Guideline Costs of Adaptation Measures

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Climate Proof Cities Consortium

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Contents

1. Why this guideline?

The Climate Proof Cities project aims to provide information to enable local policy makers to prepare strategies to adapt their cities to future climate change. The knowledge that we provide includes tools for understanding the sensitivity and vulnerability of various parts of their cities, the options they have for adapting to a changing climate and insights in possible instruments to implement the adaptation measures and strategies.

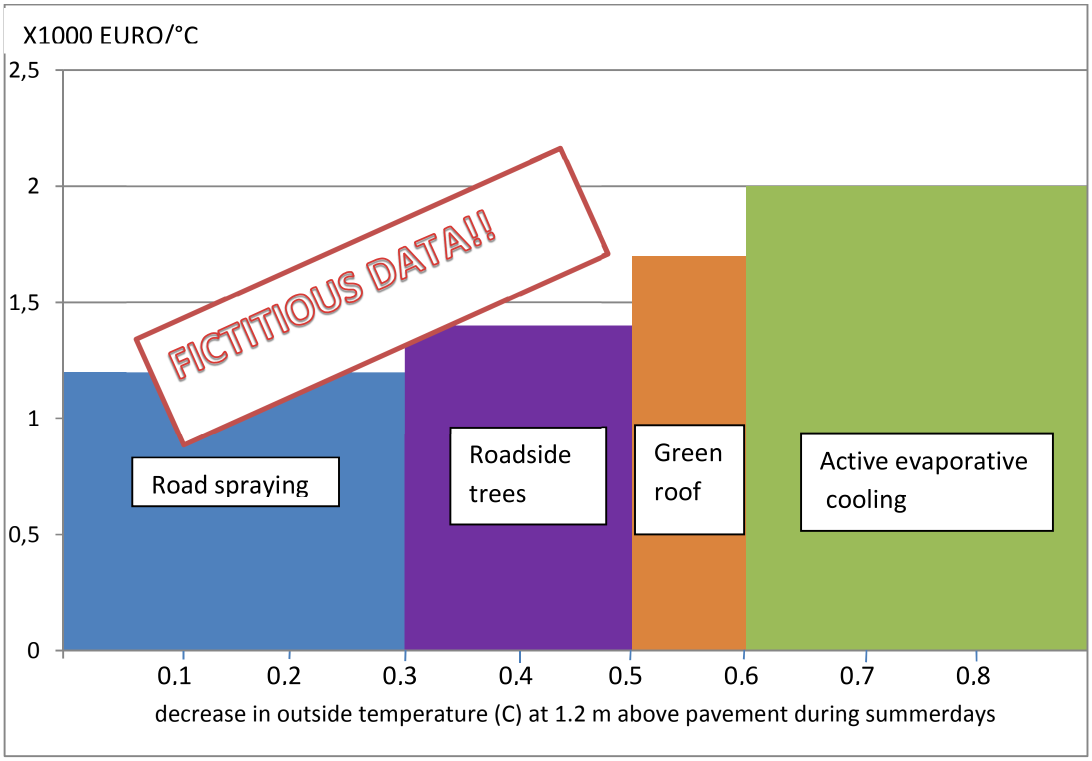
Various projects in CPC workpackage 3 aim at providing better knowledge on various options for adaptation, ranging from building to regional scale, ranging from relatively cheap measures like spraying the roads with water to relatively expensive green and blue infrastructures. The stakeholders in the CPC programme, such as local authorities, waterboards and other decision makers, will use CPC information to develop adaptation strategies for their municipality, city district or water management area. An important criterion in selecting possible adaptation measures is the cost effectiveness. To express it in the words of Jos Streng (CPC contact person in Rotterdam): How much adaptation can I get for my Euro?

