Financial methods in environmental decisions

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This free course is an adapted extract from the Open University course T867 *Managing for sustainability*: http://www.open.ac.uk/postgraduate/modules/t867.

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Financial methods in environmental decisions

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Introduction

One of the tasks of an environmental professional is to make sure that the resources they spend on environmental improvements are spent in the best possible way. This free course, *Financial methods in environmental decisions* begins by introducing some of the tools that can be used to assess the benefits of investment decisions. Conventional financial appraisal only considers the costs and benefits arising from the decisions that are directly experienced by the organisation itself. So this course concludes by looking at ways of assessing the 'external costs' – the wider costs and benefits to society as a whole – of environmental decisions.

This OpenLearn course is an adapted extract from the Open University course T867 *Managing for sustainability*.

Learning Outcomes

After studying this course you should be able to:

- understand techniques for the financial appraisal of projects
- understand private and external costs of environmental impacts and their mitigation
- understand methods for assessing the economics of environmental impacts
- understand discounted cash flow (DCF)
- work with numerical data.

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1 Financial assessment techniques

The for-profit sector survives by generating profits. Profits fund the development of the next generation of goods and services that a firm supplies. The **shareholders**, who are the owners of the business also demand that a firm makes a profit. If a company is unable to return a share of its profits through dividend payments to its shareholders or ensure that the value of its shares continues to rise, shareholders will sell their shares and invest in some other venture. As well as ensuring that it doesn't lose money, a firm has to make sure that owning shares is a better option for the shareholders than, say, investing their money in a bank or building society account.

The not-for-profit sector also needs to make its money work. Organisations in this sector may well not have shareholders who are seeking a return on their investment, but they still need to set the priorities for dealing with an almost unlimited demand on their budgets with limited resources to fund them. For example a UK local authority may have to decide whether it would be better value for its council tax and business rate payers to improve the insulation of its offices or to convert its vehicle fleet to run on liquefied petroleum gas (LPG), which is cheaper than petrol or diesel fuel.

Similarly a charity may need to decide whether it would be better to invest part of its capital reserves on the installation of photovoltaic panels on the roof of its premises and generate income from the sale of the power, or to invest the capital in a managed investment fund that will generate dividends to fund the charitable work.

This section looks at cash flow statements and then considers ways of assessing projects from the financial point of view.

1.1 Cash flow

Any economic unit is 'powered' by the flow of cash. This is true for the smallest unit – perhaps a child and her pocket money – through to households, businesses, nations and economic areas.

Like all disciplines, cash flow has its own particular terminology, which you need to understand.

Cost

Everybody is familiar with the idea of cost. In this context it simply means any expenditure (or outflow of cash) resulting from an activity.

Benefit

Benefits are the converse of costs and represent any cash inflow resulting from an activity. However you should also note that a reduction in cash outflow is also defined as a benefit even if it doesn't result in a positive inflow of cash. So if a householder installs double glazing there will be a benefit to that person in reduced heating bills although the installation will not generate any inflow of cash. Of course there will also be benefits to society as a whole such as the reduction in **carbon dioxide** and other emissions – assuming that the householder uses less heating fuel.

Cash outflows are the costs and expenses (whether capital or revenue in nature) incurred to implement and run a project.

Cash inflows are the benefits that a project is expected to provide. In this context, any savings or reductions in costs resulting from a project, which are in fact benefits, are treated as cash inflows.

The term *net cash flow* simply means the difference between the cash outflows and the cash inflows of a project. If the cash inflows of a project exceed the cash outflows, then there is a *net cash inflow.* This may also be referred to as a *positive net cash flow.* If the cash outflows of a project exceed the cash inflows, then there is a *net cash outflow.* This may also be referred to as a *negative net cash flow.*

In this context the word cash is not being used in its narrow sense, which is 'money'. The cash flows of a project certainly include money spent or received, but they also include movements of money's *worth*, that is, any form of funds, finance or value lost or gained as a result of a project.

Activity 1 Cash inflows and outflows

Allow 20 minutes to complete this activity

Imagine that ten years ago you acquired an ailing warehouse and road transport company whose assets consisted of some insubstantial buildings used as garages and a storage depot, together with five lorries which at that time were relatively new and in quite good condition. Under your direction, the business (now known as Fatcat Haulage) has grown rapidly. The premises are now quite inadequate, expensive to heat and maintain, and expensive to insure as there is only a primitive firefighting sprinkler **system** installed. The five lorries are now uneconomic to run. Diesel and repair bills have become prohibitive, breakdowns and lost running hours are excessive.

With more lorry capacity, better reliability and a faster service you could easily obtain more business. You decide to rebuild the depot with better equipment, full insulation, an effective sprinkler system and in-company lorry maintenance. You also decide to replace the five old lorries (which have been written down to scrap value in your books) with new ones.

Make a list of the cash flows relative to your investment project. Show separately:

(a) capital cash outflows
(b) capital cash inflows
(c) revenue cash outflows
(d) revenue cash inflows.

Do not attempt to attach money values to your cash flows at this stage. List the items under the above categories in descriptive terms only. Indicate which ones you think will be one-off and which ones will recur with time.

Answer

(a) Capital cash outflows:
- planning and design costs
- costs of demolition and site clearance
- site preparation work, for example civil engineering work, including access, mains services
- erection of new buildings
- new fixtures and fittings, including sprinkler system in warehouse, insulation, new racking
- new lorries
- machinery for garage
- warehouse handling equipment (for example cranes, fork-lift trucks)
- installation costs.

(b) Capital cash inflows:
- any cash inflow received from the disposal of existing hardware, for example the scrap value of the lorries
- any grants payable by the local authority or a local **development** corporation or by government departments towards any of the capital costs of the project.

(c) Revenue cash outflows:
- higher rates for new premises
- payroll cost of fitters to take on in-company repair and maintenance work
- increased power consumption for garage
- higher **water** rates and costs for uprated sprinkler system (using metered supply).

(d) Revenue cash inflows:
- increased revenue from increased business levels.
- reduction of insurance premium due to installation of new sprinkler system
- saving of outside repair and maintenance costs
- saving in heating costs (better insulation)
- saving in fuel costs (better fuel consumption).

All the capital items (a and b) will be one-off. All the revenue items (c and d) will be recurring during the life of the project.

1.2 Cash flow statement

Once you have assembled all the data for every cash outflow and every cash inflow for a project, you will be in a position to prepare a *cash flow statement*.

