OAKDENE HOLLINS
RESEARCH & CONSULTING

A working guide for determining the value of nanotechnology innovation

Sustainable products and services
Clean technologies
Resource efficiency

A report for Defra

November 2010

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Introduction

This document is part of a five piece set of reports that describe a methodology for performing a comparative valuation of a nanotechnology against an incumbent technology. The reports are entitled:

- "**A comparative methodology for estimating the economic value of innovation in nanotechnologies.**" This provides a comprehensive overview of the methodology, supporting evidence and some worked examples.
- **"A working guide for determining the value of nanotechnology innovation."** This provides a simpler document designed for non-economists to make less rigorous calculation.
- **"A calculation spreadsheet for valuing nanotechnology."** This is a spreadsheet in MS Excel format that is designed to accompany the working guide.
- **"Methodology Case studies."** A series of case studies that use the methodology for valuing nano-enabled products relevant to Defra
- **"Nanotechnologies relevant to Defra."** A short literature review to identify nanotechnologies that are relevant under Defra's remit.

If they are not readily available, these documents can be obtained from Oakdene Hollins Ltd.

Nanotechnology is the study and manipulation of materials less than 0.0000001 meters in at least one dimension. It has the potential to deliver innovative new materials and products that will have an impact in many areas of modern life. However there is little quantitative evidence of the potential economic benefits of nanotechnology. This document addresses this evidence gap by providing a simple guide on how to quantify these benefits. This methodology is comparative, thus the relative benefit of the nano- enabled product is assessed against a current incumbent product which it may replace and is not an absolute assessment of the value of a nano-enabled product.

This guide has been designed for use by:

- policy makers and governments, to perform costs benefit analysis
- industry, to estimate the social benefits of a product i.e. to compare against any potential risks
- funders, e.g. Research Councils and the Technology Strategy Board, to impartially appraise the relative benefits of proposals in allocating funding.

The Excel spreadsheet: "A calculation spreadsheet for valuing nanotechnology" that accompanies this guide removes the need for the user to perform the calculation. This guide should be used along with that spreadsheet.

A full reference document *'A comparative methodology for estimating the economic value of innovation in nanotechnologies'* is also available that provides full details on the theory and practice of performing the calculation. Where a deeper understanding and analysis is required, readers are referred to this document. The full methodology has been developed by Oakdene Hollins. It has been tested and validated through a series of case studies by a stakeholder workshop comprising interested parties from government, academia and industry and through the involvement of a steering group comprising policy makers and economists from a number of government departments.

Whilst the methodology has been developed with valuing nano-enabled products in mind, the methodology can also be used to value innovation in other emerging industries.

The structure of this document is shown in Table 1 with a reference to the full methodology. If deemed appropriate, after using this guide, further analysis using the full methodology should be performed using additional expertise from economists.

Table 1: Structure of Working Guide in relation to Full Methodology

Working Guide Chapter	Description	Steps in Full Methodology
1. Model Development	Provides background information on how to frame calculations	Steps 1-5
2. Data	Identifies data requirements and suggests proxies	Steps 6-10
3. Calculation	Shows how to input data into spreadsheet and interpret results	Steps 11-12

1 Model Development

To calculate the value, a comparative valuation between a nano-enabled product and an incumbent product (or products) that is available on the market needs to be performed. Key to this is to ensure that the comparison between the incumbent (non-nano-enabled) product and the nano-enabled product is reasonable and soundly-based and that the two products provide an equivalent 'function'. This methodology takes the premise that, under most circumstances, **an innovation does not enable completely new functions** and that traditional methods of performing the same function can be found, either from an individual product or from a suite of products.[a] Even seemingly 'breakthrough' innovations, such as new drugs, have an incumbent comparator, such as extending or improving human life, which can be valued. An important part of this concept is that the functionality (or efficacy) of the two products match. This is to ensure that, for example, only half the amount of a nano-enabled product which is twice as efficacious as the incumbent is compared.

Steps 1, 2 and 3 are dedicated to ensuring that the comparison is fair and the framework described in the paragraph above should be taken into account when performing the analysis.

As stated above, this document is a short guide for performing the calculation: further information and guidance on all the steps can be found in the main document. The step numbers described below relate directly to the sections in the full reference document.

