spemann consulting

PG-ROI

Return on Investment Analysis for Power Plant Projects

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Manual

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Contents

1 PG-ROI – General Introduction

PG-ROI is a detailed computer model for the Return on investment calculation (RoI) of thermal power plants and related projects. The name PG-ROI derives from **P**ower **G**eneration Tool for **R**eturn **O**n **I**nvestment Analysis. PG-ROI is a further development that lays its basis on the methods and functionality of the tool PROCAT. Users of PROCAT will recognize many functions and probably concentrate on the new, additional functions.

The mathematical model is transformed into a **Microsoft Excel**[1] file, running implemented macros.

PG-ROI transforms technical parameters of a power plant, its operational data, costs and market information as well as important data about the investment volume and financing. These data are combined for a most exact estimation of the economic effects of the planned investment.

The results of the calculation are displayed in detailed tables, depicted in diagrams and condensed into key investment figures that investors and suppliers can base their decisions on.

Before investing and while assessing technical options, the following questions might be decisive:

- Does a project return beneficial at all (question of absolute benefit)?
- Which of the viable options offers the highest benefit (question of choice)?

PG-ROI gives answers to these questions and prepares the necessary basis and justification for decisions.

1.1 Meet customer's and supplier's interest

PG-ROI provides the "hard facts" for the decision makers on both sides: customer and supplier.

Power producers might say:

- "We don't know how the market will change, therefore we cannot take decisions..."
- "The unit will be shut down in five years, we will not invest in new equipment now..."
- "The budget is too small for such a project, even is profitable..."
- "I would like to invest, but I need to convince the board..."

The system suppliers might answer:

- "The more profitable your plant, the better your market position..."
- "If the pay-off time is shorter than three years, your investment is profitable regardless of the long-term strategy..."
- "With the right financing, the cash flow remains in affordable scale..."
- "We provide an investment analysis that will convince your board..."

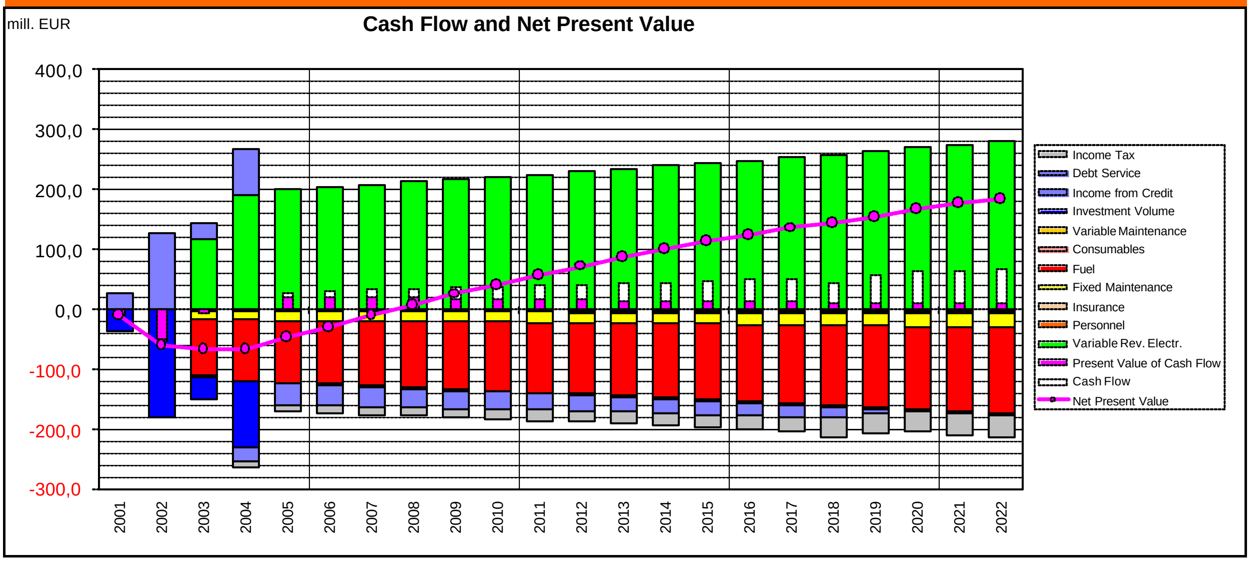
Both arguments need back up from realistic calculation models. When discussing project profitability, both parties will cooperate in order to find out the most realistic results. Only by cooperation of power plant owner and system supplier can the most profitable project alternative be determined and calculated.

PG-ROI is the tool to combine all data and make the results transparent.

Charts represent all economic aspects in an overview, including the key investment figures Net Present Value, Internal Rate of Return and Pay-Off Time, not to mention the Lifetime Electricity Production Costs:

Investment		
Debt	mill. EUR	252,000
Equity	mill. EUR	108,000
Capital Requirement	**mill. EUR**	**360,000**

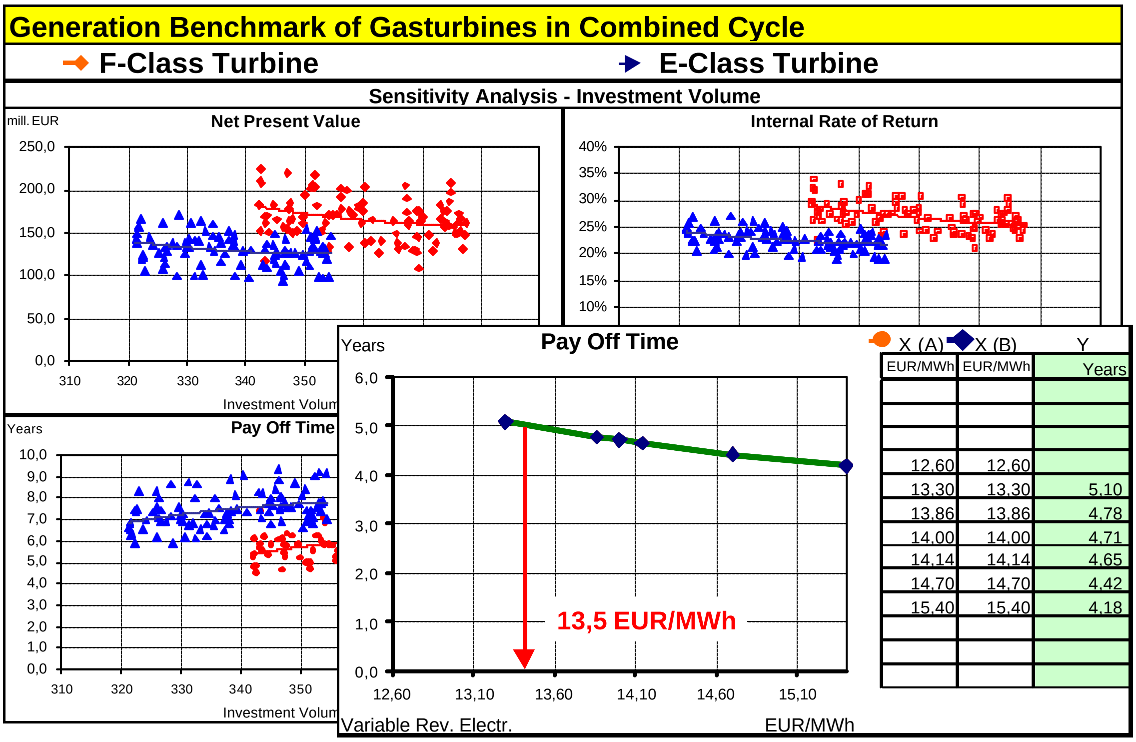
Net Present Value (10,0%) at 1.1.2002	**mill. EUR**	**184,400**
Internal Rate of Return till 2011	% / a	22,5%
Internal Rate of Return till 2022	**% / a**	**28,4%**
Pay Off Time from 1.1.2003 (a)		**5,5**



