ThermalNet

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CombNet

GasNet

PyNe

Methodology guideline on techno economic assessment (TEA)

Generated in the Framework of ThermalNet WP3B Economics

Maximilian Lauer

Intelligent Energy Europe

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Content list

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Introduction:

The intention of this guideline is to enable engineers in research and technical development to work on techno-economic assessments in a consistent and transparent way.

Techno-economic assessment TEA in principle is a cost-benefit comparison using different methods. These assessments are used for tasks such as:

- Evaluate the economic feasibility of a specific project
- Investigate cash flows (e.g. financing problems) over the lifetime
- Evaluate the likelihood of different technology scales and applications.
- Compare the economic quality of different technology applications providing the same service.

From this (incomplete) list it can be seen, that TEA is used for very different objectives.
In this guideline each item is given a specification, a description and practical advice for doing the assessment (information sources, typical values etc.). There is no specific format proposed for doing the assessment, because practical calculation uses different methods and in general is very simple using a spreadsheet program.

In chapter 1 the cost assessment is discussed in general, the terms used are specified, methods for the assessment are indicated and if possible, default values are proposed. The same is done in chapter 2 for the benefit (income) assessment. Chapter 3 describes some aspects of risk assessment. In chapter 4 the TEA methods are discussed, giving a description, showing the calculation and the interpretation of results.

The influence of taxation is not discussed in the guideline. As a simple rule taxes should be included in cost and benefit assessment, if they are not refundable (e.g. transport fuel taxes). Value added tax (VAT) usually is refunded (except for private use) and so should not be included in TEA.

1. Cost assessment

For TEA cost are separated in investment related cost (chapter 1.1) and in operation related cost (chapter 1.2). In chapter 1.3 some general remarks on cost assessment are given.

1.1 Investment related cost

Investment related cost comprise:

- Initial investment including planning and consulting cost *[I]*
- Administration and insurance cost (annual) *[i_a]*
- Cost for infrastructure (annual) *[i_i]*

Investment related costs are independent of operation and operation intensity. They will arise also from not operating plants.

1.1.1 Investment including planning and consulting cost *[I]*

The investment is the cost to the investor for project development, financing, the construction, and for getting the plant into regular operation (commissioning, operation permits and test operation phase). Also the cost for establishing the infrastructure for the project (area purchase, traffic areas, building, electrical connection to grid etc.) is included, if paid as initial investment.

Cost for planning and consulting is a significant share (~5%) of the investment, even if a mature and well known technology is used. If the technology is new and unknown, the cost for planning and consulting could be higher (up to 20 %) especially if the plant size is small (as usually in demonstration and pilot plants).

Investment cost has to be paid during the construction phase and often is financed by a loan (see also chapter 4 TEA methods”).

Depending on the choice of the owner, the investment can also be the cost for an engineering, procurement and construction (EPC) contract”, the EPC contractor agrees to deliver the keys of a commissioned plant to the owner for an agreed amount, just as a builder hands over the keys of a flat to the purchaser. Choosing this route incorporates a degree of protection for the purchaser, as the EPC contractor will generally guarantee certain minimum performance standards for the plant against which liquidated damages would be payable.

1.1.2 Administration and insurance cost $[i_a]$

Cost for administration and insurance of the plant is an annual cost. Usually it is assessed as a share of the investment sum and depending on the size and the complexity assumed to be 1 to 2 % of the investment. In special cases as very small units (e.g. very small CHP gasifiers) $[i_a]$ can be higher, up to 5 % of investment depending on the situation. In other cases (e.g. residential heating boiler in private use) $[i_a]$ it can be negligible.

1.1.3 Periodical cost for infrastructure, location, building etc. $[i_i]$

Cost for infrastructure, location, building etc are hugely variable, depending on the specific situation of the project to be assessed. The $[i_i]$ comprises all costs that are not investment and are to be paid on a periodical basis. This cost includes e.g. rent to be paid for the area used and for the building, canal dues, licence fees etc. As $[i_i]$ is highly dependent on the specific project, no indicative value can be given.