This can take any form that you like, as long as every cash outflow and every cash inflow is correctly specified. It is however the normal practice to show the *initial* cash flows – that is, those that take place when the project first incurs costs – as occurring in year 0, with subsequent cash flows being shown year by year as and when they are expected to arise. As an example, Table 1 shows a possible cash flow statement for the Fatcat Haulage project considered in Activity 2.

Table 1 is primarily intended to illustrate format, not to give an exhaustive list of all the cash flow items that could arise from this project. Perhaps from your own experience you can think of other possible cash flow items. The table should help to indicate where these would be incorporated.

The revenue cash inflows include the additional profits that, it is estimated, will come from the increased business the scheme will generate. This recurring cash inflow is shown, no doubt justifiably, as increasing year by year.

Activity 2 Cash flow statement

Allow 15 minutes to complete this activity

If the year-on-year increase in profits is accepted as a valid forecast, should any recurring cash flows in Table 1 be expected to vary instead of remaining constant as shown? Which cash flows are likely to vary and why?

Answer

The recurring cash flows in this example are the revenue inflows and the revenue outflows. Considering the revenue inflows first, the fact that business level is steadily increasing means that the savings in outside repair and maintenance costs and in fuel costs will become worth more and more in monetary terms. Think how these costs would have escalated if the old vehicles had been retained! It is only too clear how fuel prices continue to rise independently of inflation; this gives added value to the savings in both heating fuels and in diesel oil for the lorries. It would be fair and reasonable to show a continuing increase in all these cash inflow values pro rata to the increasing profits from sales.

For the revenue cash outflows, it is unlikely that the garage mechanic will be content with the same rate of pay for five years. Again, quite irrespective of inflation, you should allow for an annual pay increment of, say, 5%. It may even become necessary to pay overtime or some form of productivity bonus as the repair and maintenance workload becomes heavier. It is also well known that, as motor vehicles (and any other kind of machinery) become older and more heavily used, so the repair and maintenance costs rise. There should therefore be a continuing increase also in the materials costs and the garage power costs. To estimate these as being pro rata to the increases in business levels would be realistic.

When there are specific and realistic reasons like these for incorporating variations in recurring cash flows, it would be foolish to ignore them – irrespective of whether the variations are beneficial or adverse.

Table 1 Fatcat Haulage: cash flow statement (all money values in £000s)

		Year					
		0	1	2	3	4	5

1	**Capital cash inflows**						
	Profit on lorry trade-in values	5					
	Modernisation grant	50					
2	**Revenue cash inflows**						
	Increased sales		45	55	65	75	85
	Reduction of insurance premiums		5	5	5	5	5
	Saving of outside repair and maintenance costs		30	30	30	30	30
	Saving in heating costs		10	10	10	10	10
	Saving in fuel costs		20	20	20	20	20
3	**Total cash inflow**	55	110	120	130	140	150
4	**Capital cash outflows**						
	Site clearance and preparation	20					
	New buildings, planning and design	150					
	Fixtures, fittings, etc.	50					
	New lorries	170					
	Garage machinery and new mechanical handling equipment	20					
	Installation	15					
5	**Revenue cash outflows**						
	Increase in business rates		2	2	2	2	2
	Increase in **water** rates		1	1	1	1	1
	Payroll		15	15	15	15	15
	General materials costs		5	10	10	10	10
	Garage power costs		2	2	2	2	2
6	**Total cash outflow**	425	25	30	30	30	30

1.3 Financial appraisal of projects

Cash can be thought of as just another resource that business has to manage along with materials, fuel, water, labour and so on. It is the responsibility of managers to ensure that their organisation is using its cash, like other resources, in the most efficient way. They have to determine whether a particular project is worth investing in or which of two or more proposed projects that are competing for the same cash resources should be funded. The for-profit sector has to demonstrate the financial sense of proposals if it hopes to convince people to buy shares in the company, the public sector has to demonstrate that it is using the public's funds wisely, and the not-for-profit sector needs to demonstrate its financial probity to its governors and trustees and possibly to the appropriate regulators.

In the following subsections, you will learn how to use and interpret the results from some basic financial appraisal tools.

Payback period

The payback period is the simplest of all financial appraisal methods. While the results can be very misleading, it is a commonly used technique and is a quick method of assessing whether a proposed project is worth further investigation. All that the payback period calculates is how long it will take to recover the initial project investment out of the subsequent net cash flows, that is, how long it will take for a project to recoup the initial capital outlay.

As a simple example, if you invest £20 000 in a project for which you estimate that the positive net cash flow each year – that is, the excess of cash inflows over cash outflows – will be £5000, you expect to recover your initial investment in

Even if the net cash flow varies year by year, it is just as simple to calculate the payback period. Consider a project A with an initial investment of £100 000 and an expected pattern of net cash flows (all positive) as follows:

year 1	£45 000
year 2	£35 000
year 3	£20 000
year 4	£20 000
year 5	£15 000

It is easy to see that it will take exactly three years to recover the initial investment because

Activity 3 Payback period

Allow 15 minutes to complete this activity

Now consider a project B in which the initial investment is also £100 000 but the subsequent pattern of net cash flows (all positive) is as follows:

year 1	£10 000
year 2	£20 000
year 3	£35 000
year 4	£45 000
year 5	£50 000

What is the payback period of this project?

Answer

Calculating the cumulative cash flow

year 1	£10 000
year 2	£30 000
year 3	£65 000
year 4	£110 000

So the payback period is somewhere between three and four years.

You can now see that, although the total net cash flows over the five-year project life are less in project A than in project B, the quite different *pattern* of cash flows would favour project A.

The chief advantage in using the payback period method is that it is easy to understand and to calculate. However it has the following serious limitations:

- The method completely ignores positive net cash flows received after the payback point, whereas in project B it was these later cash flows that were the most significant.
- The method looks *entirely* at cash flow and completely ignores how much has to be invested in comparison with the size of the profits.
- The method assumes that all money is of equal value no matter when it is spent or received. Given the choice between receiving money now or in a year's time, most people would opt for the cash in hand now – a lot can happen in a year.

Many organisations use the payback period method by itself and look for payback periods of two or at most three years. As a result, many worthwhile but longer-term projects, which would give a high rate of return on the investment, are never accepted. Therefore you should never use this method as the only assessment technique.

Activity 4 Fatcat Haulage

Allow 15 minutes to complete this activity

The cash flow statement for the Fatcat Haulage project shown in Table 2 has been revised from the statement shown in Table 1 to take into account variations in cash inflows and outflows.

Assume that the cash flow values are calculated as after tax and calculate the payback period for this project.