Graphic 1-1 Overview chart of PG-ROI results

[1] Microsoft®, Windows® and MS Excel® are registered trademarks of Microsoft Corp. PG-ROI runs on versions Excel 97, Excel 2000 and Excel 2003/XP and will be adapted to future versions.

As many input parameters are unknown or only can be estimated within a range, PG-ROI provides all kinds of sensitivity analysis and a sophisticated probability analysis. They give relief in case someone does not trust the results only because the parameters are not exactly known.



Graphic 1-2 Overview chart of PG-ROI sensitivity analysis

1.2 Philosophy of PG-ROI

The PG-ROI philosophy consists of three principles:

- Flexible modeling
- Exact calculation
- Maximum user friendliness

1.2.1 Flexible modeling

Flexible modeling enables the user to use a single program to calculate the economic results of most different cases:

- New power plants
- Modernization and revamping
- Comparison of technical options

This can be used for very different kinds of power plants:

- Steam turbines and coal fired pow er plants
- Gas turbines and combined cycle power plants
- District heating plants
- Industry power plants
- Waste incinerating plants
- Nuclear power plants

PG-ROI covers the whole range from a simple modernization of a temperature control to market studies about the future of coal fired power plants in a region, and all this without any programming and within a very short time.

1.2.2 Exact calculation

The numerical exactness of a calculation is easy to achieve with modern computer programs. The problems are hidden in the details of modeling and the derivation of RoI figures. Especially this derivation according to investment theory and accounting rules often leads to wrong models and hence to wrong results, that are difficult to detect.

Starting from the input data PG-ROI determines the project's cash flow and the total costs of electricity production and in a second derives from these results the RoI figures of investment theory:

- Net Present Value (NPV)
- Internal Rate of Return (IRR)
- Pay-off Time (POT)

and the important criteria

- Levelized Electricity Production Costs (LEPC or Life Cycle Costs)

Next to the absolute amount of an investment, the timely distribution of income and payments is decisive for the return on investment calculation. If the calculation is based on a yearly summary, the RoI figures are biased and the user loses important information. Therefore PG-ROI calculates all data on a monthly resolution during the whole project. This leads to more exact results especially for the internal rate of return, which is the most widely-used decision criterion.

1.2.3 Maximum user friendliness

PG-ROI is kept as easy as possible. Data are put into frame-like tables according to the degree of details. Self-explaining click-buttons lead through the program.

PG-ROI pays special attention to various analysis and evaluations that depict the results in understandable charts and tables in order to derive clear statements:

- Step by step calculation
- Structured input data sheets
- Formatted tables of results
- Summary sheets of important results
- Charts / Diagrams
- Sensitivity analysis
- Evaluation criteria

As PG-ROI is a file of the widespread program MS Excel, every Excel user can handle PG-ROI easily. Calculations are performed using internal visual basic macros. PG-ROI runs on Microsoft Excel version 97 and 2000.

All data are displayed in tables, so that the user can recalculate every single value and will see clearly, how results are derived. With this manual, the user can find the formulas behind the calculation. The description of the employed methods is much more valuable for any user than an open source code could be, because only an experienced programmer after some time could detect the used method, but a sales representative in a customer meeting certainly will prefer reading the manual.

PG-ROI has a single input data sheet "Input" for all necessary technical and financial data. The sheet "Input" also serves as a main menu for starting the calculation and special functions, so that the user has only one interface to know.

If he needs or wants to extend the model exactness regarding operational and market figures, he can put in some of the data in a more detailed manner using additional input sheets.

A large number of output sheets contain all numerical and graphical results, named after their content and selected with a simple dialog. The huge variety of output charts and tables covers most of the user's needs, as they can be copied directly into presentations or be printed out.

Many input data are not known exactly or can only be given with a range. Besides, future market development can only be estimated with scenarios. PG-ROI considers these uncertainties and replies with a wide range of sensitivity analysis and probability approaches that are automatically and quickly calculated within a short time.

The following Chapters of this manual explain in detail the input data, the calculation methods, the program handling, output sheets and sensitivity analysis. Some examples show step-by-step, how certain cases are put into the model and how the results should be interpreted.

1.3 Services by Spemann Consulting

Spemann Consulting is specialized on the return on investment analysis of industry projects. Focused on power plants, Spemann Consulting has developed PG-ROI, a powerful and widely applicable tool.

Many suppliers of power plants and components, investors and consultants develop and employ own programs to assess the profitability of their projects. Even though the opinion exists that these calculations are simple and could be done with paper and pencil, most users agree that computer programming prevails. For developing a model, engineers and economists need to cooperate with the programmers in order to determine the technical dependencies and to integrate market and financing details correctly.

Many years of experience with programs from internal departments and external consultants show, that the cash flow often is derived incorrectly, especially concerning the integration of equity, depreciation and interests. The correct method to calculate RoI figures such as internal rate of return and pay-off time is often missing, too.

A programmer who transfers the theoretical model into a computer program often does not know about the future use of the model by the people of sales and marketing, so that some programs may calculate correctly, but do not openly show the calculation method, do not offer presentable charts and results and they are difficult to use, which leads a user to leave the tool aside and refer to simple estimations again.

For this experience, Spemann Consulting offers the whole range of services beside the PG-ROI model, which lead to a constant and beneficial use of the program itself:

- Check and benchmark of existing models and programs
- Concepts and programming of new models
- Training of employees in sales and marketing about basics in accounting, costs calculation and investment theory
- Introduction training for PG-ROI users with examples and assistance during the first projects
- Hotline about use of PG-ROI
- Calculation of projects
- Elaboration of presentations and studies
- Analysis of input data and interpretation of results
- Presentation of studies with the customer (German, English, Spanish)
- Workshops with customers and suppliers for specific case studies
- Constant development of PG-ROI including update service and specific modifications

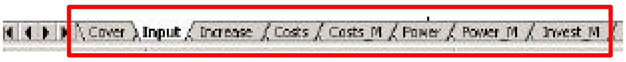
With these range of services Spemann Consulting proceeds on the vision of enhancing the methodology of economic analysis and putting the knowledge into practice.