Information on the effect of adaptation options alone is not enough to answer the policy maker's question on the efficiency of implementing one or another adaptation measure. In order to support our users in considering possible adaptation measures, CPC researchers thus should not only focus on the effect and effectiveness of the adaptation measures that they are considering, but also need to include at least a rough estimate of the cost of every measure described. This guideline explains for non-economists the key elements of calculations on the cost of adaptation measures. It also provides a guideline for a proper and systematic documentation of the steps that you have taken in costs calculations. If this guideline is followed, your results will be replicable and can be used again by researchers in other projects.

The diagram below illustrates the answer to Jos Streng that we are trying to construct: We would like to be able to arrange various adaptation measures according to their costs. With this information the user can get a first impression of the extent of adaptation measures that would be needed to reach a certain level of adaptation and of the costs that would be involved. Climate adaptation is in reality far more complicated than we can illustrate in one single graph, and probably many graphs will be needed, but nevertheless we should strive to provide the best possible information to support policy.

In short: estimating and documenting costs of adaptation measures is necessary for an appropriate support to the design of adaptation strategies. Your articles/reports will be taken seriously in scientific and policy circles if they are completed with data on the costs of adaptation options.

Figure 1: Fictitious example illustrating a cost curve for adaptation measures.



2. General background for determining costs and cost efficiency of adaptation measures

Deciding on the implementation of adaptation measures requires that (at least) two sides of the options are considered. Adaptation measures have a positive effect on current and future climate (heat , flooding, drought) and that is why we are considering them in the first place, but their implementation has also a cost.

Depending on the type of measures different "costs" are relevant: When a measure is installed for a period of many years the initial costs are called *investment expenditures*[1]. For the sake of comparison these are often recalculated into annual *capital costs* (explained in Chapter 5). Next to the costs of installing an adaptation measure, costs need to be made to let it function over the years. These are called *operating and maintenance costs*. The sum of capital costs and operating and maintenance costs per year is useful for comparing the costs of various adaptation options.

To compare the physical effectiveness of different adaptation options, conventions are needed on common units to present the effect. In this guideline we will not go into this problem: a separate guideline will be developed to improve the comparability of the effectiveness of adaptation options.

The current guideline thus deals with calculating and documenting the costs of individual adaptation options. The expected use of the cost information determines the effort that is invested in gathering the data. In principle very detailed cost estimates are possible (and this guideline gives a first insight into detailed categories and calculations). However, with a minimum investment often a good amount of relevant information can be gathered. Within CPC we should be able to compare adaptation options for use in city adaptation strategies: that means a general, not very detailed, comparison.

It is difficult to provide a guideline for the minimum effort to be invested in gathering cost data, as this depends to a high degree on the nature of the measures themselves. Important is the uncertainty involved in statements on the possible effects of adaptation measures. When uncertainty on effects is high, it does not make sense to invest much time in gathering very precise costs estimates. To clarify nevertheless the risk involved in the investment it can be helpful to indicate the margins of the estimate. However, when we are able to precisely determine , for instance, the retention of rainwater by different types of green roofs, then it makes sense to have a detailed comparison of the costs of these roofs types.

[1] terms in italics are explained in the glossary at the end of this document

3. Calculating and describing costs of an adaptation measure

3.1. Identification of the effectiveness domain of the measure

To ensure that users and other researchers can relate your data with other studies, it is important that the adaptation measure considered is described properly. When adaptation options have been defined differently, a straight comparison of their cost data does not make sense. One of the first characteristics of an adaptation measure is its aim: what problem is it addressing and in which circumstances? Therefore a first guideline is:
Describe always as precisely as possible the domain the measure is addressing. A minimal separation in categories is:

- heat,
- urban flooding,
- drought.

More information should be provided wherever possible, outlining the spatial domain of the measure (for instance overheating within buildings, or on street level) , the time domain of the measure (for instance overheating at night or at daytime hours) and other aspects (such as, "in case of extreme flooding events").
For classification purposes it might be relevant to add reference to a typology of adaptation measures, e.g, the distinction in threshold capacity/coping capacity/recovery capacity (CPC, 2011).