1.2 Operation related cost

Operation related cost comprise

- Fuel cost $[o_F]$ (chapter 1.2.1)
- Labour cost $[o_L]$ (chapter 1.2.2)
- Maintenance cost $[o_M]$ (chapter 1.2.3)
- Other cost $[o_o]$ (chapter 1.2.4)

If operation is stopped (e.g. shutdown) no operation related will arise. Some operation related costs are depending on operation intensity (as fuel cost), some are not or only partially (e.g. labour cost).

1.2.1 Fuel cost *[o_F]*

Fuel cost is the annual cost for the supply with fuels (main fuel, additional fuels). Electricity cost is usually integrated in "other cost". Alternatively the cost for electricity should be integrated in fuel cost, if electricity demand is a substantial part of the energy consumption.

Fuel cost is usually predominant in the cost structure of a biomass project. Therefore it has to be assessed with utmost care. Two elements are very important for doing the assessment:

- The specific fuel cost at the plant gate (/GJ or /t etc.) over the lifetime
- Fuel consumption (amount of fuel needed in GJ/a or t/a etc.).

<u>Specific fuel cost:</u>

Specific fuel cost is the cost the plant has to pay for a unit fuel at the plant (including loading and transport cost) without taxes (VAT).

The assessment of specific fuel cost and its development over the lifetime of the plant is difficult, as in most European countries no developed market for biomass exists and prices are very volatile. The production cost for the fuel (e.g. wood chips) is not applicable for fuel cost assessment, because it illustrates only the absolute cost minimum but not the price that has to be paid during the technical lifetime of the plant. The best case for the TEA would be information out of a negotiated contract for fuel supply over the lifetime. This will rarely be available. A good and practicable information source is to contact fuel suppliers and their associations (farmer associations, sawmills, wood processing industry) and to ask for their expectation. Companies using a similar biomass for production uses (e.g. pulp mills, chipboard industry) are also a good source for information. These companies will probably give no information on their actual feedstock cost but deliberately talk about their expectations on price development. This information is exactly what is needed for the fuel cost assessment.

Mistakes are sometimes made by neglecting the fuel quality necessary for the specific use. Biomass as fuel can have very different quality in terms of size, water content, admixtures of soil, metals etc. Also the prices can be quite different.

<u>Fuel consumption (Amount of fuel needed)</u>

The fuel consumption is calculated from the capacity, the efficiency and the availability of the plant assessed.

For describing the availability of the plant two specifications are used in Europe:

- Capacity factor (kWh produced per year / maximum continuous rating x 8760)
- Full capacity operations time (kWh produced per year / maximum continuous rating in kW)

The calculation of the annual fuel amount seems to be relatively simple but is often a source for wrong TEA results. The reason is a too optimistic assessment of the efficiency in regular operation and a too optimistic assessment of availability. As an example the full capacity operation time of a simple industrial process heat boiler will be hardly more than 7000 h/a full capacity operation time corresponding to a capacity factor of 0,8. This includes a 24 h/d full load operation near capacity all days per year except some days for operation and maintenance (and maybe one or two minor failures in operation). On the other hand a residential heating boiler in Central Europe has a maximum of 1400 h/a full capacity operation time corresponding to a capacity factor of 0,16. Most biomass to energy plants will be in between these two figures. If the assessment is done for a project using a new and unproven technology the utmost care has to be given to a realistic assessment of the availability. A figure of 5000 h/a full capacity operation time or even more seems to be very optimistic in this case, at least for the first 5 years.

1.2.2 Labour cost *[o_L]*

Labour cost is the total cost to be paid for the staff needed for operating the plant. It includes social security contributions (if applicable). Labour cost should be indicated as annual costs, so special regulations for holidays, illness etc. are included. The number of staff assumed to be needed for operating the plant should respect these facts. Particular care should be taken with CHP or other plants designed to operate on low load factors. Sometimes it may be possible to employ staff on a semi-casual basis, but sometimes permanently contracted staff will have to be paid even if the plant is not operating. A variety of local arrangements can mitigate this but it must be considered in advance.

