiwan's nanotechnology programme is focused on commercialisation of applications; 62% of funding will be directed to this end whilst the remainder will be used for basic academic R&D, setting up of research facilities and training/educational programmes (16).

### **Peoples Republic of China (PRC)**

- 12) PRC has been identified as one of the best performing countries in nanoscience, government support for nanotechnology amounts to \$240 million in the next five years (2003-2007). This represents a four-fold increase over the previous five years (17). Local government would be responsible for similar or greater investment (\$240 to \$360 million) over the same time scale (18). A proportion of this funding will be used in the setting up of a National Nanotechnology Centre and a supporting network of other Nanotechnology Centres. Resources will be made available to facilitate nanotechnology innovation by SMEs. Many high-tech companies are investing in China e.g. Veeco, the manufacturer of atomic force

microscopes/scanning tunnel microscopes, has collaborated with the Chinese Academy of Science to set up a research centre (18).

### **Germany**

13) Germany is viewed to have a good model for running and financing scientific R&D. To date there has been strong federal government funding for nanotechnology with some \$128 million being made available in 2003 alone for the competence centres/networks. The funding is distributed effectively through this network of research institutes which provide an essential interface between basic research and industry (12)(19). In addition, a separate nanobiotechnology initiative is currently running with a total budget of \$55 million spanning 2002-2007 and in 2003 a further \$87 million has been provided for a new nanoelectronics programme (20). In 2001 it was estimated that private industry funded nanotechnology projects to the extent of at least \$71 million (21). Companies participating in collaborative R&D projects are expected to match public funding.

### **UK**

14) The Department of Trade and Industry (DTI) in 2002 dedicated some \$48 million to nanotechnology on top of existing funding for subject-specific research councils (12). Recently, an injection of \$144 million has been made for nanotechnology R&D and commercialisation over a six year period (2003-2008) - \$80 million for the applied research programme supporting collaboration between industry and the science base and \$64 million for new and existing facilities making up the MicroNanoTechnology network. Government expects this investment will also secure additional industry and regional spending on nanotechnology anticipated to exceed \$320 million (19)(22).

15) In the past 2 years there has been a significant increase in government support for nanotechnology research in universities in particular the new University Innovation Centre in microsystems and nanotechnology at the universities of Newcastle and Durham and Interdisciplinary Research Collaborations (IRCs). The latter initiatives, based on the universities of Oxford and Cambridge have been funded to the extent of \$30.5 million (19).

16) A major concern for nanotechnology in the UK is that industry will not come on board quickly enough to benefit from publicly funded basic research done in the universities.

### **France**

17) The French government announced in 2003 a major research action plan for the advancement of nanotechnology and microelectronics with a budget of \$57 million. Central to this initiative will be the involvement of the MINATEC centre (the Centre for Innovation in Micro and Nanotechnology) inaugurated in 2002 in Grenoble. This \$193 million facility aims to

collocate research, industrial development and education. It will host start-up companies as well as assisting pilot programmes for medium-sized concerns and contributing to the R&D programmes of large corporations (12)(19). Multinational companies are already involved in the government initiative e.g. the alliance of Motorola, Philips and STMicroelectronics in the Crolles 2 venture also based in Grenoble with a total R&D budget of \$1.2 billion for microelectronics and nanotechnology in the timescale 2003-2007 (23).

### **Switzerland**

18) Over the period 2000-2003, \$22 million per year has been made available by the Swiss government to facilitate research into nanotechnology; the highest per capita spending in the world. Funding will increase for the period 2004-2007. The Commission for Technology and Innovation will organise an initiative costing about \$33 million to promote Switzerland internationally as a centre of excellence in micro and nanotechnology (13). To date, the country has focused its efforts to bringing nanotechnology to existing industrial processes rather than “disruptive” technologies (24).

19) Many international corporations, such as IBM and Siemens, have located part of their research activities in Switzerland. More than 120 companies are cooperating with Swiss academia through the Top Nano21 programme in the development of micro and nanotechnology (25).

### **Belgium**

20) The Wallonia regional government has committed \$15 million to its programme “Nano” to support a number of major research projects. Universities will work with research institutes in the first phase of basic research (2-3 year duration). A second phase will bring in industrial partners. In addition, the Wallonia-integrated Nanotechnology Network (WiNN) is a forum for academics to share ideas and provide advice to industry. Similar networking activities are also encouraged in the Flanders region (12)(13).

### **Netherlands**

21) Government funding in 2002 for nanotechnology was \$7 million but is expected to rise with the implementation of the new national research initiative (12).

### **Singapore**

22) The Singapore government provided \$36.7 million over the period 1997-2002 for nanotechnology. There are a number of collaborations with private concerns with particular attention being paid to nanoelectronics and biomedical fields (15).