3.2. Identification of the measure

Sufficient detail on the adaptation measure should be given to avoid ambiguity, to define the performance characteristics and to clarify special circumstances limiting applicability of the measure.

3.2.1. Description of the adaptation measure

Describe the measure paying attention to technical details of importance for the effectiveness (for instance the thickness of the various layers constituting a green roof, the type and height of vegetation, the age and density of the vegetation).

Example: The roof spray system consists of PVC tubes mounted on wooden blocks forming a square grid with 10 meter distance between the tubes, with on every five meters a spray nozzle connected directly to the tubes. With a controller linked to a thermometer spray time and intervals between sprays can be regulated.

3.2.2. Performance characteristics of an adaptation measure

The effectiveness of a given adaptation measure should be stated for the domain under consideration, as well as the operating conditions. Reasons for any limitations or enhancements of performance should be stated.

Examples:

This commercially produced active evaporative cooling system achieves, according to the industry, a temperature difference in heat wave situations (T 28,5°C, RF 58%) of 8,2°C between in and outgoing air. At RF values between 30 and 60%, the energy saving is 50% compared to a traditional air conditioning of the same capacity.

The effectiveness of green roof type A with regard to rainwater retention is 52% if the green roof is installed on top of a flat roof for rainshowers of 6-10 mm/hr. See table XX for retention rates by various roof angles and rainshower intensities.

3.2.3. Lifetime of the measure

The anticipated technical lifetime of a measure should be stated. If applicable, state the time before the measure will be fully effective (e.g. in the case of planting trees).

3.2.4. Side effects

Any side effects of the measure should at least be described, and ideally quantified.

Example: Green facades area able to collect particulate matter from the air (Ottelé, 2011); an effect of green facades on PM concentrations in ambient air has not been demonstrated yet, however.

In stating the side effects of vegetation on the concentration of particulate matter or other pollutants, be aware of diverging views in the literature.

3.3. Describing the costs of an adaptation measure

3.3.1. Cost components

Installing an adaptation measure in most cases involves costs. The most simple division of these costs is into:

- Investment expenditure: the total expenditure for all materials, installations, land, plants, etc. at the start of the life time of the adaptation measure that will last for a longer period (a year or more);
- Operating and maintenance costs: the costs of energy, water, materials and services that are needed to operate and maintain the adaptation measure during its lifetime. Usually these cost are given per year.

In your study, you should explicitly state which cost components have been included in the reported cost data.

1. As a minimum, the total investment expenditure and total annual operating/maintenance costs should be reported separately.
2. Annual operating and maintenance costs should be split between energy, water, other materials and services, labour, and fixed operating/maintenance costs.
3. If it is possible to disaggregate the cost data further between the individual cost elements, then this should be done (see Box 1).

BOX 1: Check-list of cost components

1. Investment Expenditure

1.1 Adaptation Equipment Expenditure

This element of investment expenditure may include, for example, additional expenditure relating to the purchase of: materials and equipment (such as concrete, pumps, waterpipes) and any associated freight of materials or equipment.

[Note: The type(s) of equipment purchased should be given.]

1.2 Installation Expenditure
This element of investment expenditure may include, for example, additional expenditure relating to the purchase of:
-project definition, design, and planning
-engineering, construction and field expenses
-the purchase of land
-general site preparation
-buildings, civil and horticultural works (including electrical; piping; planting; painting; etc.)
-performance testing
(Note: Where known, the time taken to install the abatement measure should be given.)

These cost often can be estimated from general guidelines and catalogues.

2. Annual Operating and Maintenance Costs

2.1 Energy Costs

This element of operating and maintenance costs may include, for example, additional costs relating to the purchase of electricity or other energy sources. These costs can be calculated from the estimated energy use during a year.

2.2 Materials and Services Costs

This element of operating and maintenance costs may include, for example, additional costs relating to:
-water consumption
-replacement parts
-consumption of chemicals
-environmental services such as sewage cleaning services, or horticultural services.