The cost per employee depends on the specific national situation and the qualification needed. Information on specific labour cost can be easily obtained from e.g. national industrial associations.

1.2.3 Maintenance cost *[o_M]*

Maintenance cost is all expenditures for cleaning, overhauls, servicing etc. Part of that will probably be paid to external contractors as service companies or technology supplier. Maintenance cost is related to the production intensity (e.g. cost for servicing) but also to the operation time (e.g. cost for overhauls) or are needed on a regular basis (cleaning).

Sometimes maintenance cost are indicated as specific cost related to the product (e.g. /MWh). This is applicable, if there is sufficient experience with comparable plants (size, operation, technology). In the case of biomass conversion technologies this can only be applied to very few widespread technologies (as maybe biomass boilers similar in use and size). No values on this are known from literature.

As maintenance costs are not only related to the production, it seems to be better to do the assessment based on the investment *[I]* for the specific equipment.
Usually a share of the investment is taken for the annual cost of maintenance. Indicative values are given below. They are deduced from a German guideline on some special cases of TEA (VDI 2067, withdrawn in the meanwhile)

Type of equipment:	annual share of investment *[I]*
Infrastructure	0,3 to 0,5 %/a
Buildings	0,8 to 1,2 %/a
Mechanical equipment *)	2,0 to 3,5 %/a
Electrical equipment	1,8 to 2,2 %/a
Thermo chemical conversion equipment	2,0 to 4,5 %/a

*) for complex equipment as IC-engines o_M is indicated up to 9 %/a of I

As the maintenance effort needed for the different kinds of equipment is very different, for TEA there should be a value taken according to the complexity of the equipment and taking into consideration the intensity of operation. It should also be remembered that maintenance cost is rarely evenly spread over the plant lifetime. Certain key components of the power generation plant will require major overhaul or replacement after a specific period in service e.g. steam turbines or boiler tubes. Manufacturer's recommendations are the best guide to this.

Many large scale systems will require regular inspection of pressure vessels for health and safety or insurance requirements and this requirement will sometimes dictate the minimum period that can elapse before a plant is next shut down for maintenance. Such requirements need to be factored into both availability calculations and maintenance costs.

1.2.4 Other cost *[o_O]*

"Other cost" comprise all cost other than fuel, labour or maintenance costs. It depends on the specific project what is to be summarized in this cost category. Examples for other costs are monitoring cost (e.g. emissions), consumables, licences to be paid etc. Also cost for waste disposal (ashes) and cost for treating contaminated waste water should be summarized in other cost. Other cost" should be indicated as annual cost.

1.3 General remarks on cost assessment

In cost assessment for new technologies or uses there are two problems to be mentioned.

The first is the difficulty to produce **realistic data** for the cost components. The biggest obstacle is the assessment of the investment cost, but in principle it concerns all cost components. It is specific to research and technical development, that no exact data are known for the technologies to be developed or tested. So cost assessment can only be made on comparative basis looking at existing similar technologies or applications with data available. In some cases it helps to introduce size factors or country specific factors (cost relations in different countries) but in general, no specific advice can be given for assessing cost for technologies not realized before.

The second problem in cost assessment is taking into account **contingencies** (not expected cost). Especially assessing new technologies as a broad tendency cost are underestimated in TEA, even if the cost assessment is done very carefully and based on reliable data. As a matter of experience after the realization of a project it can be seen, that the overall cost in reality are in most cases significantly higher than expected in the TEA. The reason for this is non expected cost (contingencies). The effect of neglecting contingencies is relatively low, if various new technologies are compared to each other. But the TEA gives wrong results, if mature technologies (robust data available) are compared to new technologies (no experience from realized projects). In this case only the introduction of a contingency factor can help to avoid a wrong (too optimistic) result of TEA. Contingency factors should be put on the overall cost. Depending on the experience with the technology and the complexity of the project contingency factors should be chosen from 1.05 to 1.25.