2 Input data and functions

2.1 Input data for PG-ROI

For the PG-ROI Return on Investment calculation, generally the following information about each option needs to be available:

- Technical data (power, efficiency, operating hours)
- Investment volume and payment schedule
- Financing (credits and their payback conditions)
- Operating costs (fuel, personnel, maintenance etc.)
- Operating revenues for generated electricity



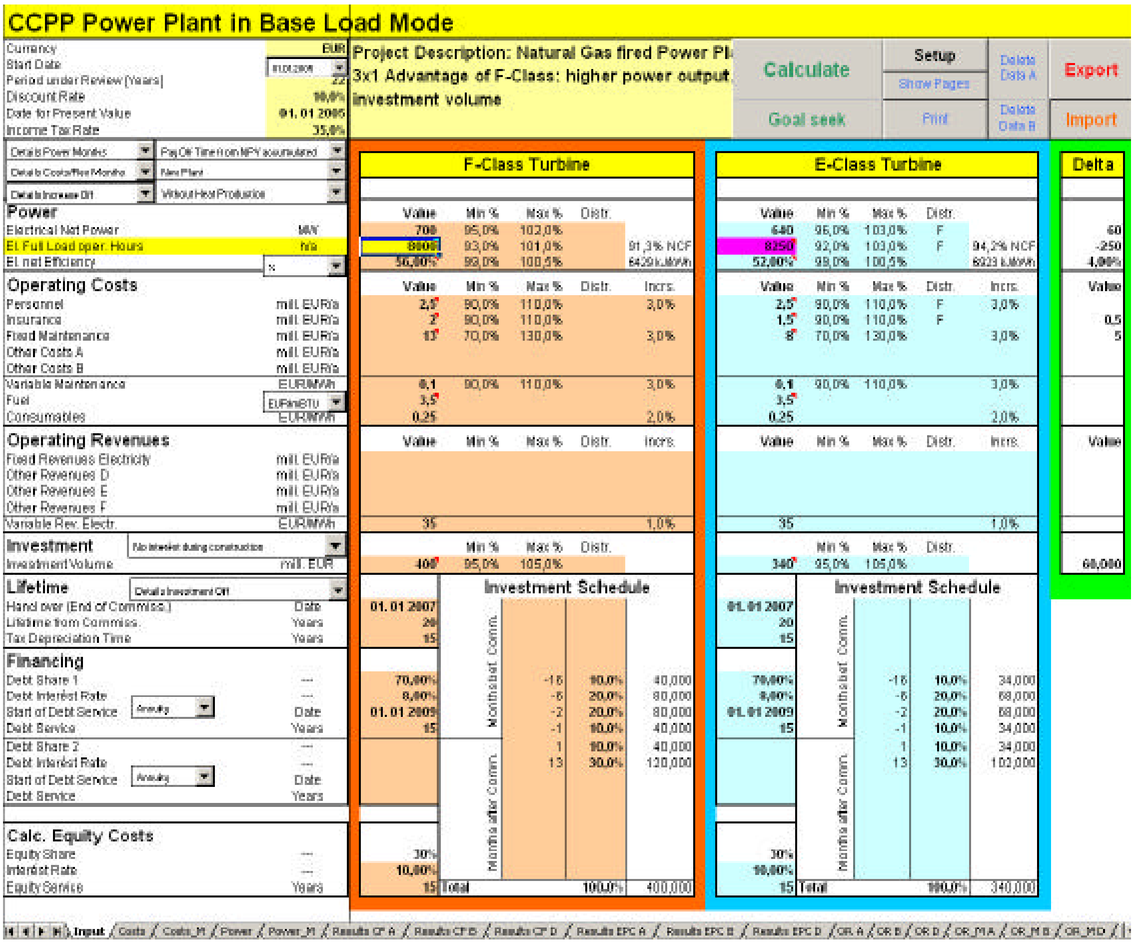
PG-ROI contains several input sheets:

- **Input** is the central input data sheet.
- **Increase** is used, if the increase (or escalation) factors of costs and revenues differ over the years.
- **Costs** and **Costs_M** are for yearly and monthly details for several costs.
- **Power** and **Power_M** are for yearly and monthly details of operating hours.
- **Invest_M** enables monthly detailed input of payment schedule, credit lines and a detailed schedule of depreciation.

The sheet "Input" always will be filled in while the other sheets will only be used, if detailed data are available. The following Chapters explain, how to input data into the sheets and illustrate the way they affect the results.

2.2 Sheet „Input“ for input

The PG-ROI-sheet „**Input**“ is the central input data sheet. Aside from general information like project name, currency, interest and discount and tax rate, technical operating data as well as operating costs, revenues and financing conditions are entered here.



Graphic 2-1 Menu Sheet "Input" for Data input

All colored cells are **input cells**, in which data must be or can be filled in. All **units** are indicated (e. g. mill. USD or USD/MWh), they adapt automatically, if another currency is employed.

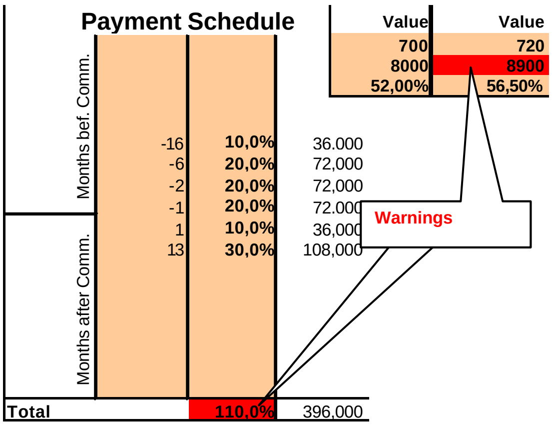
There is no general assignment of the cells that must be filled in or can be filled in. It depends on the specific point of view and the specific question to be solved for the determination, which information is needed.

The cells that can be filled in may be empty without any problem. For example the cell "income tax rate" does not be to be filled in which leads to the negligence of any tax payments. On the other hand the efficiency is needed in most cases.

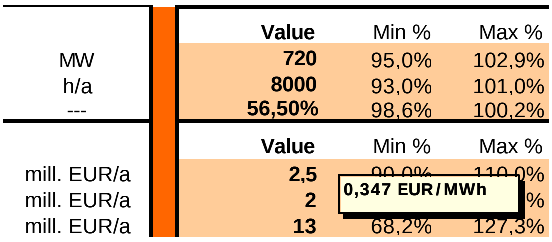
PG-ROI employs some **logic controls**, so that apparently wrong input data or missing cells are marked with red during data input. This coloration gives a hint, where wrong parameter could be, but it does not prevent the program from calculating. So if in special cases a strange value is wanted, the program accepts it.

Examples: Operating hours > 8760 h are technically impossible; the sum of single payments must reach 100%.

Some input cells have **comments** that appear, when the mouse stops over the respective cell.