2.3 Labour Costs

This element of operating and maintenance costs may include, for example, additional costs relating to operating, supervisory, and maintenance staff.
An example of this category is the additional costs of maintaining public green spaces.

2.4 Fixed Operating/Maintenance Costs

This element of operating and maintenance costs may include, for example, additional costs relating to: insurance premiums, license fees, emergency provisions, other general overheads. If relevant, expected costs at the end of the lifetime of the installation (costs of demolishing or removal) can be included too.

3.6.2. Report costs in physical data and in prices

It is helpful to future users of cost data to understand the physical materials which the costs refer to, and their prices. Taking electricity for example, it is helpful to know the quantity of electricity used and its price, as well as the cost: for example: 'The electricity cost is 220,20 Euro per year (1000 kilowatt-hours per year at a price of 0,2202 Euro per kilowatt-hour)'.

Taxes (and subsidies), especially VAT should be reported separately when mentioning the costs of adaptation measures.

3.6.3. Report costs as additional

All costs should be measured in relation to an alternative. The alternative most commonly employed is a projection of the existing situation, i.e. the situation in which the *adaptation measure* has not been installed. This is usually called the '*base case*'. Therefore, only *additional costs* actually incurred relative to the '*base case*' should be included in the reported cost data.

When reporting on costs of adaptation measures, the reported cost data should only relate to direct costs; indirect costs (the second order effects associated with changes in demand in market sectors of the economy) should be excluded from the cost data.

3.6.4. Avoided costs

Where climate adaptation measures produce non-climate benefits, *revenues* or *avoided costs*, these should be reported separately from *investment expenditures* and *operating and maintenance costs*.

Examples of non-environmental benefits, revenues and avoided costs:
Non-environmental benefits: increased productivity; recreation value.
Revenues: sale of wood or wood chips; generated electricity sales.
Avoided costs: energy use, water, materials and services, labour.

It is recommended that non-environmental benefits, *revenues* or *avoided costs* are also stated in physical terms, such as:
· amount of energy saved;
· quantity of material or water recovered and sold;
· number of man-hours saved.

3.7. The year to which data apply

Provide always the year that applies to the following data:

- Cost data
- Currency exchange rates
- Climatological data (e.g. 2012, 1990 [as average of the period 1975-2005], 2050)

Remember that cost data are not fixed for ever. It is recommended to use most recent background data available.

3.8. Document data uncertainties

A large number of uncertainties are associated with performance and costs of most adaptation measures. These uncertainties are partly caused by lack of available information, and partly caused by the impossibility to define the key assumptions behind the cost data. Future prices, wages and inflation are always unknown, but can be based on scenarios or on ad hoc assumptions (both need to be referenced).

The standard way to deal with data uncertainties is to provide data ranges for all data, as far as possible.

When comparing several adaptation options together with differing uncertainties in the data, using a data quality rating system may be considered. You can use such as system to give a qualitative indication of the reliability of data estimates in comparative tables.

The following general data quality system is recommended for all estimated data:

A. An estimate based on a large amount of information fully representative of the situation and for which all background assumptions are known.
B. An estimate based on a significant amount of information representative of most situations and for which most of the background assumptions are known.
C. An estimate based on a limited amount of information representative of some situations and for which background assumptions are limited.
D. An estimate based on an engineering calculation derived from a very limited amount of information representative of only one or two situations and for which few of the background assumptions are known.
E. An estimate based on an engineering judgement derived only from assumptions.

(source: (EMEP/EEA, 2009)).

EXAMPLES
The above figure of 3600 Euro/yr is a best estimate. The potential range in maintenance costs of the installation is estimated to be 1100 - 18100 Euro/yr.'

Reduction of energy use by employing green roofs ranges between 22 and 45%. This estimate has a data quality E (data quality system defined in EMEP/EEA 2009).

3.9. References to data sources

The sources and origins of all data should be recorded as precisely as possible so that data may be traced at a later date if necessary. If the data source is a published report or database then a standard bibliography will normally suffice. If the data source is a verbal or other undocumented communication, this should be clearly stated.