Step 1
Firstly, a decision needs to be made regarding how to define the nano-enabled product that is to be valued. It is recommended that the product range selected is not diverse (otherwise the comparison may not be meaningful). Conversely if the product range is narrowly defined there may be a risk that the product is not launched due to company failure or unforeseen technical problems.

Step 2
The next step is to think about what function the nano-enabled product performs. Unfortunately, a robust yet simple method for determining this is not available, but five key steps can be used as a guide:

1. Investigate the nano-enabled product.
2. Determine the intended use of the product.
3. Determine the desired function of the product.
4. Frame the output so that it is measureable.
5. Define the relationship between functionality and the product.

Step 3
Once the nano-enabled product has been well defined, and the function that it provides has been discussed, the incumbent product that will be replaced by the nano-enabled product can be identified. Broadly, there will be two types of nano-enabled products:

- Those that provide the same functionality as a single incumbent technology (usually at an increased efficacy or reduced cost).
- Those that combine the functionality of several incumbent products.

It is important to identify an incumbent technology that provides the most closely matched functionality. For the majority of cases examined, the incumbent technology will be a clearly defined and obvious choice for comparison. In some cases, however, lateral thinking around what the product does may be necessary when attempting to value seemingly new products e.g. conceptualising a seemingly new product such as a 'breakthrough' cancer drug as having the functionality of extending human life.

Where the nano-enabled product provides a functionality that can only be matched by a number of different incumbent products, each of these incumbent products should be identified, together with the amount needed to match the nano-enabled product.

[a] *It is important to stress that this is not the same as the difference between radical and incremental innovation and is not discussed within the context of this document.*

It is not possible to value a product that performs an unprecedented function, so where it is not possible to identify one or more incumbents the calculation cannot be performed. For example, it was impossible to predict the value of the Sony Walkman prior to its launch. A possible avenue for evaluating a nano-enabled product with a new function is to find a product that best matches its functionality. In such instances it is important to understand and record that the valuation is likely to be an underestimate.

Step 4

To approximate and simplify the valuation, the nano-enabled product can be thought of as having one of four effects on the marketplace when it replaces the incumbent product:

I. The market size remains unchanged.
II. The market size is increased compared to that of the incumbent.
III. Functionality is enhanced over existing products but in a fixed market size.
IV. Functionality is enhanced over existing products with increased sales.

Two decisions need to be made in order to determine the scenario within which the product should be valued:

1. Is the nano-enabled product replacing single or multiple incumbent technologies?
2. Is the market mature and unlikely to increase if the price was to change?

The combination of these two questions allows selection of an individual scenario from the matrix in Figure 1.

Figure 1: Choosing between scenarios

		Functionality	
		Single	**Multiple**
Market size	**Increasing**	II	IV
	Fixed	I	III

One of these should be selected to complete the methodology.

Step 5

The last aspects of model development are to determine the geographic location and the timeframe over which the value of the nano-enabled product will be assessed, e.g. the EU for 20 years. These parameters can be selected or defined based on a particular agenda or question that needs to be answered.

Summary

At the end of this process, the model should be defined for the calculation, with these parameters set:

- the nano-enabled product
- the nano-enabled product's function
- the incumbent(s)
- the scenario
- the geographic area for the calculation
- the timeframe over which the technology will be valued.

The next section describes where the data will be collected from to perform the calculation.

2 Data Collection

Once the model development has been completed the next task is to identify and gather the data required to perform the calculation. Table 2 lists the data required and either the suggested source or, where data are unavailable, the suggested method of obtaining a proxy. More details on how to develop proxies can be found in the relevant steps of the full methodology. (Clearly, where data are readily available they should be used in preference to a proxy.)

Table 2: Data required for all Scenarios

Parameter	Description	Suggested Source or Proxy Method	Relevant Step of full methodology
Q_0	Initial market quantity	Market research	Step 9
P_0	Incumbent price	Market research	Step 8
C_A	Incumbent unit cost	Average sector margins	Step 7
C_N	Nano-enabled product unit cost	Derived from incumbent unit cost	Step 7
P_N	Nano-enabled product price	Market research or Assume to equal incumbent price	Step 8
V_A^i	Volume of externality for incumbent product	Published research	Step 10
V_N^i	Volume of externality for nano-enabled product	Published research	Step 10
C^i	Unit cost of the externality	Standard damage costs (see Appendix A of this working guide)	Step 10
$\%_A$	% of production of the incumbent product located in the targeted geographical location	Market research	Step 11
$\%_N$	% of production of the nano-enabled product located in the targeted geographical location	Market research	Step 11

Where more than one incumbent product is needed to match the functionality of the nano-enabled product (under Scenarios III and IV) the data in Table 3 are required for **each additional product** (product 'B', 'C', 'D' etc).