Graphic 2-2 Warnings on input values



Graphic 2-3 Comments on input values

These comments contain additional information about use of other units, like the conversion from absolute costs (mill USD) to specific costs (USD/MW). Please use the button "update comments" in the main menu for update after input of new values.

The Chapters about "Data input" explain in detail, how to fill in data into single cells.

2.3 Sheet „Input“ as main menu

The sheet „Input“ also serves as main menu with the following buttons and drop-down menus:

The functions of the buttons are detailed in the following Chapters while the drop-down menus are part of the modeling as described in Chapter 3.

Graphic 2-4 Click buttons in sheet „Input“

2.3.1 Calculate

The command button "calculate" starts a complete calculation of the project. Depending on the performance of the used computer, this calculation takes short time (with today normal computers approx. 20 sec).

The status bar at the lower edge of the Excel screen shows the actual status of the calculation. Calculations should not be stopped – but in case of intentional or unintentional stop the input data should be verified (or imported again) and the calculation should be started again.

2.3.2 Goal seek

The goal seek function adapts a selected input value until a desired result figure is reached, hence it is the reverse calculation for answering the following questions (e. g.):

- What is the allowed investment volume that leads to a 3 years pay-off time?
- How many hours the plant must operate so that the internal rate of return reaches 25%?

Please refer to Chapter 5.7 and the examples for more detailed information.

2.3.3 Language

The language of all input and output sheets can be selected with the drop-down switch "Language" between German, English and Spanish. Command buttons and dialog windows always are English.

2.3.4 Sheet protection

Whoever uses PG-ROI can change the format of tables and charts according to his needs. The protection that is applied to each sheet can be removed with the menu Extras \ Protection \ Unprotect sheet.

The unprotected sheet can be reformatted e. g. with scaling chart axis or emphasizing certain cells in tables.

It is recommended to save the changed file with a new name in the same directory and to start a new calculation with the original version of PG-ROI again.

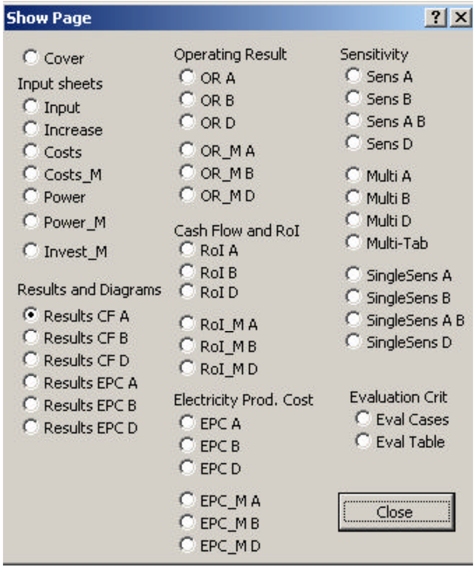
2.4 Sheet selection

PG-ROI consists of many table sheets, which can be selected at the lower edge of the picture. The order of the sheets is as follows:

- Input sheets
- Results overview
- Results tables
- Sensitivity analysis

With the „F2“ button a dialog window is displayed which is used to select the sheets directly thus shortening the search.

The "Cover" sheet contains the project name and the designation of the options; it can be adapted to the respective case.



Graphic 2-5 Sheet selection with dialog

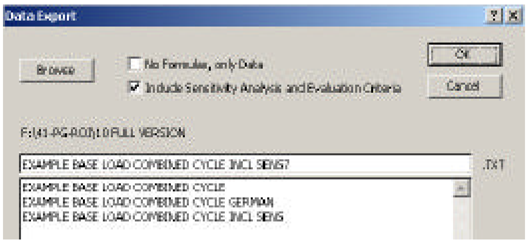
2.5 Import and export of data

The data are to be preferably stored and sent to several users in the form of a text file because it needs only little storage capacity and can easily be sent via e-mail. Sending text files only improves data security because anybody who does not have PG-ROI can practically not do anything with these data.

With the „**Import**“ button previously created txt-files can be read in. For this, the path and the name of the file to be exported are selected in the **Import and Export Dialog Window** via the browser. The dialog window shows a list of the existing txt-files for selection.

With **Export** the file is named via the same dialog. With the „Create Directory“ button a new directory can be created as entered in the input line (first enter the directory, then click the button).

With Export it is possible to include the sensitivity analysis data and evaluation criteria, too. Additionally, only the values of input cells can be exported instead of formulas. By this method, formula references in cells are replaced by the displayed value, which is especially suitable for external links.



Graphic 2-6 Import and export dialog

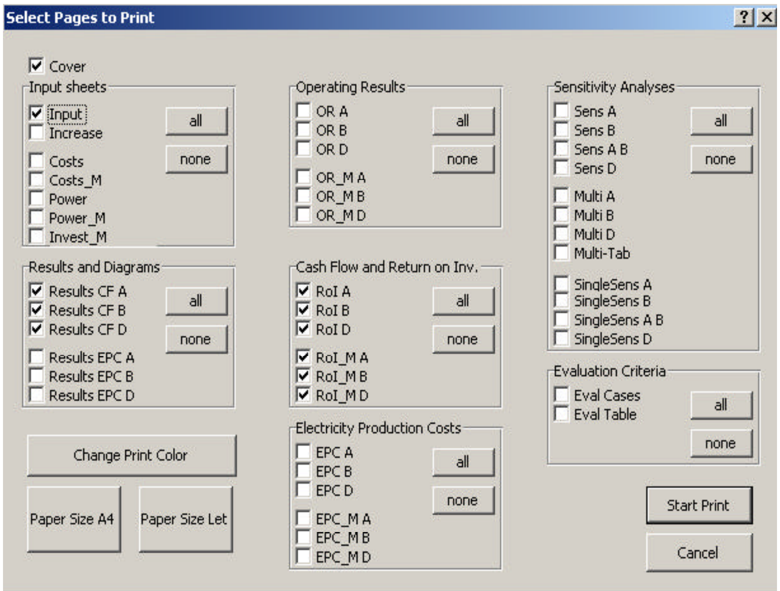
2.6 Print out

The „Print pages“ button opens a window to select input and output pages. To ease the selection, the two buttons „all“ and „none“ are used to select all cells of a category.

On confirmation with „Start Print“ a request for the selection of direct print-out or print-preview appears.

The button „Change Print Color“ allows to switch the **Color on Print-out** on or off so that the input sheets, tables and results can be printed out in black and white. Only diagrams are left as they are and printed out in color (or grey scales with black-and-white printers). Else all pages will be printed in color.

Additionally, the **Paper Size** of all sheets can be changed to DIN A4 or US Paper Size Letter.



3 Modeling projects

3.1 Option A / Option B / Delta

PG-ROI offers the possibility of calculating two options (normally named Option A and B) and the difference between them (Delta), which is a special feature of this program. When calculating only one single option this feature is superfluous and only Option A should be considered. In most of the cases, however, simultaneous calculation of two options is needed (particularly with regard to modernization projects and the comparison of options).