It is recommended that the origin of the data is also explained. For example:

- performance data might be based on engineering judgement, on modeling, on limited laboratory trials, or on field measurements in selected situations;
- cost data might be based on engineering judgement or on supplier's prices.

In each of these cases the source of the basic information should be referenced.

EXAMPLE
'energy savings by employing green roofs are estimated to be 4700 Euro/yr'.

The assumptions for this calculation are:

- the simulated yearly energy consumption of a 966 m^2 green roof with 100% grass (181 MWh) versus a conventional roof (200MWh) (Wong et al., 2003);
- a surface area of the roofs in the project of 3200m^2 (e-mail communication with Mr A.Janssen);
- an gas price of 0.0772 Euro/KWh (http://www.energy.eu) for the Netherlands in November 2011.

If cost data for individual measures are aggregated, for example within a scenario study, the aggregation method should be recorded.

EXAMPLE
'The costs of decoupling rainwater from the sewage system, were calculated assuming that 45% of the houses would choose for surface infiltration using vegetation, 20% of the houses would be equipped with surface infiltration through porous stony materials and 35% would have subsurface infiltration using porous concrete pipes'.

4. Dealing with Inflation

The general price level of products and services and their relative prices change over time. The cost of adaptation measures will thus also change over time. This creates two problems for making cost calculations: 1) to be comparable, the costs of adaptation measures need to be based on a common year (see Section 4.1) and 2) price changes in operating and maintenance costs in the future should be taken into account (see Chapter 5, second calculation).

4.1. Dealing with cost data from different years

Cost data for different adaptation measures or for the components of adaptation measures may relate to different years. To be able to combine these in a single cost estimate, we need to express all raw cost data in the prices of a common year (For CPC it is recommended to use the year 2010 as the common base year).

A general procedure for expressing the raw cost data in the prices of a selected year is given below. The procedure is expressed in terms of the '*base*' *year* of a study, but it could just as easily refer to any year of interest.

Step 1:

Calculate the "Price adjuster":

$$\boldsymbol{price\ adjuster} = \frac{\text{appropriate } \textit{price index} \text{ for the '}\textit{base}\text{' } \textit{year} \text{ of the analysis}}{\text{appropriate } \textit{price index} \text{ for the year to which the raw cost data pertains}}$$

Step 2:

$$\boldsymbol{adjusted\ cost\ data} = original\ cost\ data \times price\ adjuster$$

Where price adjustments have been made to express the cost data in a chosen year, then the price index used to make these adjustments should be stated and referenced. An important source of European price indices is Eurostat. In the Eurostat dataportal you can find several price indices. Most useful is to look for the "Harmonised index of consumer prices, HICP, annual data".
http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database

5. Calculating total annual costs

For comparing the costs of measures with different lifetimes (e.g. green roofs with a life time of 20 years with semi-permeable pavement with a life time of 50 years), the costs during the lifetime of an adaptation measure need to be made comparable. This is typically done by converting all the *cash flows* during the life of an adaptation measure to *annual costs*. By using a *discounting* procedure, the *opportunity cost of the capital* that is and will be spent on the adaptation measure is captured.

As we are interested in real economic costs (and not in the financial costs, which include interest costs and depreciation allowances), a discounted cash flow approach can be used:

> *Total annual cost* = the *present value* of the total cost stream (*investment expenditure* plus net *operating and maintenance costs*) *x capital recovery factor*.

The most easy case is when the operating and maintenance costs are expected to remain constant (in real terms) over the lifetime of the adaptation measure. In this case the total annual costs are calculated by computing first the *annual capital costs* of the equipment using a capital recovery factor, and then adding to this the annual *operating and maintenance costs*.

Example:

The example presented below is based on the following data set (Euro, 2010 prices):

Investment Expenditure:	250.000
Adaptation equipment	187.500
Direct installation	62.500
Net *Operating/Maintenance Costs:*	75.000
Energy	20.000
Labour	50.000
Materials	5.000
Revenue/Avoided Costs	0
Equipment lifetime	5 years
Discount rate[1)]	8%

NOTE: 1) In the Netherlands in 2007 the official discount rate for government projects has been set at 2.5%. See below.