Table 3: Additional data required for Scenario III and Scenario IV

Parameter	Description
P_B	Price for incumbent enhanced performance
C_B	Unit cost for incumbent enhanced performance

Parameters P_0 and C_A detailed in Table 2 should then be modified by summing the relevant component prices and costs:

$$C_A = C_A + C_B + C_C + C_D + \text{etc}$$

and

$$P_0 = P_0 + P_B + P_C + P_D + \text{etc}$$

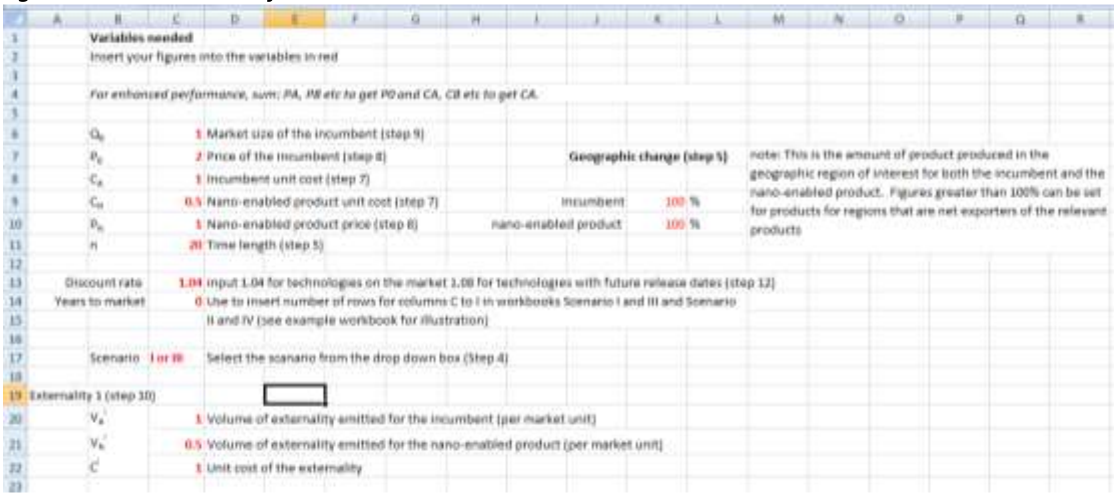
3 Calculation

This chapter shows how to perform the calculation of benefits using the accompanying spreadsheet. Figure 2 shows a screenshot of the 'Variables' tab from the spreadsheet (some of the rows are hidden to aid viewing – up to three externalities can be included). The data obtained in the previous section are entered into the red figures. Also, there is a drop down box to select the appropriate scenario.

For the other parameters:

- The discount rate should be set to 1.04 for technologies already on the market and 1.08 for technologies with future release dates.
- Years to market can be entered for future release dates (although the rows will need to be manually adjusted – see 'Example' tab).

Figure 2: A screenshot of the 'Variables' tab



Once all the data have been entered the results can be found under of the calculation tab.

A certain amount of modification to the spread-sheet is necessary if the overall timeframe for the calculation is different from the default (20 years). If the timeframe is less than 20 years, the surplus rows can be deleted; if the timeframe is longer than 20 years, rows need to be added and the formulae within the 'Value over 20 years' and 'Terminal value' need to be appropriately modified (further details of these calculations can be found in **Step 12**).

To take account of products that have not yet come to market, a modification of the spreadsheet is necessary. Certain rows and cells need to be moved to account for the fact that the product will not be entering the market for a defined time. The 'Example' tab describes the process for making this modification.

Figure 3 gives some example results for Scenario I or III. The left side of the screen shows the raw calculations of benefits attributed to producer surplus, consumer surplus and externalities for a given year; which is summed in $\Delta S_{(t,0)}$. The right side of the screen adjusts this calculation to account for two aspects:

- firstly, that the technology will not replace the incumbent instantaneously, but will rather diffuse into the market over time
- secondly, to account for risk using a discount factor.