2. Benefit assessment

In the case of bioenergy plants TEA the benefit will be the earnings from selling the product(s) produced. In some cases also the selling of carbon credits or emission certificates could be an additional benefit (see below).

Earnings from selling products *[b_{el}, b_{th} …etc]*

From the project data the amount of products produced is well known. (capacity * full capacity operation time). This amount needs to be realistic, taking into account the plant's own (electricity or other) requirements and the losses between the point of production and the point of purchase. The difficulty is usually in assessing the price acceptable to the market. As the product price is usually the only variable on the benefit side utmost care has to be taken in order to avoid wrong results.

For electricity production the price is usually clear. A discussion with the purchaser (often the grid company) will indicate the prices for delivery. For heat production the assessment is very difficult and depends on the use of the heat, competing alternatives for the contactor etc. No specific advice can be given for this assessment. Some of the most important facts to consider are:

- Availability of the plant and the heat production (does production rhythm and risk of failure (maximum time out of service) fit to the needs of the buyer (depends also on backup possibilities)?
- Cost of alternatives for the buyer of the heat
- Is the heat production band load or peak load type?

Usually in TEA the price of the heat produced tends to be overestimated. So, the assessment should be done very careful.

Premiums for green generation

In some countries in Europe feed-in tariffs exist which specify the purchase price for bioelectricity. However, in other countries the use of green certificates" is increasingly common. With this system generators get awarded a green certificate related to the units of green electricity that they produce. These certificates are then traded independently from the electricity generated and provide separate revenues. The value of a green certificate is not fixed and can vary depending on market conditions, although some countries specify a “buy-out price”, which effectively represents a minimum figure, below which the price will not fall for the duration of the legislation. In most countries where certificates are traded this income is in addition to any that may be obtained from the carbon credits under European ETS discussed below. However, in a number of cases national governments are considering reducing the level of support they offer via certificate schemes in anticipation that the income generators will receive in the long term from the European ETS will compensate this. Careful consideration needs to be given to this and other possible legislative changes in the long term.

Earnings from selling carbon credits and emission certificates

In Europe the ETS (emission trading system) is established obliging big companies to acquire Emission Certificates for the Greenhouse Gas emissions produced. An additional system is to be established with carbon credits also accessible to companies non affected by the ETS.

Today under the European ETS (emission trading system) in some special cases additional benefit could be generated. If a company needs less emission certificates by switching partly from fossil fuels to bioenergy, the avoided cost for buying certificates could be seen as an additional benefit of the bioenergy plant. The price for the certificates is very volatile due to the new and emerging market. Benefits by generating and selling carbon credits may be of some importance to benefit assessment in the future. The rules to generate and to trade carbon credits are unclear up to now.

3. Risk assessment

Risk assessment is methodically not incorporated in TEA. But risk have to be considered before doing a TEA, otherwise the results produced would be probably without any relevance. Risk analysis is dealing with several criteria (examples):

- Financial risk
- Environmental risk
- Technical risk
- Social risk

Some of these are interrelated to each other (e.g. technical and financial), some are not.
To illustrate the need to make some consideration of risk related to the project a typical example is discussed below.
A project is to be assessed on economical availability. Several bioenergy technologies should be compared. For the choice of the technologies to be assessed some aspects of risk analysis should be considered:

- If the bioenergy plant is a stand alone plant (example: heat production in sawmill for drying wood) availability and failure risk will be of minor importance for realisation. So also emerging technologies with some risk of unexpected failure or production breakdown can be taken into consideration.
- If the bioenergy plant is integrated into an industrial production (example: energy supply of a pulp and paper mill) availability has to be extremely high (~ 99.5 %) and the risk of unexpected failure extremely low. A failure of the bioenergy plant would induce a stop to the whole production. The financial risk created by the technical risk of the bioenergy plant would be inacceptable. Only very reliable technologies should be chosen for the TEA, otherwise the result is of no relevance.