To keep it simple, we assume that the equipment has no resale value at the end of its lifetime.

The annual capital costs are calculated by multiplying the investment expenditure in the starting year (C_0) with a capital recovery factor:

$$\left[\frac{r(1+r)^n}{(1+r)^n-1}\right]$$

in which r is the discount rate and n the estimated useful lifetime of the equipment. And therefore:

$$A_t = C_0\left[\frac{r(1+r)^n}{(1+r)^n-1}\right] = 250{,}000\left[\frac{0.08(1.08)^5}{(1.08)^5-1}\right] = 250{,}000\ (0.2505) = 62{,}614 \text{ Euro}$$

where A_t stands for the Annual Capital Costs in year t.

In the Netherlands the official discount rate for government projects has been set at 2.5%[2]. It is recommended to use this rate in calculations for CPC.

In this case, the *total annual cost* of the adaptation equipment are:

Annual Capital Cost:		
Annual recovered capital	+62,614 Euro	
Sub-total		= +62,614 Euro
Net *Operating and Maintenance Costs*:		
Energy	+20,000	
Labour	+50,000	
Materials	+5,000	
Revenue/Avoided Costs	-0	
Sub-total		= +75,000
Total Annual Cost		=137,614

The calculation becomes more complicated when the components of the operating and maintenance costs change in real prices. In that case we have to determine first the present value of the total costs of an adaptation measure over its lifetime and then apply a capital recovery factor.

Step 1: to determine the present value of all costs of an investment the following formula can be used:

$$PVC = \sum_{i=0}^{n} \frac{C_t + OCt}{(1+r)^t}$$

Where

C_t … total *investment expenditure* on the adaptation measure in period *t* (the period *t* is typically one year);
OC_t … total *operating and maintenance costs* during period *t*;
r… the *discount (interest) rate* per period.
n… the estimated useful lifetime of the equipment in years.

The *present value* of the total cost stream of the adaptation equipment of the example given above is 549,446 Euro; the table below summarises the calculations. This amount represents the total cost to be recovered in equal annual amounts (denoted by A_t) over the lifetime of the equipment.

Therefore, the *total annual cost* of the pollution control equipment is given by

$$A_t = PVC\left[\frac{r(1+r)^n}{(1+r)^n - 1}\right]$$

$$=549{,}446 \text{ Euro} * \left[\frac{0.08(1.08)^5}{(1.08)^5 - 1}\right] = 549{,}446 \text{ Euro} * (0.2505) = 137{,}613 \text{ Euro.}$$

[2] https://zoek.officielebekendmakingen.nl/kst-29352-5.html

Where $\left[\frac{r(1+r)^n}{(1+r)^n-1}\right]$ is the capital recovery factor.

Example: Calculating the *present value* total cost of the *climate adaptation measure (Euro)*

Year	0	1	2	3	4	5
1 Discount factor[1]	1.000	0.9259	0.8573	0.7938	0.7350	0.6806
2 Investment Expenditure (a+b):	250,000	-	-	-	-	-
a Equipment cost	187,500	-	-	-	-	-
b Installation costs	62,500	-	-	-	-	-
3 Operating and Maintenance Costs (a+b+c-d):	-	75,000	75,000	75,000	75,000	75,000
a Energy	-	20,000	20,000	20,000	20,000	20,000
b Labour	-	50,000	50,000	50,000	50,000	50,000
c Materials	-	5,000	5,000	5,000	5,000	5,000
d Revenue/Avoided Costs	-	-	-	-	-	-
4 Total cost (2+3)	250,000	75,000	75,000	75,000	75,000	75,000
5 Discounted total cost (1*4)	250,000	69,443	64,298	59,535	55,125	51,045
6 PVC (sum line 5)	549,446					

Notes: [1] The discount factor is given by $1/(1+r)^t$.