Therefore, PG-ROI offers three possibilities to choose the options or variants to be calculated.

Calculation of a single plant: If it is only one single plant, which is to be calculated without options, then all data for Option A should be filled, while the cells of Option B remain empty (use button "Delete B" allows to delete all input cells for Option B).

Calculation of two options without Delta: If there are two options for a project, the dropdown menu „Options A and B" should be selected. In this case, all technical and financial data of the project are entered separately for Options A and B, and both options are calculated simultaneously but separately. The results of the Delta Calculation must be neglected, they are useless.

Calculation of two options with Delta: With the **Delta Calculation** it is possible to compare both options A and B directly in addition to the method described above. It often provides significant information even if the direct calculation of A and B does not allow any interpretation. See the example of modernization for details of such a case.

The colored frame of the options (red, blue and green) appearing throughout the whole program makes it easy to identify the options.

The selection of the options to be calculated and the possible ways of interpretation of the respective results require some practice at the beginning. Therefore, several examples of typical questions are given in Chapter 7.

Here some preliminary remarks to the description of this method in Chapter 6 are given: The data for the differential investment (Option A minus Option A) are automatically determined. It is a fictive investment, the row of payments of which is obtained from the difference between the rows of payments of the two Options A and B by simply subtracting the revenues, costs, capital services, taxes and so on. However, the key RoI figures cannot be obtained by simple subtraction but have to be calculated on the basis of the different row of payments. This applies in a similar way also to the specific electricity production costs, where the absolute difference in costs is referred to the increase or decrease in power.

Advantage of the Delta calculation: One great advantage of the differential investment calculation is, that costs and revenues that will not change cancel out by subtraction so that they no longer appear in the difference investment.

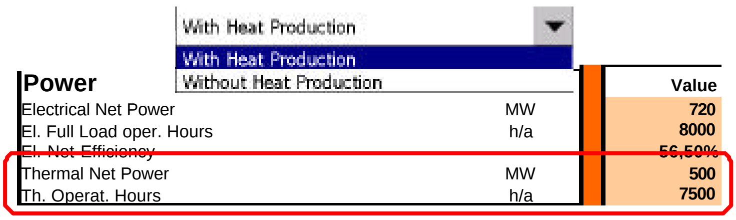
This is typical for modernization projects where the efficiency may change by replacing a row of blades, but the personnel costs will remain constant and are not relevant to this calculation.

3.2 Heat production

PG-ROI provides special input cells for the calculation of thermal power plants, which sell heat or steam apart from their main product, i.e. electricity. The cells are displayed when the dropdown "With Heat Production" is selected.

The revenues realized by the sale of heat are included in the operating results and cash flow similar to the revenues achieved by the sale of electricity.

The revenues from heat output are evaluated like an income (i. e. negative cost) for the specific electricity production costs. It means that electricity is considered to be the main product, and the generated heat is considered to be the spin-off product. A more detailed description of this so-called remaining costs calculation is given in Chapter 5.3.



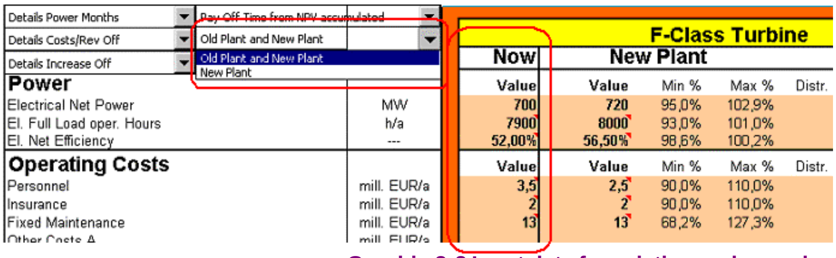
Graphic 3-1 Input data for heat production

3.3 Old and new plant (modernization)

By means of the dropdown window „Old/New Plant“ further columns open or close (column „Now“) for entering the actual values of an existing plant.

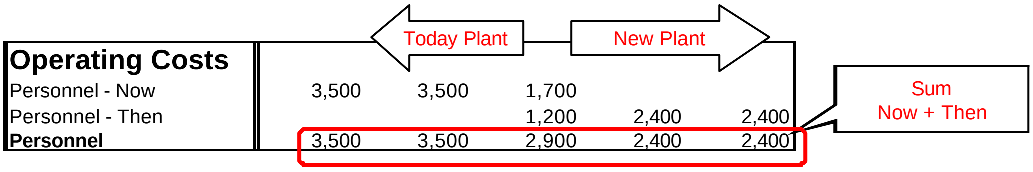
This case assumes that a plant is already in operation but will be replaced later by a new or modernized one. At the moment of commercial handover (see Chapter 4.9), the data of the new plant will be valid instead of the old ones.

It goes without saying, that for completely new power plants ("Greenfield"), there are no data of an existing plant so that „New Plant“ is selected. New plants are so to speak a special case of modernization...



Graphic 3-2 Input data for existing and new plant

Electricity production as well as the operating costs and revenues for the old and new plant are added to represent one fictive plant for which all further results are calculated.



Graphic 3-3 Summary of existing and new plant

Due to the calculation of the results of both the old and new plant, PG-ROI offers the unparalleled possibility of evaluating the modernization of power plants. Chapter 7.2 contains a detailed description of a complex modeling of such modernization.

3.4 Details power and costs

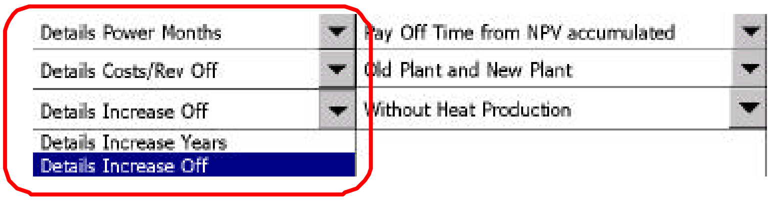
PG-ROI offers three different **Detailing Degrees** dependent on the exactness of input data and the wanted exactness of calculation:

- In the simplest calculation mode it is assumed that the values (e.g. operating hours, costs and revenues) do not change throughout the whole period under review.
- Data of annual exactness are entered separately and distributed evenly to the months of the year.
- Data of monthly exactness the distribution can be considered for the first 5 years (60 months) and for the remaining time the data are taken on an annual basis.

Step-by-step detailing applies only to certain input parameters, i.e. full load operating hours and other costs and revenues providing a sufficiently accurate modeling for most of the projects.

The calculation is made on a monthly basis in each of the three cases (e.g. for the payment schedule and the start of commercial operation), even though the monthly resolution in tables and diagrams prevails only for the first 5 years.

Switch-over is possible via „Details Power“ and „Details Costs/Revenues“ in the dropdown menu. More description of detailing power and costs can be found in the respective chapters. Its importance (particularly its effect on the internal rate of return) is explained in Chapter 7.3.