So even if risk assessment is not a specific topic to TEA, the risks related to a project should be kept in mind and respected in the design of TEA.
Most developers will carry out some form of risk assessment as part of their project activities. Techno-economic assessment can be used to help inform this risk assessment and, conversely risk assessment can identify key areas that could be tested in a sensitivity analysis as part of the techno-economic analysis. For example for a novel technology it might be relevant to test

the robustness of the TEA to availabilities significantly lower than anticipated, particularly in the early years. These can help guide investment and contractual decisions. In a new market it might make sense to test the impact of increases in feedstock cost or of having to switch to an alternative supplier.

4. TEA methods

Several TEA methods are discussed in this section:

- Static cost benefit assessment (chapter 4.1)
- Annuity method (chapter 4.2)
- Net cash flow table (chapter 4.3)
- Net present value (discounted cash flow) (chapter 4.4)
- Internal rate of return (chapter 4.5)

In the chapters the method is described, the calculation discussed and the use and interpretation in TEA discussed.

In general the guideline in hand is made for the use of technical scientists. Sometimes not all aspects of some economic issues and methods are used, so it may seem to be in contradiction with classical economics. These cases are indicated in the text. The reason for this is to keep the guideline as simple as possible.

A list of abbreviations used in the guideline is attached as chapter 5 in order to have a better overview and a connection between the calculation in section 4 and the description in sections 1 and 2.

4.1 Static cost benefit assessment

Method:

Static cost benefit assessment is a comparison of benefit and cost of one average year without taking into account interest rate and inflation rate etc.

Calculation:

$$r = b_{tot} - c_{tot}$$

with:

$$b_{tot} = b_{el} + b_{th} + b_{other}$$

$$c_{tot} = c_{inv} + c_{op}$$

using:

$$c_{inv} = A + i_a + i_i \quad with \ \cdots \ A = \frac{I}{n}$$

$$c_{op} = o_F + o_L + o_M + o_O$$

<u>Interpretation and use:</u>

Static cost benefit assessment is very easy and quick to do without needing tools such as computers (or even calculators with higher power functions). Neglecting interest rates and inflation rates makes the result quite imprecise (in general too optimistic), especially in cases with high interest rates or a big difference between inflation rate and interest rate. It can only be used for a preliminary check e.g. of an idea, just to investigate whether further investigation should be done or not.

<u>Sensitivity analysis:</u>

Due to the imprecise results of this method with the unavoidable underestimation of investment related cost, a sensitivity analysis based on TEA done with static cost benefit assessment is not sensible..

4.2 Annuity method

<u>Method:</u>

In principle it is the same as the static cost benefit assessment, but for payback of the investment the interest rate is included in the calculation of the annuity. The annuity is a fixed and constant annual payment usually over the lifetime of the investment. It comprises the capital payback and the interest. The inflation rate (and the rise of cost and of income over the lifetime) is usually not taken into account. This method considers the net benefit (income less cost) for each year of project operation just as the static method does, but spreads the initial investment cost over the project lifetime using an assumed interest rate. It does not take into account any changes or diminution in the value of the incomes received or costs expended each year.

Calculation:

$$r = b_{tot} - c_{tot}$$

with: $$b_{tot} = b_{el} + b_{th} + b_{other}$$

$$c_{tot} = c_{inv} + c_{op}$$

$$c_{inv} = A + i_a + i_i \cdots with \cdots A = a * I$$

Using

$$a = \frac{p * (1+p)^n}{(1+p)^n - 1}$$

$$c_{op} = o_F + o_L + o_M + o_O$$

Interpretation and use:

The annuity method is very useful for simple TEA, rather realistic in results as long as inflation rate is not too high and not too different to the interest rate. The results of TEA on different projects are easy to compare with each other and the calculation is transparent and easy to understand. A disadvantage of the annuity method is that it is not possible to distinguish variations in costs and benefits from one year to the next – the same net benefit is applied to every year. Also the time delay between investment and first year of regular operation can not be considered (at least not without loosing the transparency). The annuity method is widely used in continental Europe by technicians (not by economists and financing specialists) for preliminary project assessment.