Table 2 Fatcat Haulage: revised cash flow statement (all money values in £000s)

		Year							
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1	**Capital cash inflows**								
	Profits on lorry trade-in values	5							
	Modernisation grant	50							
2	**Revenue cash inflows**								
	Profits from increased sales		45	55	65	75	85	85	85
	Reduction of insurance premiums		5	5	5	5	5	5	5
	Saving of outside repair and maintenance costs		60	73	86	100	113	113	113
3	**Total cash inflow**	55	110	133	156	180	203	203	203
4	**Capital cash outflows**								

	Site clearance and preparation	20							
	New buildings	150							
	Fixtures, fittings, etc.	50							
	New lorries	170							
	Garage machinery and new mechanical handling equipment	20							
	Installation	15							
5	**Revenue cash outflows**								
	Increase in business rates		3	3	3	3	3	3	3
	Increase in water rates		15	16	17	17	18	19	20
	Payroll		7	9	10	12	13	13	13
	Material costs								
	Garage power costs								
6	**Total cash outflow**	425	25	28	30	32	34	35	36
7	**Net cash flow**	(370)	85	105	126	148	169	168	167

Parentheses indicate a negative cash flow or a net cash outflow.

Answer

The payback period for the lorry modernisation project is about 3 years and 4 months. After the first three years, there is still £54 000 to be recovered from the year 4 net cash flow of £148 000.

Average gross rate of return

The average gross annual rate of return method is entirely concerned with profitability; the payback period is completely ignored. This method calculates the average proceeds, that is, positive net cash flow, per year over the life of the project and expresses this average as a percentage return per year on the project investment. This can be explained by looking again at my example project A.

The variables in the equations stand for the following:

- *PI* is initial project investment
- *NCF* is positive net cash flow
- *L* is project life.

Where *PI* = £100 000, *NCF* = £135 000, and *L* = 5 years:

Expressed as a percentage return on the initial investment, this is 27% per year or

Activity 5 Average gross annual rate

Allow 15 minutes to complete this activity

Calculate the average gross annual rate of return on project B.

Answer

Expressed as a percentage return on the initial investment of £100 000, this is 32% per year.

If you compare project A and project B – as you might well do in real life – you see that project A gives the better payback period but project B offers the higher gross annual rate of return. Hence the recommendation never to use either of these methods alone. It is better to use both methods and then decide whether your main objective is quick payback or high rate of return in the longer term.

When you have arrived at the average gross annual rate of return for a project, you then compare that rate with the interest rate you would have to pay on any money that you borrowed to finance the project. If the rate of return exceeds the financing cost rate, you can proceed with the project. If it does not, you should either try to find a cheaper source of finance or not proceed with the project.

Average net annual rate of return

The average net annual rate of return method is a variation on the average gross annual rate of return method. It assumes full recovery of the whole project investment, including fixed asset costs (such as buildings and machinery), out of net cash flows before calculating the rate of return on the investment. Because of this, the average annual rate of return is expressed as a percentage of the average capital employed instead of as a percentage of the original investment.

This can be illustrated with the same two examples that I used previously.

The variables in the equations stand for the following:

- *PI* is initial project investment
- *NCF* is positive net cash flow
- *L* is project life
- *ANCF* is average net cash flow.

Project A

This is then divided by the average capital employed (ACE), which in this case is calculated on the basis of the initial outlay of £100 000, and a final outlay of zero, that is

Project B

So the overall result from the net method identifies project B as the better option, the same as from the gross method.

Discounted cash flow methods

Rate of return and payback period calculations, described in the previous subsections, provide a good starting point for appraising an investment, but they ignore what is often termed the *time value of money*.

If you were offered the choice of accepting £100 now or in one year's time, you would almost certainly take the money now to spend and enjoy the proceeds or perhaps invest and earn some interest. In contrast, if the choice were between £100 now and £200 in a year's time you might well decide that it is better to wait and get the higher sum – assuming that you are confident the offer will still stand in a year and that you don't have an urgent need for the money now. But if the choice were between £100 now and £110 or maybe £120 in a year's time, the situation is less clear-cut.

Organisations have to take decisions like this one all the time and one way of making the decision is to look at the interest rate that could be earned on the money. Suppose that the interest rate on a savings account offered by a reliable and trustworthy bank is 3%.

Investing the £100 for one year would give

If the £103 is reinvested for a further year the result would be

You may recognise this processing as compounding. Calculating compound interest has the following general formula

where

P = the initial amount invested (the principal)

r = the percentage interest rate

n = the number of years.

Or in financial language you can say that if the interest rate is 3% the *future value* of £100 in one year is £103 and in two years is approximately £106, and so on.

The converse of this is known as the *present value* (PV) and, rearranging the above formula, the present value of £P in n years' time is given by

Activity 6 Present value

Allow 15 minutes to complete this activity

What is the present value of £215 in three years' time if the interest rate is 5%?

Answer

Using the above equation for the present value

Table 3 shows the present value of £1 receivable at the end of each year for periods ranging from 0 to 30 years and interest rates ranging from 0 to 10%. If you have access to a spreadsheet package, you might find it interesting to recreate this table yourself.

Table 3 Present values of £1

Time (years)	**Interest rate (%)**									
	1	2	3	4	5	6	7	8	9	10
1	0.990	0.980	0.971	0.962	0.952	0.943	0.935	0.926	0.917	0.909
2	0.980	0.961	0.943	0.925	0.907	0.890	0.873	0.857	0.842	0.826
3	0.971	0.942	0.915	0.889	0.864	0.840	0.816	0.794	0.772	0.751
4	0.961	0.924	0.888	0.855	0.823	0.792	0.763	0.735	0.708	0.683
5	0.951	0.906	0.863	0.822	0.784	0.747	0.713	0.681	0.650	0.621
6	0.942	0.888	0.837	0.790	0.746	0.705	0.666	0.630	0.596	0.564
7	0.933	0.871	0.813	0.760	0.711	0.665	0.623	0.583	0.547	0.513
8	0.923	0.853	0.789	0.731	0.677	0.627	0.582	0.540	0.502	0.467
9	0.914	0.837	0.766	0.703	0.645	0.592	0.544	0.500	0.460	0.424
10	0.905	0.820	0.744	0.676	0.614	0.558	0.508	0.463	0.422	0.386
11	0.896	0.804	0.722	0.650	0.585	0.527	0.475	0.429	0.388	0.350
12	0.887	0.788	0.701	0.625	0.557	0.497	0.444	0.397	0.356	0.319
13	0.879	0.773	0.681	0.601	0.530	0.469	0.415	0.368	0.326	0.290
14	0.870	0.758	0.661	0.577	0.505	0.442	0.388	0.340	0.299	0.263
15	0.861	0.743	0.642	0.555	0.481	0.417	0.362	0.315	0.275	0.239
16	0.853	0.728	0.623	0.534	0.458	0.394	0.339	0.292	0.252	0.218
17	0.844	0.714	0.605	0.513	0.436	0.371	0.317	0.270	0.231	0.198
18	0.836	0.700	0.587	0.494	0.416	0.350	0.296	0.250	0.212	0.180
19	0.828	0.686	0.570	0.475	0.396	0.331	0.277	0.232	0.194	0.164
20	0.820	0.673	0.554	0.456	0.377	0.312	0.258	0.215	0.178	0.149
21	0.811	0.660	0.538	0.439	0.359	0.294	0.242	0.199	0.164	0.135