### **Australia**

23) Announced in Jan 2002 that the Australian Research Council will spend \$86.4 million on public sector research institutes over five years on four priority areas which include nanotechnology (15).

### **Canada**

24) The Canadian National Research Council has created the National Institute of Nanotechnology in Calgary, with funding for five years (2002-2006) i.e. \$60 million each from the Canadian and Alberta state governments (1)(26).

### **Ireland**

25) The government is intent on building a knowledge-based economy. Since 1999 it has invested in a nanotechnology research infrastructure, in particular the National Microelectronics Research Centre which has an international reputation as a nanoresearch facility. The government has spent \$31 million on nanotechnology from 2000 to 2002 (12)(13).

26) Ireland is also the home of some significant nanotechnology start-ups e.g. Ntera has raised \$26 million from private investors to commercialise ultra-thin display technologies. Several multinational companies with an Irish base are progressing in nanotechnology R&D and are being strongly supported by Enterprise Ireland (13)(27).

### **Luxembourg**

27) The government has provided a research budget of \$7.5 million to set up a European nanotechnology research centre (13).

### **Italy**

28) The National Research Council has instituted a research programme in nanotechnology (1998-2000) with \$4.4 in government funding (13).

### **Austria**

29) The Austrian government has introduced a new "Nano" initiative and has allotted \$15.7 million for 2003 and proposes to provide \$27.2 million for 2004 – this funding will cover R&D projects, the setting up of networks and education/training programmes (28).

### **Denmark**

30) The Danish government has allocated \$3.8 million per year from 2003-2005 to establish a basis for nanotechnology and nanoscience research in order to facilitate their participation in ongoing EU activities under FP6 (29).

### **Finland**

31) There is government funding for “nanoprojects” within the current national R&D programme but with no clear breakdown of the amounts provided for nanotechnology (29).

### **Sweden**

32) There is government funding for nanotechnology R&D projects in 2003 as part of the national science initiative (29).

### **Norway**

33) Norway has two major government initiatives with nanotechnology components - FUNMAT with a budget of \$24.4 million per year over five years and NANMAT newly launched in 2003 with \$7.4 million funding. The exact funding for nanotechnology projects is presently unknown (29).

### **Hong Kong**

34) The Hong Kong authorities have funded specific nanotechnology projects of 2-3 year duration in 2001 and 2002 to the tune of at least \$2.3 and \$5.3 million respectively to further basic R&D and facilitate commercialisation of applications. Industry has provided matched funding for many projects (30).

**Table 1 Summary of Global Research & Development Expenditure on Nanotechnology**

<b>Geographic Area/Country</b>	<b>Central Government Funding</b>	<b>Private and Other Public Initiatives</b>
<b>World</b>	Seven fold increase in six years i.e. \$0.43 billion in 1997 to \$3.0 billion in 2003 <sup>(1)</sup>	Total public and private funding estimated to amount to \$4.0 billion in 2002 <sup>(3)</sup> 100 venture capital (VC) groups invested \$0.5 to \$1.0 billion in 2002 <sup>(3)</sup> World-wide nanotechnology industrial production estimated to exceed \$1.0 trillion in 10 to 15 years <sup>(4)</sup>
<b>USA</b>	NNI funding in 2003 \$770 million <sup>(5)</sup> NNI funding in 2004 \$849 <sup>(5)</sup> Senate has approved \$3.7 billion over the next four years <sup>(5)</sup>	Industry/private sector matched NNI funding of \$697 in 2002 <sup>(5)</sup> State/local authorities funding was ~half the 2002 NNI funding <sup>(5)</sup> \$500 million of private equity funding for nanotechnology start-ups in 2002 <sup>(6)</sup> More than half the world start-ups are in the USA <sup>(6)</sup> Major state initiatives in addition to the NNI e.g. California will invest \$400 million over four years <sup>(7)(8)</sup>
<b>Japan</b>	Government funding in 2003 ~ \$800 million <sup>(5)</sup>	Most of the large companies have entered nanotechnology field including NEC, Hitachi, Sony, Mitsubishi, etc., and have spent an estimated \$830 million in 2002 <sup>(9)(10)</sup>
<b>EU</b>	FP6 has directly allotted \$780 million over the period 2002-2006. Figure viewed as serious underestimate – optimistically funding from other thematic areas may result in much more (\$0.95 to \$1.95 billion per year) <sup>(11)</sup>	By and large, industry fails to match public-funded research – private funding to EU initiatives presently run at about \$100 million per year <sup>(12)(13)</sup>
<b>South Korea</b>	For 2002 government allocated \$154 million <sup>(14)</sup> Further \$1.1 to \$1.2 billion to be invested over a period of ten years and will be funded on a 2:1 basis by public and private means respectively <sup>(14)</sup>	
<b>Taiwan</b>	Sept 2002 the government launched a six year \$667 million investment <sup>(16)</sup>	