The final estimate of the benefits is given in the 'MVA' column. Estimates of the value are given for:

- each year
- over the 20 year period
- as a terminal value (summing the benefits indefinitely).

These results are interpreted as follows:

- In 2010 the nano-enabled product will be worth £2,000 to the UK economy, rising to £878,000 in 2030.
- The nano-enabled product will bring benefits of £13m over 20 years to the UK economy.
- The nano-enabled product has a net present value to the UK economy of £24m.

At the end of the calculation it is worth performing a sensitivity analysis of the results. This is a simple matter of re-performing the calculation after entering slightly different values for the variables. This helps identify which variables are most likely to influence the benefits, and to what degree (both positively and negatively).

Figure 3: Example Results

Microsoft Excel - Value

	B	C	D	E	F	G	H	I	J	K	L
1		**Surplus**					**Diffusion Rate**		**Discounted value**		
2	Year	Producer surplus	Consumer Surplus	Externalities	$\Delta S_{(t,0)}$		%	$\Delta S_{(t,0)}^{D}$	Year	MVA	
3	2010	0.500	0	0.5000	1.000		0.2	0.002	1	0.002	
4	2011	0.487	0.05	0.5128	1.050		0.7	0.00735	2	0.007	
5	2012	0.474	0.1	0.5263	1.100		2	0.022	3	0.020	
6	2013	0.459	0.15	0.5405	1.150		5	0.0575	4	0.049	
7	2014	0.444	0.2	0.5556	1.200		10.9	0.1308	5	0.108	
8	2015	0.429	0.25	0.5714	1.250		20.5	0.25625	6	0.203	
9	2016	0.412	0.3	0.5882	1.300		34	0.442	7	0.336	
10	2017	0.394	0.35	0.6061	1.350		50	0.675	8	0.493	
11	2018	0.375	0.4	0.6250	1.400		66	0.924	9	0.649	
12	2019	0.355	0.45	0.6452	1.450		79.5	1.15275	10	0.779	
13	2020	0.333	0.5	0.6667	1.500		89.1	1.3365	11	0.868	
14	2021	0.310	0.55	0.6897	1.550		95	1.4725	12	0.920	
15	2022	0.286	0.6	0.7143	1.600		98	1.568	13	0.942	
16	2023	0.259	0.65	0.7407	1.650		99.3	1.63845	14	0.946	
17	2024	0.231	0.7	0.7692	1.700		99.8	1.6966	15	0.942	
18	2025	0.200	0.75	0.8000	1.750		100	1.75	16	0.934	
19	2026	0.167	0.8	0.8333	1.800		100	1.8	17	0.924	
20	2027	0.130	0.85	0.8696	1.850		100	1.85	18	0.913	
21	2028	0.091	0.9	0.9091	1.900		100	1.9	19	0.902	
22	2029	0.048	0.95	0.9524	1.950		100	1.95	20	0.890	
23	2030	0.000	1	1.0000	2.000		100	2	21	0.878	
24							Value over 20 years			**13**	
25								terminal value		**24**	

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Ben is a Senior Consultant at Oakdene Hollins. He holds and PhD in green chemistry and supercritical fluids, and has a background in university technology transfer. At Oakdene Hollins Ben is the lead consultant on sustainable technologies, the manager of the Centre for Remanufacturing and Reuse and a technical advisor on televisions for EU Ecolabel. He has authored many reports on sustainable innovation, waste & recycling and remanufacturing. He has particular expertise in nanotechnology, innovation, remanufacturing and standards.

Peter Willis MSc BSc
Peter, our in-house econometrics expert, recently joined us with a first class degree in economics from the London School of Economics and an MSc with distinction from University College London. His range of expertise includes: economic losses and carbon impact of waste in the UK food and drink supply chain; investigating the volatility of PRN prices for the structure and outlook for UK markets in secondary steel and aluminium; and a review of market failures in remanufacturing, and polices to alleviate them.

Alastair MacGregor, BSc MSc CFA
Alastair MacGregor is a Senior Consultant at Oakdene Hollins. He holds an MSc from Cranfield University in Economics for Natural Resource and Environmental Management and previously worked for 10 years as an investment manager. In his capacity as an environmental economist he has produced reports on recycling economics, resource efficiency sustainable materials management.

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