22	0.803	0.647	0.522	0.422	0.342	0.278	0.226	0.184	0.150	0.123
23	0.795	0.634	0.507	0.406	0.326	0.262	0.211	0.170	0.138	0.112
24	0.788	0.622	0.492	0.390	0.310	0.247	0.197	0.158	0.126	0.102
25	0.780	0.610	0.478	0.375	0.295	0.233	0.184	0.146	0.116	0.092
26	0.772	0.598	0.464	0.361	0.281	0.220	0.172	0.135	0.106	0.084
27	0.764	0.586	0.450	0.347	0.268	0.207	0.161	0.125	0.098	0.076
28	0.757	0.574	0.437	0.333	0.255	0.196	0.150	0.116	0.090	0.069
29	0.749	0.563	0.424	0.321	0.243	0.185	0.141	0.107	0.082	0.063
30	0.742	0.552	0.412	0.308	0.231	0.174	0.131	0.099	0.075	0.057

The principles of discounted cash flow (DCF) allow possible investments to be reviewed by using the table of present values (Table 3), or discount factors as they are also known, to determine the time in a project's life when payments are made and when income is earned. The term *discount rates* is used rather than interest rates. You can think of the discount rate as being the rate of return or profit that a project will make. In general you can assume that a project will not go ahead if investing in it, which carries some risk, is estimated to give a lower rate of return than investing the money in a secure bank account.

The use of discounted cash flow is best illustrated by means of a worked example, as demonstrated in Activity 7.

Activity 7 Discounted cash flow

Allow 25 minutes to complete this activity

A landfill site operator is considering installing an engine to generate power by burning landfill gas. It is estimated that the capital cost of the engine, generator, control equipment and connections to the grid will be £1000 000. The annual staffing, operating and maintenance costs will be £300 000. The annual income from the sale of power will be £315 000 in the first year and £630 000 in each following year. The capital costs have to be paid at the start of the project and the total project life is expected to be 5 years. If company policy states that a rate of return of 5% must be achieved, is the project worth pursuing?

Answer

The first stage in the process involves drawing up a cash flow statement. In the example, this is relatively straightforward. However you should appreciate that because I have said that the capital investment takes place at the start of the project, its present and future values are the same. This is indicated by placing this expenditure in year 0 – more complex projects will involve staged payments over more than one year. I have also assumed that the income starts to arrive in year 1.

The cash flow statement is shown in Table 4.

Table 4 Cash flow statement (all money values in £000s)

Year	0	1	2	3	4	5	Total
Capital cost	–1000						–1000
Operating cost		–300	–300	–300	–300	–300	–1500

Income		315	630	630	630	630	2835
Net cash flow	–1000	15	330	330	330	330	335

The next stage is to adjust the net cash flow in each year by multiplying it by the appropriate discount factor. This is shown in Table 5 for a discount rate of 5% (with the values taken from Table 3).

Table 5 Discounted cash flow (all money values in £000s)

Year	**0**	**1**	**2**	**3**	**4**	**5**	**Total**
Capital cost	–1000						–1000
Operating cost		–300	–300	–300	–300	–300	–1500
Income		315	630	630	630	630	2835
Net cash flow	–1000	15	330	330	330	330	335
Discount factor	1.00	0.952	0.907	0.864	0.823	0.784	
Discounted cash flow	–1000	14.28	299.31	285.12	271.59	258.72	129.02

The final cell in the right-hand column (£129 020) represents the net present value (NPV) of the project. This is positive, so the project has met the target rate of return of 5%.

It is often useful to calculate the rate of return of a project, which is represented by the discount rate that achieves an NPV of zero. Again, this is something you might want to try if you have access to a spreadsheet. If you do so, you will find that the NPVs of 8% and 9% are £25 928 and –£5406 respectively, so the rate of return is somewhere between 8% and 9%. If you use a 'goal seek' function on a spreadsheet, you will find that the rate of return is 8.82%.

In principle all DCF calculations can be performed in this way, but it can get long-winded for projects with long lifetimes, such as a reservoir or road. If it is clear that a cash flow will occur over a long period, it is possible to sum the discount factors and multiply this sum by the cash flow.

Example 1

What is the present value of £300 000 received annually for a period of 5 years if the discount rate is 4%? Use Table 3 to look up the discount factors.

Table 6 shows the present value of £1 received annually for different time periods.

Table 6 Present value of £1 received annually

Time (years)	**Interest rate (%)**									
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
1	0.990	0.980	0.971	0.962	0.952	0.943	0.935	0.926	0.917	0.909
2	1.970	1.942	1.913	1.886	1.859	1.833	1.808	1.783	1.759	1.736