Sensitivity analysis:

By changing parameters of the assessment the sensitivity of the results can be easily investigated. In practice the influence of parameter changes should be investigated for one parameter after the other, so the influence of the specific parameter variation on the results can be seen. Doing this the sensitivity of the results to changes of different parameters can be investigated.

It is frequently found that fuel price and product selling price (sometimes also availability) are particularly significant parameters for sensitivity variations and so special care should be taken with these values.

4.3 Net cash flow table

Method:

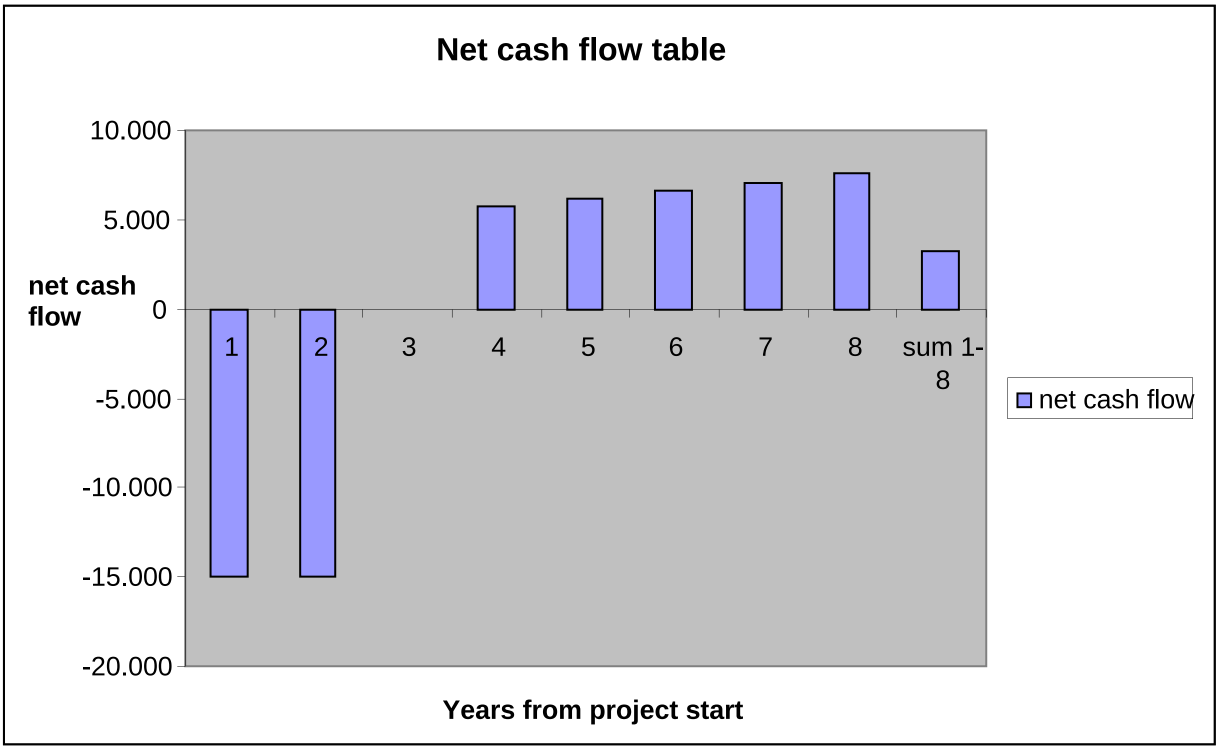
For every year of the project period from starting with the project development until to the end of technical lifetime all cost paid (in cash) and benefits received (in cash) are calculated and the annual cash flow is calculated as benefit minus cost. Cost for a capital loan (capital payback and interest rate if applicable) has to be included. (Economists have a slightly differentiated understanding of establishing a cash flow analysis, see also in http://en.wikipedia.org/wiki/Cash_flow)

Calculation:

An example for the calculation of the net cash flow (NCF) is given in the table below. In this a project is shown assuming a development and construction phase of 2 years (when the investment is done) and a technical lifetime starting in year 3 and ending after year 8 (six years).It is assumed that the investment is paid from own capital (without bank loan). In case of using a bank loan, the cash flow for the investment in year one and two would be zero (= paid out of the loan) but in the years 3 to 8 an annuity (or another form of payback of capital and interest) would be added to investment related cost”

Example for a cash flow table

	year from start of project development								
	1	2	3	4	5	6	7	8	Sum 1-8
benefits [btot]			6.000	12.000	12.760	13.483	14.293	15.150	
operation cost [cop[			5.000	5.250	5.513	5.788	6.078	6.381	
investment related [ia+ii]			1.000	1.030	1.061	1.093	1.126	1.159	
Investment [I]	15.000	15.000							
sum of payments	15.000	15.000	6.000	6.280	6.573	6.881	7.203	7.541	
net cash flow (NCF)	-15.000	-15.000	0	5.720	6.187	6.602	7.090	7.609	3.208



In the first two years the net cash flow is negative, because of the investment (money is paid out, no income), in the third year the first benefits (income from selling products), but due to production start with limited availability (so NCF =0) and from year 4 to 8 the production is working properly. In the example shown the development of income and cost elements over the years is assumed to be different (different rates of increase). It would also be possible to include reinvestments during the lifetime or include the value of the investment after technical lifetime (as benefit) and other linear or non-linear effects.

Interpretation and use

Net cash flow table gives an excellent overview on the timeline of incomes and payments over project period. It shows how many years it will take before the first positive cash flow can be expected, gives an indication on questions of financing and shows in a very simple way the overall situation of a project.

Net cash flow analysis can only be applied to specific projects with very good information on all benefit and cost issues available. It is not sensible to use the method for comparative technology assessment or to investigate the economic viability of a technology application. Even if the net cash flow analysis is a valuable instrument for illustrating the development of benefit and cost and the cash flow over project development phase and technical lifetime, the sum of all cash flows gives only indicative information on the economic viability of a project, because the sum of the net cash flows over the period is not the value of the project for the investor. For this the net present value of the cash flows over the years has to be calculated (see chapter 4.4).

Sensitivity analysis:

Assumptions on different developments of prices and cost can be integrated easily. The influence of these parameters can be investigated in a sensitivity analysis by varying them in the net cash flow table.

4.4 Net present value (discounted cash flow)

Method:

Net present value (NPV) is a standard method for the financial appraisal of projects. This is the most common technique used by most professional practitioners of techno-economic assessment. It effectively accounts for the fact that capital investment is outlaid at the start of a project, but returns are not received until later, by which stage their value, in real terms has diminished (1 euro today is more valuable than the promise that 1 euro will be paid in five years time). This is accounted for by the introduction of a discount rate", which represents the decrease in value of the payment because it is not paid at the time of the capital outlay but a number of years hence. So the overall economic result of a project realization can be expressed in present money.

It is calculated by discounting the cash flows in the net cash flow table (see chapter 4.3) by the discount rate and by making the sum over the project period. The discount rate varies depending on who is investing and how – they should be set at a level that represents what value the investor places on receiving money now rather than in the future. For a limited number of publicly funded bodies this might equate to something similar to an inflation rate, for a low risk commercial project it will always be higher than the prevailing interest rates (why would one invest my money in this project if one could stash it in bonds and be guaranteed a return of x) and for most projects it will be significantly higher than prevailing interest rates – unless there is an external agenda in terms of subsidy, intervention, third party interest or whatever.

In typical techno-economic project assessment the discount rate should be set at least two percent above the interest rate of a bank loan.

Calculation:

The net present value of every year is discounted to the year 0 by the discount rate using the formula

$$NPV_n = \frac{NCF}{(1+d)^n}$$

The net present value of the project NPV_{tot} is the sum of the discounted cash flows for every year of the project period.

$$NPV_{tot} = \sum_{1}^{n} NPV_n$$

Practically these calculations are done using the same worksheet as it is established for calculating the net cash flow table.