Graphic 3-4 Dropdown menus for detailing

3.5 Details increase rates

There are two options for increase rates offered by PG-ROI:

- Constant over the period under review (e.g. annual increase in fuel costs by 2%)
- Annual steps (3% in the first year, 2% in the second, 5% in the third year, and so on).

This detailing makes it very easy to reproduce scenarios for future market developments. Detailed information on the input data and an example is given in Chapter 4.4.3.

3.6 Details Investment

For some projects, the components of which the investment consists, are known more detailed. In this case it might make sense, to establish a detailed investment and payment schedule according to the project schedule and the prices of the major components. It also allows mirroring the payments from credit line on the payment schedule.

For this objective, PG-ROI offers the detailed input data sheet “Invest_M” which will be described in chapter 4.10.

4 Data input

4.1 Overview input data

There is a great number of input data. It depends on the questions to be solved for determining, what parameters, data and technical values are necessary for the respective project.

General Data	**Operating Costs**	**Investment**
Start date	Personnel	Invest. volume incl. payment schedule
Period under review from start date	Insurance	Date handover
Discount rate	Fixed maintenance	Lifetime from handover
Date for present value	Other fixed costs	Tax depreciation time
Income tax rate	Fuel	**Financing**
Power	Consumables	Debt shares 1 and 2
Electrical net power	Variable maintenance	Debt interest rates 1 and 2
El. full load operating hours	**Operating Revenues**	Start of debt service 1 and 2
Electrical net efficiency	Fixed revenues electricity	Debt services 1 and 2
Thermal net power	Fixed revenues heat	Equity share
Thermal full load operating hours	Other fixed revenues	Equity interest rate
Degradation factors	Variable revenues electricity	Equity service
	Variable revenues heat	Payment schedule

Graphic 4-1 Overview input data

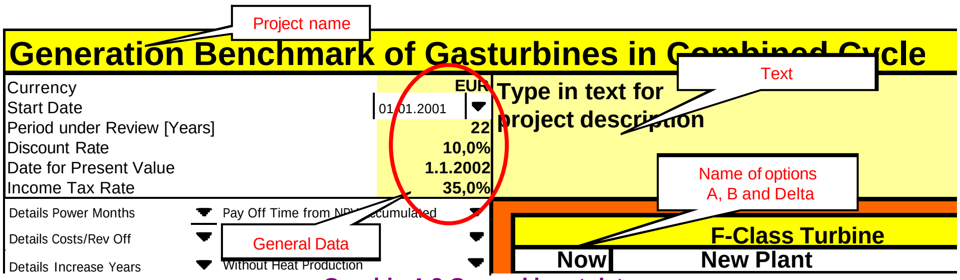
4.2 General data

The general data are entered in the upper part of the „Input" sheet; they are also used for the calculation of both options.

Only the **project name** is entered in the top cell of the sheet "Cover", it appears on each print-out of PG-ROI.

The name of the options A, B and Delta A-B are entered below it. The Delta option is often designated as „Advantage of ‚A' over ‚B'". They are also indicated on all sheets.

Additional description text fits into the cell next to the input data.



Graphic 4-2 General input data

The **currency** is free to choose, at best a three-letter code. This currency applies to all monetary units in the program; conversion from other currencies is to be effected separately or entered as a formula in the input cells.

The **start date** is the date at which calculations begin and, at the same time, the starting point of the time axis in the diagrams for cash flow and electricity production costs. For the sake of clarity, it is always at the beginning of a calendar year, to be selected from a dropdown menu.

Note: When changing the start date, the time axis in the details will change, but the input data will not change automatically.

The **period under review from start date** is the number of years (5 to 50 years) for all calculations. Any inputs for investment, costs and revenues lying beyond the period under review are not taken into consideration. It corresponds also to the length of the X-axis in the diagrams for cash flow and electricity production costs.

The period under review must be given by the user because the profitability and all key investment (RoI) figures will change with a different period under review. In certain cases, a fixed period under review, e.g. 25 years, is not advantageous because various options can differ particularly in the lifetime (see example Modernization). However, in general, the period under review normally should be the sum of the construction period and lifetime.

The present values of costs and revenues are accumulated over the period under review. The results in diagrams and tables are also shown until to the end of the period under review.

The **user gives the discount rate**. When entering a discount rate = 0, the present value and the nominal value are identical. Typical values lie between 6 and 12%. More information about the discount rate is to be found in Chapter 6.2 "Dynamic investment theory".

The **date for present value** is decisive for all calculations made to compare payments and costs of different periods. It is the date to which all future costs and revenues are discounted so that the resulting present values can be compared.

Advantage date for present value: With PG-ROI, the date for the present value can be set freely. This is a difference between PG-ROI and other comparable models where the date of handover (start of commercial operation or end of commissioning) is often necessarily used as the date for the present value. PG-ROI allows to select other dates, like for example a milestone „contract closing" or even a so-called end value, i.e. the opposite of the present value with "up-counted" interests at the end of the period under review. For more information see Chapter 6.2.1 "Cash flow and present value".

The **income tax rate** is entered in percent. The taxable income of each year is multiplied by this tax rate (if the income is positive). The tax rate can lie between 0% (no tax) and 100%. Carrying forward of losses is not provided.

4.3 Technical data

There are many parameters available for a technical description of a power plant (e.g. data of the water-steam cycle, gross power, own electricity consumption, fuel specifications and so on). However, almost all of them are irrelevant for calculating the economic efficiency and should be used only in special programs for the configuration of power plants.

With PG-ROI only data with an economic effect, are taken into consideration:

- Electrical net power
- Electrical net efficiency
- Operating hours

Power		Value
Electrical Net Power	MW	720
El. Full Load oper. Hours	h/a	8000
El. Net Efficiency	---	56,50%
Thermal Net Power	MW	500
Th. Operat. Hours	h/a	6000

Graphic 4-3 Technical input data

With heat production, the parameters for the thermal net power and the thermal operating hours are added to the calculation.

In this way, PG-ROI allows to describe all kinds of technically completely different power plants.

If the dependence of quantities on additional parameters is to be taken into consideration as well, this can be done without difficulties by linking the PG-ROI input cells to external Excel tables by means of formulas.

4.3.1 Electrical power

The **electrical net power** is the maximum power fed into the distribution grid. It is given in MW. The gross power produced by the generator and the own electricity consumption are not taken into consideration.

If an individual value for the electrical net power does not sufficiently reflect the actual load behavior, it is possible to enter three additional load points on the sheet „Power“ (see Chapter 4.3.4) together with the respective efficiency and number of operating hours. The average efficiency is then calculated automatically.

4.3.2 Electrical full load operating hours

The term **electrical full load operating hours** means the theoretical number of hours the plant operates over one period at the given electrical net power. It is an arithmetical equivalent quantity and must not be equated with the actual number of operating hours.