3	2.941	2.884	2.829	2.775	2.723	2.673	2.624	2.577	2.531	2.487
4	3.902	3.808	3.717	3.630	3.546	3.465	3.387	3.312	3.240	3.170
5	4.853	4.713	4.580	4.452	4.329	4.212	4.100	3.993	3.890	3.791
6	5.795	5.601	5.417	5.242	5.076	4.917	4.767	4.623	4.486	4.355
7	6.728	6.472	6.230	6.002	5.786	5.582	5.389	5.206	5.033	4.868
8	7.652	7.325	7.020	6.733	6.463	6.210	5.971	5.747	5.535	5.335
9	8.566	8.162	7.786	7.435	7.108	6.802	6.515	6.247	5.995	5.759
10	9.471	8.983	8.530	8.111	7.722	7.360	7.024	6.710	6.418	6.145
11	10.368	9.787	9.253	8.760	8.306	7.887	7.499	7.139	6.805	6.495
12	11.255	10.575	9.954	9.385	8.863	8.384	7.943	7.536	7.161	6.814
13	12.134	11.348	10.635	9.986	9.394	8.853	8.358	7.904	7.487	7.103
14	13.004	12.106	11.296	10.563	9.899	9.295	8.745	8.244	7.786	7.367
15	13.865	12.849	11.938	11.118	10.380	9.712	9.108	8.559	8.061	7.606
16	14.718	13.578	12.561	11.652	10.838	10.106	9.447	8.851	8.313	7.824
17	15.562	14.292	13.166	12.166	11.274	10.477	9.763	9.122	8.544	8.022
18	16.398	14.992	13.754	12.659	11.690	10.828	10.059	9.372	8.756	8.201
19	17.226	15.678	14.324	13.134	12.085	11.158	10.336	9.604	8.950	8.365
20	18.046	16.351	14.887	13.590	12.462	11.470	10.594	9.818	9.129	8.514
21	18.857	17.011	15.415	14.029	12.821	11.764	10.836	10.017	9.292	8.649
22	19.660	17.658	15.937	14.451	13.163	12.042	11.061	10.201	9.442	8.772
23	20.456	18.292	16.444	14.857	13.489	12.303	11.272	10.371	9.580	8.883
24	21.243	18.914	16.936	15.247	13.799	12.550	11.469	10.529	9.707	8.985
25	22.023	19.523	17.413	15.622	14.094	12.783	11.654	10.675	9.823	9.077
30	25.808	22.396	19.600	17.292	15.372	13.765	12.409	11.258	10.274	9.427
35	29.409	24.999	21.487	18.665	16.374	14.498	12.948	11.655	10.567	9.644
40	32.835	27.355	23.115	19.793	17.159	15.046	13.332	11.925	10.757	9.779

Example 2

A water supply company is proposing to construct a reservoir on a river at point X at a cost of £5.86 million. No further increment in water storage would be needed for 29 years. It has been suggested that three smaller reservoirs costing £3.25 million, £3.60 million and £4.33 million would be financially and environmentally preferable. However this scheme would require the construction of the second reservoir after 13 years and the third 9 years later. Investigate the financial aspects of the two alternatives for discount rates of 6% and 8%. Assume that the cash to build the first reservoir is required in year 0, the cash for the second is required in year 13, and in year 22 for the third reservoir.

Answer

The capital costs of the first scheme are all met at the present time, so the present value is £5.86 million for both rates of return.

In the case of the second scheme at a rate of 6% the present value is given by giving the total as

Therefore, the one-reservoir scheme is the more financially attractive.

At a rate of 8% the PV of the second scheme is given by

giving the total as

At 8% the three-reservoir alternative is preferable, even though the total capital cost is almost twice as great as the single-reservoir scheme. Looked at in another way, if the difference between the cost of the larger and the first-stage reservoir (£5.86m – £3.25m = £2.61m) were to be invested at 8% (say), by the time the second reservoir had to be built the amount available (£6.58m) would be more than sufficient to meet the cost of £3.6m, and the accrued surplus again invested would likewise be more than sufficient to meet the cost of the last reservoir (in fact £5.96m would be available).

2 External costs

> They hang the man and flog the woman,
>
> Who steals the goose from off the common,
>
> Yet let the greater villain loose,
>
> That steals the common from off the goose.

This widely used traditional quotation is generally thought to have arisen in seventeenth-century England at a time when parliament was passing Acts that allowed landowners to enclose common land for their own use. This practice led to many people losing their rights to cultivate land, graze their livestock and take wood for fuel use. In effect these families lost their livelihood.

Moving to the present day, 'the commons' has a wider meaning for environmental specialists. It refers to any resource held in common for the use or benefit of society as a whole such as air, water, land and eco-systems. In the modern context, the above quotation suggests that the commons can be degraded or removed at no cost to the person or organisation causing the damage.

Activity 8 Sustainable resource management

Allow 20 minutes to complete this activity

Take a few moments to write down some commons in the context of sustainable resource management.

Answer

Your list will no doubt reflect your own concerns about the environment, but the commons that I am most concerned about at present are:

- the global atmosphere and the build-up of carbon dioxide and other greenhouse gases
- the local atmosphere and vehicle exhaust fumes in the high street of the town where I live
- the depletion of fish stocks
- the possible loss of the green belt (an area of undeveloped land separating my town from the neighbouring towns)
- depletion of fossil fuels.

This is quite a wide-ranging list covering global and local issues, different environmental media (land, air and water), quantifiable areas such as local atmospheric levels of oxides of nitrogen (NOx) and less quantifiable issues such as the loss of green-belt land.

In conventional economics, the cost of damage to the commons is neglected when compiling balance sheets, profit and loss accounts and financial statements. The cost of producing a good or providing a service is calculated by summing the costs of raw materials, energy, labour and other direct and indirect costs. These costs are known as the *private costs*.

It can be argued that, to calculate the true cost of an activity to society as a whole, costs should be apportioned to any damage caused to the commons and these damage costs should be taken into account. In this context, the commons could include people's health, the general environment, buildings and crops. These damage costs are often referred to as *external costs* (or *externalities*). The discipline of environmental economics involves determining the level of these external costs and using economic instruments to make organisations and individuals liable for the external costs that they generate. Considering external costs raises significant questions such as:

- How should the commons be valued?
- Who should receive any payments made for causing damage to the commons?
- What should ultimately happen to such payments?

In this activity, you will look at the first of these questions.

Activity 9 How should the commons be valued?

Allow 20 minutes to complete this activity

You have probably realised that quantifying these external costs is a highly complex subject. Spend a few minutes thinking about the examples that follow and then write down some of the problems in determining the external costs and how you would set about determining their correct level in each case:

(a) the **emission** of carbon dioxide and other greenhouse gases from power generation
(b) the emission of arsenic (which is carcinogenic) from a metal-refining plant
(c) the extinction of a particular species of butterfly due to farm pesticide use.

Answer

(a) Greenhouse gas emissions

Much of the problem lies with determining who is affected by the damage and who should be compensated. For example, in the case of emissions from a fossil fuel power station in central USA should damage to the local community only be considered, or should rising sea levels that affect communities in (say) Asia be taken into account?

If this question can be solved there are several ways of determining costs such as:

- equating the damage cost to the cost of capturing and storing the carbon dioxide generated
- equating a given emission to a given rise in sea level and setting the cost equal to the cost of dealing with that rise through sea defences
- estimating the global loss of life due to temperature and sea level rises and allocating a sum to each life lost.