Interpretation and use:

The net present value gives an indication how much the project will increase the investors property over the whole project period in today's money value. It is useful especially for long project periods, high inflation rates and non linear developments in prices, cost etc

The net present value NPV should have at least the value zero. In this case the investor exactly recoups all his cost over the lifetime of a project (using the assumed discount rate). If the NPV is positive, the investor's property will be increased by this value after the project lifetime. If NPV has a negative value, the project is not to be realized without suffering losses taking into account the assumed discount rate.

As all methods using cash flows, the net present value NPV or discounted cash flow should only be used for assessing very specific projects with all information available. It is an excellent tool for comparing different projects.

Sensitivity analysis

The effect of input parameters can be investigated in a sensitivity analysis by varying them in the spreadsheet calculation.

4.5 Internal Rate of Return (IRR)

Method:

The Internal Rate of Return is the average annual return rate on the initial investment when considering all costs and benefits over the given project period. It is calculated on present money value. It uses discounted cash flow techniques to answer the question: "*At what discount rate does the net present value (NPV) of my project equate to zero?* This is a useful measure for investors: if they invest the initial capital for the project period they will receive a return on their investment equivalent to the IRR each year of the project.

The method is widely used by professional project evaluators and investment consulters.

Calculation:

The IRR is the discount rate for which NPV_{tot} is zero (see section 4.4). The calculation practically is done iteratively by variation of the discount rate in the NPV_{tot} worksheet calculation.

Interpretation and use:

The internal rate of return (IRR) is a valuable figure in order to assess the economic quality of a project. If there are more than one possible projects to be compared to each other, the internal rate of investment gives an indication on the most profitable one, independent of project size and technology.

It allows some judgments of the efficacy of the investment. If the IRR is low (less than could be obtained with bank cash deposits) it would be pointless investing in a project where the capital was unsecured and the return not guaranteed to get only that rate of return. For a project to be an attractive investment the IRR should be higher than other options the investor has for investing that money, taking into account the degree of risk associated with the investment.

Sensitivity analysis

By varying the input parameters of the cash flow model, a sensitivity analysis can easily be done.

5. Abbreviations used

A	*annual cost for paying back the investment cost (see chapter 4.2)*
a	*annuity factor = the share of the investment, that has to be paid on a annual basis to pay off the investment (constant repayments over the technical lifetime) (see chapter 4.2)*
b_{tot}	*total annual benefit (chapter 2) =* b_{el} + b_{th} + b_{other} *(see chapter 2)*
b_{el}	*earnings from selling electricity per year (chapter 2)*
b_{th}	*earnings from selling thermal energy per year (chapter 2)*
b_{other}	*other benefits per year (e.g. from selling carbon credits) (chapter 2)*
c_{tot}	*total annual cost (chapter 1)*
c_{inv}	*total investment related cost per year (chapter 1.1)*
c_{op}	*total operation cost per year (chapter 1.2)*
d	*discount rate (explanation and discussion see chapter 4.4)*
I	*Investment cost including planning and consulting (hapter 1.1.1)*
i_a	*administrative and insurance cost (annual) (chapter 1.1.2)*
i_i	*periodical cost for infrastructure, location building, (given as annual cost; chapter 1.1.3)*
n	*project period (project development + construction + technical life time in years)*
NCF_n	*Net cash Flow (for year n), (chapter 4.3)*
NPV_n	*net present value (for year n) (chapter 4.4)*
o_{tot}	*total operation related cost per year, (chapter4.1)*
o_F	*Fuel cost (per year) (chapter 1.2.1)*
o_L	*Labour cost (per year) (chapter 1.2.2)*
o_M	*Maintenance cost (per year) (chapter 1.2.3)*
o_O	*Other cost (per year) (chapter 1.2.4)*
p	*interest rate [in %/100; 5%=> 0,05]*
q	*inflation rate [in %/100; 5%=> 0,05]*
r	*annual result of cost benefit comparison*
T	*technical lifetime (from start of regular operation to end of regular operation in years)*

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