The electrical full load operating hours is related to the **NCF** (Net Capacity Factor) as follows:

The Net Capacity Factor does not equal availability, which refers to the planned and achieved timely availability according given

$$\text{full load operating hours } [\text{h}] = \frac{\text{produced electricity per year } [\text{MWh}]}{\text{net electrical power } [\text{MW}]}$$

$$\text{Net Capacity Factor } [\%] = \frac{\text{produced electricity per year } [\text{MWh}]}{\text{net electrical power } [\text{MW}] \cdot 8760\text{h}}$$

Formula 4-1 Full load operating hours and net capacity factor

definitions. The NCF reflects solely the actually generated amount of energy in relation to the theoretical upper limit.

The full load operating hours of each year are equally distributed to the months starting at the end of commissioning over the total lifetime. For example, if commercial operation starts in May 2002 and the lifetime is 10 years, the operating hours from May 2002 to April 2011 will be 1/12 of the annual full load operating hours for each month.

If this equal distribution does not correspond to the actual situation, the operating hours can be directly fixed for individual years and months as described in the following Chapter.

The equivalent operating hours that are normally used for the calculation of life time and maintenance intervals of gas turbines, are to be calculated from the real operating hours (full load or partial load) and from factors for the operation mode (e. g. the number of start-ups). As this calculation depends on the specific data for each turbine, PG-ROI cannot consider them. In this case, they must be calculated in a separate way, whose results will reflect in operating hours, degradation factors and maintenance costs.

4.3.3 Efficiency

The value of the **electrical net efficiency** is entered in percent. It is an indicator for the degree of the plant's utilization of heat and is calculated by dividing the produced electricity by the employed energy in the form of fuel. In many cases, instead of the electrical net efficiency η, its reciprocal, the specific heat consumption w is indicated in Kilojoules of thermal energy per generated Kilowatt hours of electricity. Conversion is as follows:

$$\text{efficiency}\,[\eta] = \frac{\text{net electrical power output}}{\text{used calorific energy}}\left[\frac{\text{kW}}{\text{kJ}/\text{s}}\right] = \frac{3600}{\text{w}}\left[\frac{\text{kWh}}{\text{kJ}}\right]$$

Formula 4-2 Efficiency and specific energy consumption

Calculation starts out from an average efficiency over the whole lifetime. This means that run-up and run-down periods, where power and efficiency are reduced, have to be included in the efficiency calculation or entered step-by-step via the four loads.

The specific heat consumption is indicated in the comments to the efficiency on sheet „Input“ (for updating the comments, please click on button „Update Comments“).

4.3.4 Heat production

Select „With heat production“ on the „Input“ sheet, if the power plant produces and sells steam in addition to electricity.

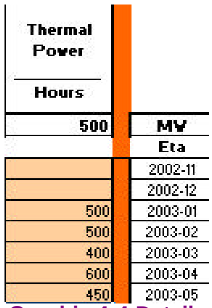
Analogically to the electrical net power the **thermal net power** of electricity and heat producing plants is given in MW. It corresponds to the heat fed into the grid.

The thermal **full load operating hours** are the equivalent number of operating hours when the plant works at the given thermal net power over a period. It is given in operating hours per year.

The thermal net power is multiplied by the thermal full load operating hours to determine the variable revenues.

Fuel costs do not change by the production of heat. Moreover, the thermal efficiency is not taken into consideration because heat is considered to be a by-product. Consequently, the efficiency only refers to the electrical power, which is fed into the grid. It would make no sense to state the thermal power without indicating the electrical power or operating hours.

The operating hours for heat production can be entered on an annual or monthly basis similar to the electrical power. The only difference is that for heat production there is only one load, its value is entered in the „Input“ sheet.



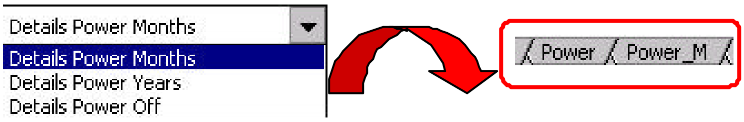
Graphic 4-4 Details heat production

4.3.5 Details power and operating hours

By selecting „Details Power“ in the dropdown menu, new input sheets open.

- „Power“ on an annual basis and
- „Power_M“ on a monthly basis

in which the **full load operating hours** can be entered individually for each year or even for each month during the first 5 years.



In this way, PG-ROI allows to create models for the following cases:

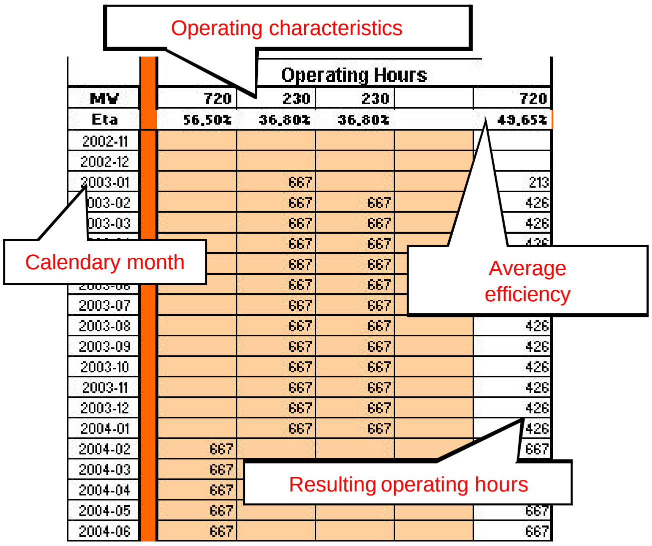
- Changing between **full load operation** and **partial load operation** with different efficiency (e.g. for minimum load during the night)
- Step-by-step commissioning of gas turbines and heat recovery steam generators
- Temporary stop of gas turbines and boiler during a modernization period

The chart is a detail of the sheet „Power_M“, showing the modeling of a step-by-step commissioning of a power plant. The nominal power is 720 MW at an efficiency of 56.5%, but first only one gas turbine with 230 MW and 36.8% efficiency is put into operation in the month 01/2003, followed by the second gas turbine one month later, and the HRSG another 12 months later so that from 02/2004 the plant works according to its final configuration and the inputs for the gas turbines are no longer necessary.

In addition, the number of operating hours (in this case 8000h / 12 = 667h) of the individual months could be varied.

The individual loads are used to calculate the **number of full load operating hours**. In one cell of the table sheet the average efficiency over the total period is calculated for information.

Advantage flexibility: Different **loads** (e.g. full load, medium load, minimum load) usually result in different efficiencies. PG-ROI allows to enter up to four loads independently of each other. The first of which corresponds to the base data of the Input sheet.



Graphic 4-5 Details power and operating hours

If Details Power Months or Details Power Years is selected, only those operating hours are taken into consideration, which are entered in the „Power“ or „Power_M“ sheets. The value for the annual full load operating hours entered in the „Input“ sheet is irrelevant to the calculation but can advantageously be used for formula links to the sheets „Power“ and „Power_M“. This proves to be of great advantage in sensitivity analyses, which vary only the value of the sheet “Input” – but due to the formula links the derived values will change as well.