(b) Arsenic emissions

In this case, the impacts will be generally felt in the local environment, but several questions still arise:

- What value should be put on each fatal and non-fatal **cancer**?
- Should this value be different for younger and older people?
- How are cancers with long latency periods dealt with? (Should cancers caused now and in 20 years' time have different values?)
- Is just the cost to the health service of treating each cancer considered or is a sum added to cover the loss of earnings of the victim, or is an additional sum included to attempt to compensate society for the loss of or harm to one of its members?
- Are employees at the plant treated differently from non-employees? It could be argued that the former have some choice in their decision to become exposed.

(c) Species extinction

This is an even more problematic area. On one hand, it could be argued that a species has no intrinsic value and therefore there should be no external cost. On the other hand, imagine a species of butterfly that pollinates a particular plant that forms part of a chain that has some ultimate value to humankind. In this case, it could be reasonable to allocate a value to the butterfly. Alternatively it is possible to take a less anthropocentric view and argue that the loss of any species devalues the planet as a whole and some level of compensation is appropriate.

2.1 Determining external costs

A detailed method for determining the external costs of energy production processes was developed by the ExternE project, funded by the European Union (EU), which began work in 1991. Although still concentrating on energy production, the ExternE methodology has since been used for transport, waste management and several industrial processes. If you want to know more about the ExternE method, a number of articles are available on the ExternE website at http://www.externe.info/

2.2 External cost assessment of the European incineration directive

Under a directive of 1989, limits were placed on the atmospheric emissions from municipal waste incinerators operating within the EU (European Commission, 1989). In 1994 a draft directive was published which suggested, among other measures, tightening the emission limits. A selection of the 1989 limits and 1994 proposals are summarised in Table 7. Limits were also set for **heavy metals** but the combination of metals was different in the two directives.

Table 7 EU municipal waste incineration limits

Pollutant	**1989 limit** (mg m^{-3} seven-day average)	**Proposed 1994 limit** (mg m^{-3} 24-hour average) (ng m^{-3} for dioxins)
Dust	30	10
Organic carbon	20	10
Carbon monoxide	10	50
Dioxins	*	0.1
HCl	50	10
HF	2	1
SO_2	300	50
NOx	–	200
NH_3	–	10

The UK's Energy Technology Support Unit was asked by the European Commission to assess the costs and benefits of the proposed changes (Brown, 1996). Determining the private costs of the measure is beyond the **scope** of this course, but quantifying the externalities provides an interesting example of the use of this tool.

The assessment was based on the ExternE methodology, which can be summarised as:

- determining the emissions
- using dispersion modelling tools to determine the exposure to potential receptors
- evaluating the uptake pathways by receptors (for human exposure)
- using the dose–response function to assess the **damage** caused
- valuing the damage caused.

The emissions were calculated for a range of incinerator sizes fitted with several pollutant abatement systems. All the systems met the requirements of the directive, but the spread of technologies allowed comparisons between the systems common in different countries.

The dispersion modelling used standard atmospheric dispersion models that took account of both local (less than 50 km from the source) and long-range (more than 50 km from the source) receptors. As explained by Friedrich et al. (2001) the longer-range dispersion allowed the formation of secondary pollutants such as sulfate and nitrate aerosols and ozone to be covered.

The number of receptors affected by the pollutants depends on the height of the discharge and the number of people in the area. This was taken into account by considering three discharge heights (50 m, 90 m and 100 m) and three specific areas within the EU (Paris, Stuttgart and Birmingham).

When modelling the uptake, the ExternE approach was adopted of assuming that for macro-pollutants, such as sulfur dioxide (SO_2) and oxides of nitrogen (NOx), exposure is all due to inhalation. For micro-pollutants such as heavy metals and dioxins, multiple pathways must be taken into account. These pathways are summarised in Figure 1.1. In both cases, ExternE models were used to estimate the uptake of most substances and models from the US Environmental Protection Agency (USEPA) and the World Health Organization (WHO) were used for dioxins and mercury.

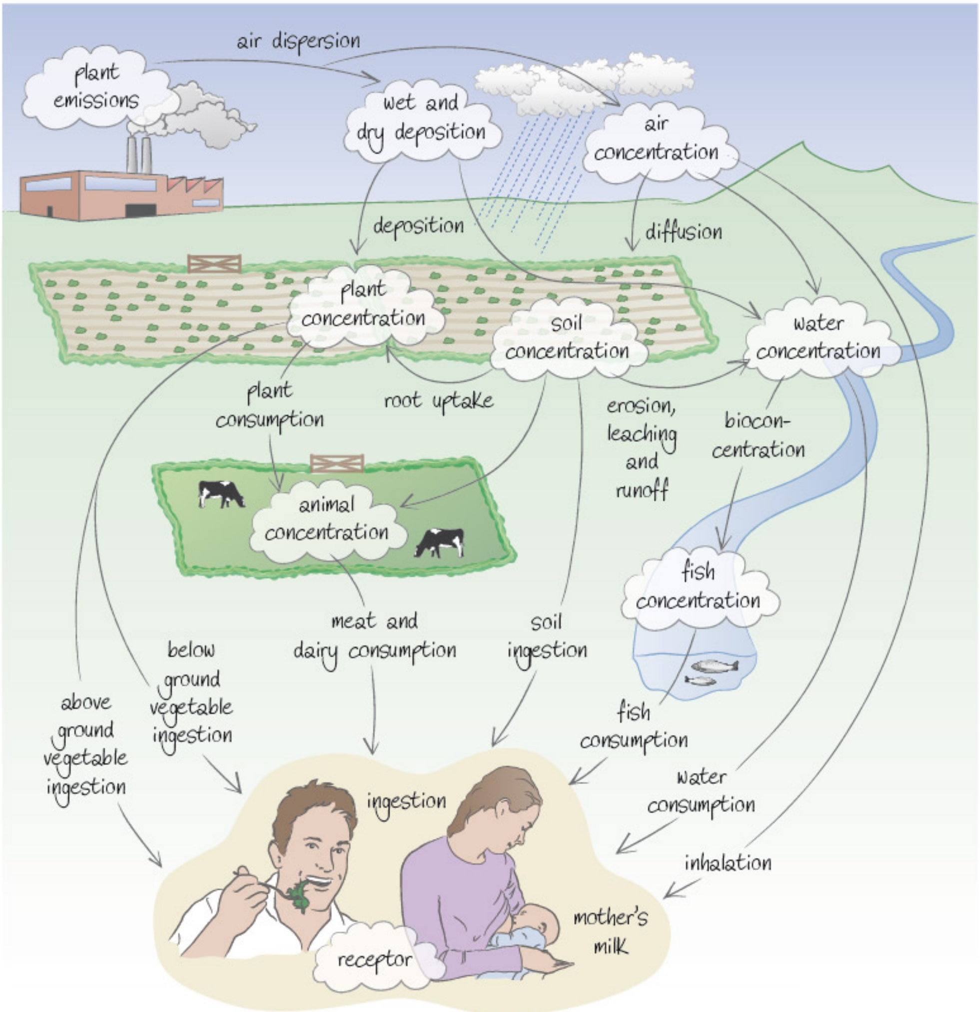

Figure 1 Micro-pollutant uptake pathways

Once the doses were established, the ExternE methodology was used to determine the damage caused.