Expressed in general terms, the *total annual cost* of an adaptation measure may be calculated with the use of a *capital recovery factor* in one of two ways:

$$\text{total annual cost} = C_0\left[\frac{r(1+r)^n}{(1+r)^n-1}\right] + OC \text{ or}$$

$$\text{total annual cost} = \left[\sum_{t=0}^{n}\frac{C_t + OC_t}{(1+r)^t}\right]\left[\frac{r(1+r)^n}{(1+r)^n-1}\right]$$

Note: The second formula offers greater flexibility in that it provides a framework for explicitly accounting for the effects of *real* price escalation on the various *operating/maintenance cost* components. As real prices in most cases change over time, the second formula is most used in cost-benefit analyses.

When reporting annual cost data, the approach which has been used to derive the annual costs should be given, along with all underlying assumptions, including:

- the lifetime of the measure used in the calculation;
- the time period required to install the adaptation equipment;
- the *discount rate(s)* used;
- the relevant cost components, including assumptions regarding the treatment of residual (salvage) value.

Examples of how to report *total annual costs*

Approach used:
'*total annual cost* were computed by amortising the *present value* of the total cost stream'

Underlying assumptions:
'the equipment was assumed to have a technical lifetime of 12 years'
'the total cost stream was *discounted* at a *real* rate of 2.5 per cent'
'the costs of the adaptation equipment were 250,000 Euro in 2008.

6. Glossary

Additional cost/expenditure
This term refers to the difference between all costs incurred under the *base case* (i.e. in the absence of the *adaptation measure*) and those costs incurred when the adaptation measure is implemented.

Annual capital cost
An equal, or uniform, payment made over the useful life of the *adaptation measure*, which has the same *present value* as the initial *investment expenditure*. The annual capital cost of an asset essentially reflects the *opportunity cost* to the investor of owning the asset. Annual capital costs are equal to the initial *investment expenditure* multiplied by an appropriate *capital recovery factor*. Equally, annual capital costs may be approximated as the sum of an annual *depreciation charge* and the time-adjusted average interest charge on the unpaid balance.

Base case
The term used to identify the situation prior to implementation of an *adaptation measure*. In the context of scenarios or other future projections, the base case is the situation that would evolve in the absence of the policy/regulation under study; in this context the projection of the base case is often referred to as the 'business-as-usual' scenario, or 'baseline'.

Constant prices
See *real prices.*

Current prices
See *nominal prices*.

Deflation
A decrease in the *general price level* or an increase in the *purchasing power* of money.

Depreciation charge
Capital goods (e.g. installed equipment for adaptation) are typically used up over a period of time. Each year, a portion of the usefulness of these assets expires, therefore a portion of the original *investment expenditure* should be recognised as an annual (capital) cost. The term depreciation refers to the systematic allocation of the cost of an asset to expense over the accounting periods making up its useful life.

Direct costs
Direct costs refer to those costs that can be primarily attributed to the *adaptation measure*. That is, direct costs measure the value of the additional resources used to purchase, install, operate and maintain the adaptation measure.

Discounted cash flow
The *present value* of expected future *cash flows*.

Discount factor
The *present value* of a single unit of currency (e.g. Euro £, $,...) received at some future date.

Discount rate
The rate used to discount future *cash flows* to their *present value*.

Discounting
The process of determining the *present value* of future *cash flows*.

Efficiency
A measure of the effectiveness of an *adaptation measure* in reducing vulnerability to a given hazard resulting from a given impact.

General price level
The weighted average price of all goods and services in the economy, relative to their prices at some fixed date in the past. The general price level shows what is happening to prices on average, not what is happening to the prices of individual goods. Increases in the price of specific goods and services does not necessarily imply that the average price level has changed. For example, increases in the price of gasoline may be offset by decreases in the price of electricity, in which case, the average price level will thus remain constant. For the average price level to move upward, the prices of a majority of commodities traded in an economy have to increase. Changes in the general price level are measured by the consumer *price index* with a *base year* assigned a value of 100.