<b>Geographic Area/Country</b>	<b>Central Government Funding</b>	<b>Private and Other Public Initiatives</b>
<b>China (PRC)</b>	Government support amounts to \$240 million in the next five years (2003-2007) <sup>(17)</sup>	Local government responsible for similar or greater investment (\$240 to \$360 million over the same time scale <sup>(18)</sup> Resources to be made available to foster innovation by SMEs <sup>(18)</sup> Many high-tec companies investing in PRC e.g. Veeco, the manufacturer of atomic force microscopes, has with Chinese Academy of Science set up a research centre <sup>(18)</sup>
<b>Germany</b>	Federal government provided funding of \$128 million in 2003 for the competence centres/networks <sup>(12)(19)</sup> Separate nanobiotechnology and nanoelectronics initiatives also funded to the tune of \$55 million (spanning 2002-2007) and \$87 million (starting 2003) respectively <sup>(21)</sup>	Estimated that private industry provided in 2001 at least \$71 million in funding for nanotechnology projects <sup>(21)</sup>
<b>UK</b>	DTI provided \$48 million in 2002 <sup>(12)</sup> Further injection in 2003 of \$144 million for R&D and commercialisation over six year period <sup>(19)(22)</sup>	Government expects the investment in 2003 to result in additional industry and regional spending anticipated to exceed \$320 million <sup>(19)(22)</sup>
<b>France</b>	Government announced a \$57 million programme in 2003. Central to this initiative will be the \$193 million MINATEC facility inaugurated in 2002 in Grenoble <sup>(12)(19)</sup>	Multinational companies are already involved in this initiative e.g. the alliance of Motorola, Philips and STMicroelectronics in the Crolles 2 venture also based in Grenoble – has a R&D budget of \$1.2 billion (2003-2007) for microelectronics and nanotechnology <sup>(23)</sup>
<b>Switzerland</b>	Swiss government has provided \$22 million per year (2000-2003); the highest per capita spending on nanotechnology in the world. Funding in 2004-2007 will be increased <sup>(13)</sup> . Commission for Technology and Innovation to spend \$33 million promoting Switzerland as a centre of excellence in nanotechnology <sup>(13)</sup>	More than 120 companies are cooperating with Swiss academia in the development of micro and nanotechnology <sup>(25)</sup>
<b>Belgium</b>	Wallonia regional government has committed \$15 million to its “Nano” programme (projects of 2-3 years duration) <sup>(12)(13)</sup>	The second phase of the “Nano” programme will be to bring in industrial partners <sup>(12)(13)</sup>
<b>Netherlands</b>	Government funding in 2002 was \$7 million but is expected to rise with the implementation of the new national research initiative <sup>(12)</sup>	
<b>Singapore</b>	Government provided \$36.7 million in the period 1997-2002 <sup>(15)</sup>	There are a number of collaborations with private concerns with particular attention on nanoelectronics and biomedical areas <sup>(15)</sup>

Geographic Area/Country	Central Government Funding	Private and Other Public Initiatives
<b>Australia</b>	Announced in Jan 2002 that \$86.4 million will be spent over five years on four priority areas which include nanotechnology <sup>(15)</sup>	
<b>Canada</b>	National Institute of Nanotechnology set up with total funding of \$120 million over five years <sup>(1)(26)</sup>	
<b>Ireland</b>	Government has spent \$31 million in the period 2000-2002 <sup>(12)(13)</sup>	Ireland is the home of some significant nanotechnology start-ups e.g. Ntera has raised \$26 million from private investors to commercialise ultra-thin display technologies. Several multinational companies with an Irish base are progressing in nanotechnology R&D and are being strongly supported by Enterprise Ireland <sup>(13)(27)</sup>
<b>Luxembourg</b>	Research budget of \$7.5 million provided to set up a European nanotechnology research centre <sup>(13)</sup>	
<b>Italy</b>	Government funding of \$4.4 million from 1998 to 2000 <sup>(13)</sup>	
<b>Austria</b>	The Austrian government has introduced a new "Nano" initiative and has allotted \$15.7 million for 2003 and proposes to provide \$27.2 million for 2004 <sup>(28)</sup>	
<b>Denmark</b>	Government has allocated \$3.8 million per year from 2003-2005 <sup>(29)</sup>	
<b>Norway</b>	Two major government initiatives with nanotechnology components - FUNMAT with a budget of \$24.4 million per year over five years and NANMAT newly launched in 2003 with \$7.4 million funding. <sup>(29)</sup> The exact funding for nanotechnology projects is presently unknown	
<b>Hong Kong</b>	Authorities funded projects of 2-3 year duration in 2001 and 2002 to the extent of at least \$2.3 and \$5.3 million respectively <sup>(30)</sup>	Industry has matched funding for many projects <sup>(30)</sup>

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