Valuation of the impacts was based on willingness to pay. In the case of mortality, it is important to stress that the sum does not represent the value of a life, which is priceless, but people's willingness to pay for a reduction in the risk of death. This willingness is based on research using opinion surveys and monitoring expenditure on items such as nicotine patches among smokers and purchase of cars with airbags (when airbags were an optional extra rather than a standard fitting).

Results

The results in terms of damage cost per tonne of each pollutant emitted are shown in Table 8 for Stuttgart and a 90 m discharge height; the values for Paris are higher and those for Birmingham are lower due to differences in the exposed populations. Not surprisingly dioxins and heavy metals result in the highest damage costs and health impacts are far more important than building damage.

Table 8 Damage cost per tonne emitted

Pollutant	Impact	Damage cost (€ per tonne)
Dioxins	health	2.43×10^9
Cadmium	health	1.04×10^6
Arsenic	health	1.27×10^6
Chromium	health	1.05×10^6
Nickel	health	2.14×10^4
Particulate matter	health	147 500
Oxides of nitrogen	health	63 248
Sulfur dioxide	health	27 494
Ozone	health and crops	5 060
Sulfur dioxide	buildings	614
Oxides of nitrogen	buildings	307

Source: Brown (1996, pp. 5–17)

Burning a tonne of waste releases different quantities of each pollutant so a more useful value is the damage caused per tonne of waste burned and this is shown in Figure 2. The range of values represents the different pollution abatement systems considered.

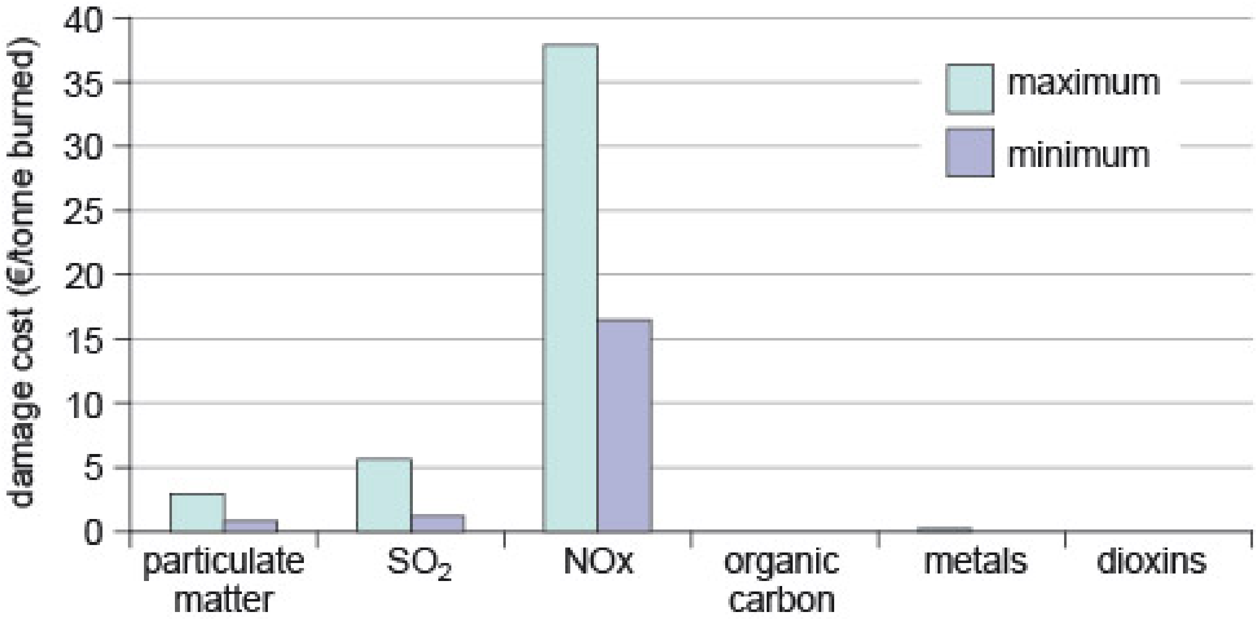

Figure 2 Range of damage costs (€ per tonne burned)

Adapted from Brown, 1996, pp. 5–18

Figure 2 demonstrates the, possibly counter-intuitive, result that oxides of nitrogen are by far the most significant pollutant and that dioxins, although they have a much higher profile, have no detectable damage costs.

2.3 Using external costs

Figure 2 suggests that the external cost of municipal waste incineration is somewhere in the range of €17 to €40 per tonne burned.

Activity 10 National policies

Allow 15 minutes to complete this activity

What could a government do with the information in Figure 2?

Answer

Firstly, a government could use the information as a basis to introduce an incineration tax to ‘correct’ this market failure. However, if it was not coupled with similar taxes on other waste disposal methods, it would distort the waste disposal market by, for example, encouraging more landfill.

Secondly, the information could be used with data on the cost of abating NOx emissions to establish the economically optimum **emission** limit.

Finally, it could be used to justify research and **development** into improved and lower-cost methods for abating NOx.

Command and control

Command and control uses laws and regulations to prohibit or restrict undesirable practices. For example, under the terms of the USA's Clean Air Acts, the operators of specified industrial processes are obliged to apply the principal of maximum achievable control technology (MACT) to control pollution. A series of standards document what MACT represents for each industry and, in effect, set the emission limits.

Other command-and-control measures include the EU's incineration **directive**, phasing out of CFCs (chlorofluorocarbons) in many countries through bans on their use, the banning of leaded petrol and the requirement for cars to be fitted with catalytic converters in many developed countries.

The principal advantage of a regulatory approach is that, provided that it is properly implemented, the reduction in pollution in a given country or area can be predicted accurately. Also, properly policed regulations cannot be avoided; there is no scope for an organisation or individual to take the attitude 'I can afford to so I'll continue to pollute'.