Inflation
An increase in the *general price level* or a decrease in the *purchasing power* of money.

Interest cost (charge)
A charge made for the use of money. The yearly interest charge on the unpaid capital balance is one part of the *annual capital cost*.

Interest rate
The ratio of the interest charged in any one time period to the original *investment expenditure*.

Investment expenditure
The total expenditure made in a given year to purchase equipment for adaptation and all expenditures associated with installing the equipment and making it operational. This includes the purchase of land, general site preparation etc., if required.
Investment expenditure is distinct from the capital cost of an *adaptation measure*. Capital goods provide services over a number of years and therefore only a portion of the original investment expenditure is recognized as an annual (capital) cost. In contrast, investment expenditure indicates the total value of the capital good in the year of acquisition and thus does not reflect the use of the asset over time.

Nominal (Current) prices
Nominal or current price variables refer to values at the prices ruling when the variable was measured. Such prices have not been adjusted for the effects of *inflation*.

Operating and maintenance costs
The cost of the energy, labor, materials and services required to operate and maintain the *adaptation measure* during a single year. Operating and maintenance costs may include fixed annual costs associated with administration, insurance premiums and other general overheads. However, they exclude any costs associated with the financing and depreciation of plant or equipment. These are covered through the use of a *capital recovery factor* when determining *total annual costs* or *annual capital costs*.
As operating and maintenance costs are incurred annually throughout the useful life of the environmental protection measure, they are also known as recurring costs.

Opportunity cost
The value of a scarce resource in its next best alternative use. The true economic cost of a resource is given by its opportunity cost.

Opportunity cost of capital
The expected rate of return that is foregone by investing in the *adaptation measure* rather than in the best alternative investment.

Present value
The amount of money today considered equivalent to a cash inflow or outflow expected to take place in the future. That is, the discounted value of future cash flows.

Price deflator
A price indicator used to convert (to deflate) between *nominal* and *real* prices. The Gross Domestic Product (GDP) deflator at market prices is an example of such a price indicator. The GDP market prices deflator provides an index of inflation in the economy as a whole, and therefore is equally applicable in removing the effects of inflation from industrial and domestic prices.

Price index
Index numbers, which have no units, are values expressed as a percentage of a single base figure. For example, if the average current price of heavy fuel oil (HFO) was Euro 579.45 per tonne and Euro 464,87 per tonne in 2011 and 2010 respectively, the price in 2010 was 80 per cent of that in 2011. In index terms, the average price of HFO in 2010 and 2011 was 80 and 100 respectively. This is an example of a *current* price index. Price indices can just as easily be expressed in *real* terms by making the appropriate adjustments for *inflation*.

Purchasing power
The ability of money to buy goods and services. As the *general price level* rises, the purchasing power of money declines. Thus, in periods of *inflation*, an ever increasing amount of money is required to represent a given amount of purchasing power.

Real (Constant) prices
Real or constant price variables adjust *nominal* variables for changes in the general level of prices. They are inflation-adjusted prices.

Side-effects
Effects arising from the implementation and operating of an *adaptation measure* that are not included in the reported adaptation performance and cost data. For example, an adaptation measure designed to reduce temperature in buildings by evaporative cooling, may have 'side effects' in terms of noise levels. Similarly, an adaptation measure may reduce the urban heat island effect but increase air emissions.

Technical life
The estimated 'physical' life of an *adaptation measure*, i.e. the time at which the asset literally wears out due to 'physical' deterioration. The estimated technical life of an *adaptation measure* is a function of the assumed maintenance regime; a good repair policy may lengthen the life of the asset.

Total annual cost

The total annual cost of an *adaptation measure* corresponds to the uniform annual payment required to cover both the annual *operating and maintenance costs* net of *revenues*/*avoided costs*, as well as the *annual capital costs* in the form of capital recovery and the cost of capital.

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