Economic instruments

Economic instruments are market-based incentives such as taxes and subsidies to encourage behaviour change. Examples include:

- *Carbon taxes*. India introduced a coal tax (in effect a carbon tax) of 50 rupees (€0.74 at October 2011 rates) for every tonne of coal extracted or imported into the country. The intention is that the tax revenues will be used to fund clean-energy projects.
- *Sales tax reductions*. The state of Arkansas, USA, exempts pollution control equipment from its sales tax (the equivalent of VAT).
- *Tax on polluting substances*. Arizona has a surcharge on environmentally hazardous substances with the revenues raised being used to fund environmental improvement projects.

Proponents of economic instruments claim that they have the following advantages over regulations:

- They provide an incentive to go beyond the bare minimum that a regulation may specify.
- Organisations can respond flexibly to measures and use the most cost-effective method of reducing pollution – although this also applies to regulations if they specify the end rather than the means.
- They can raise revenue through taxes for investment elsewhere.
- They are cheaper to administer and enforce than emission-limit-based regulations.
- They can be fairer in that a prescribed emission limit may be cheaper per unit of output for a large generator to achieve than a smaller operation. However an emissions tax would allow both firms to optimise the trade-off between abatement costs and tax payments.

Whichever approach a government uses – and most governments will use a combination of regulations and economic instruments – methods similar to those mentioned in this subsection can be used to determine a justifiable level of tax or subsidy, or establish an optimum emission limit for a given pollutant.

Activity 11 External costs

Allow 15 minutes to complete this activity

In 1993 a study for the UK government estimated that the external costs of the atmospheric and water pollution resulting from the landfilling of waste were in the range –£0.80 to £9.02 per tonne – a negative value represents a benefit to the environment. When a landfill tax was introduced in 1996 it was set at £7.00 per tonne; by 2015 it had reached £82.60 per tonne. Why is the tax so much higher than the external costs?

Answer

The tax is intended to encourage business and local authorities to change their behaviour. It provides an incentive to reduce waste generation and to use more sustainable waste management methods such as **recycling**, composting and energy recovery. If the landfill tax was set at £9 per tonne, landfill would still be far cheaper than these environmentally better management processes.

Also, the estimated external costs didn't include the material **resources** that would be 'lost' from the economy through landfilling.

Carbon taxes

One use of external costs that has been discussed in many countries and implemented in some is a carbon tax. The principle is that the tax would encourage the development of low-carbon energy sources – which are often more costly than fossil fuel sources – while generating funds that could be used to either mitigate the impacts of climate change or subsidise low-carbon fuels.

Conclusion

This free course, *Financial methods in environmental decisions* has introduced some of the tools that can be used to assess the benefits of investment decisions. The business case for any environmental expenditure has always to be justified using a range of financial assessments. At the organisation level, tools such as payback periods and discounted cash flow allow the short-term and long-term financial implications of a measure to be assessed.

Externalities is a way of evaluating the costs to society as a whole by placing monetary values on environmental impacts. This tool is used by governments in the formulation of regulations and in setting environmental taxes and subsidies.

This OpenLearn course is an adapted extract from the Open University course T867 *Managing for sustainability*.

Glossary

Cancer

The disease which results from the development of a malignant tumour and its spread into surrounding tissues.

Carbon dioxide

A heavy, colourless gas that does not support combustion. It dissolves in water to form carbonic acid. Carbon dioxide contributes about 60% of the potential global warming effect of anthropogenic emissions of greenhouse gases. Although this gas is naturally emitted by living organisms, these emissions are offset by the uptake of carbon dioxide by plants during photosynthesis; they therefore tend to have no net effect on atmospheric concentrations. The burning of fossil fuels, however, releases carbon dioxide fixed by plants many millions of years ago, and thus increases its concentration in the atmosphere.

Consequences

The effects (or impacts) of a particular situation, action or event. Impacts may be positive (benefits) or negative (costs, or harms). Risk assessments usually focus on assessing the potential negative consequences (the harm) that may result from the realisation of identified hazards

Damage

A loss of inherent quality suffered by an entity.

Development

A process of economic and social transformation that is not easily defined. While often viewed as a strictly economic process involving growth and diversification of a country's economy, development is a qualitative concept that entails complex social, cultural and environmental changes.

Directive

A European Union legal instrument identifying an outcome binding on all member states, but leaving the method of implementation to national governments through national legislation.

Emission

One or more substances released to the water, air or soil in the natural environment. Compare environmental release, pollution and environmental intervention.

Heavy metals

A collective term used for metals with the potential to cause harm when they are released into the environment. Typically it includes mercury, lead and cadmium, as well as zinc, chromium and certain other metals with wide industrial use and potential toxic effects.

Impact

See Consequences.

Particulate matter

Generally used for solid particles (dust) emitted from processes and dispersed in the atmosphere. The term can also include liquid droplets.

Recycling

Re-processing waste or scrap materials for the production of new goods or services on the same quality level. If the quality of the goods and services produced with recycled material is lower, then the process has been called downcycling. cf. Closed-loop recycling and Open-loop recycling.

Resources

Materials found in the environment that can be extracted from the environment in an economic process. There are abiotic resources (non-renewable) and biotic resources (renewable).

Scope

The agreed boundaries of a risk assessment and the risks to be assessed within those boundaries.

Shareholders

Any person or organisation that holds shares in a company.

System

A collection of operations that perform a desired function.

Valuation

The process of weighting characterised environmental interventions against each other in a quantitative and/or qualitative way. This process results in an environmental performance index.

Water

Water consists of two hydrogen atoms and one oxygen atom (H2O). Water, which covers three-quarters of the Earth's surface, and accounts for over 60% of its mass, regenerates and redistributes through evaporation and other atmospheric processes. Water vapour absorbs about 17% of solar radiation in the troposphere, thus making it one of the two principal greenhouse gases. Of the solar energy absorbed by the Earth's surface a little more than half goes into latent heat, which is heat absorbed by water because of its transformation from a liquid to a vapour. When these molecules condense back into a liquid, usually higher in the atmosphere, they release that energy back into the atmosphere as local warming.

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Friedrich R., Rabl A. and Spadaro J. (2001) 'Quantifying the costs of air pollution: the ExterneE project of the EC', *Pollution atmosphérique*, Dec 2001, pp. 77–104.

Acknowledgements

This free course was written by Stephen Burnley

Figures

Figure 1: © The Open University

Figure 2: Brown, 1996

Table 8: Brown, 1996

Course image: Ale-ks/iStockphoto.com

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