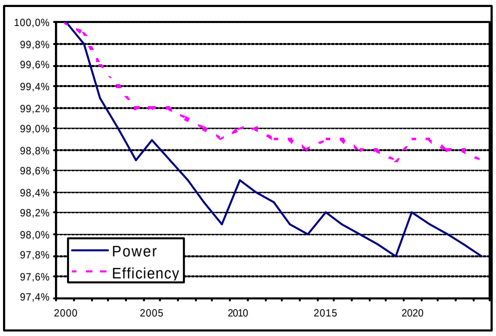
Please note: the given data for the start date and lifetime do no longer determines the period of operation – the data manually entered into the sheets “Power” and “Power_M” override them and prevail.

Other possibilities are described in the examples at the end of the manual.

4.3.6 Degradation factors

In many power plants and turbines, the performance decreases over time (output and efficiency). The reasons are not important for PG-ROI, but only the calculatory effect on output and fuel costs. Data input for such degradation is foreseen in the sheets „Power“ and „Power_M“) by using so-called degradation factors, on for electrical output (MW) and one for efficiency (eta). Typically, these factors are in the range of 98 to 100%, they come back to higher values after modernization or major maintenance works (see graphic for typical degradation curve).

If they are no factors in the table, PG-ROI assumes the factor 1, so that it is not necessary to fill in all cells, only the ones different from 1.



Degradation Factor

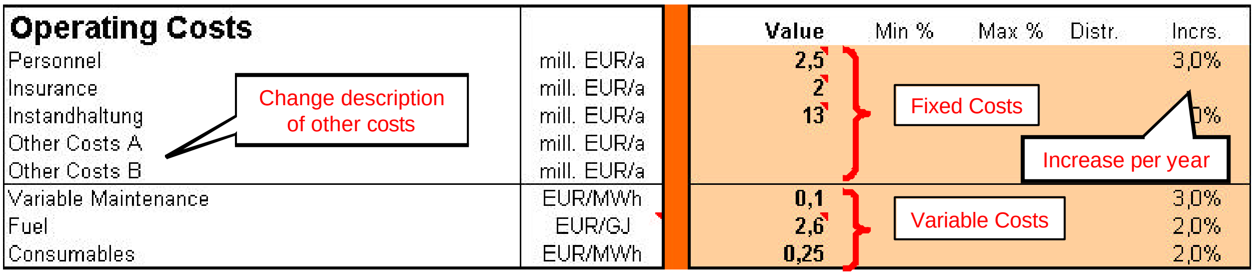
%

MW	Eta
99,80%	99,90%
99,30%	99,60%
99,00%	99,40%
98,70%	99,20%
98,90%	99,20%
98,80%	99,20%
98,50%	99,10%
98,30%	99,00%
98,10%	98,90%
98,50%	99,00%
98,40%	99,00%
98,30%	98,90%
98,10%	98,90%
98,00%	98,80%

Graphic 4-6 Degradation factors

4.4 Operating costs

The operating costs consist of fixed and variable components:



Graphic 4-7 Overview operating costs

The fixed operating costs are personnel, insurance, fixed maintenance costs and two other arbitrarily selectable kinds of costs. The names of these costs c an be arbitrarily adapted and will appear in all input and output sheets.

The fixed operating costs of each year are equally distributed over the months from the start of commercial operation to the end of total lifetime. If commercial operation starts in May 2002 and the lifetime is 10 years, the insurance costs from May 2002 to April 2011 would be 1/12 of the entered value for each month.

This does not apply to the other costs, if the detailing of costs is activated (see Chapter4.4.3).

The variable operating costs consist of the variable costs of maintenance, fuel and consumables.

The variable costs are entered as a specific quantity per generated MWh of electricity or per GJ. To obtain the absolute value, the variable costs are multiplied by the generated amount of electricity [MWh] of each month.

All costs are subject to the respective annual **rates of increase**, which are entered into the cells beside the costs.

Increases in costs always become effective in January of a new calendar year. If the start date is the 1st of January 2002, the first increase will be in January 2003, the second in January 2004 and so on. A monthly distribution of the increase rates is not provided for. The costs remain constant for each month of the year.

If the costs do not increase at a constant rate over the period of the project, this increase can be given individually for each year. See Chapters 3.5 and 4.3.3 on the use of detailed rates of increase.

4.4.1 Fixed operating costs

The three types of costs, personnel, insurance and (fixed) maintenance are given and will increase according to the entered rate of increase. Moreover, there are two other freely selectable types of costs.

Personal costs are entered directly. In many cases, it is possible to determine them as a formula on the basis of average annual wage multiplied by the average number of employees of the power plant.

Insurance costs are directly entered.

Sometimes a percentage of the investment volume is used for determining insurance costs (ranging from 0.5 to 2%).

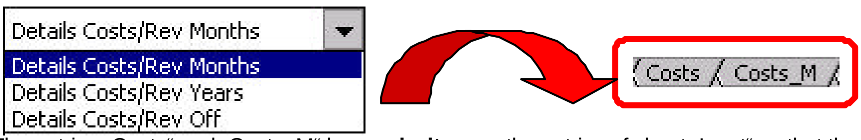
For many power plants it is advantageous to divide the **maintenance** costs into fixed and variable costs. The fixed maintenance costs are entered in million monetary units per year. In many cases, a value per kW or MW of installed net power is indicated because standard values for different types of power plants can be found. Multiplying the specific costs by the installed electrical net power does the conversion to absolute values at best.

The two items **Other costs A and B** can be used, if required, as for example extra maintenance costs or a fee on CO_2 emission. By linking the costs to the operating hours (Power, Power_M) it is relatively easy to create a CO_2-calculator.

mill. EUR	Turbine Blades	Other Costs B
2001	2,1	
2002		
2003	2,5	
2004		
2005		
2006	2,1	
2007		
2008		
2009		
2010	2,5	
2011		

Graphic 4-8 Details costs

A special feature of Other Costs A and B is that they can be given directly for individual years or months. On selection of „Details Costs/Revenues“ in the dropdown menu, the separate **input sheets „Costs“** (years) and **„Costs_M“** (months) open and allow to enter the costs and revenues individually for each month or year.



The entries „Costs“ and „Costs_M“ have **priority** over the entries of sheet „Input“ so that the previously given lifetime for the plant in sheet „Input“ are not taken into consideration. Instead, calculations are made using directly the amount of money specified for the individual periods multiplied by the respective rate of increase.

In this way, discontinuous costs, e.g. shift or extension of maintenance intervals, can well be included in the calculation. The operating hours or off-periods will then be entered with monthly resolution in sheet „Power_M“ as well as the respective extra costs, e.g. under the designation “Turbine Blades” in sheet „Costs_M“.

4.4.2 Variable operating costs

Three types of costs make up the variable operating costs, which increase according to their respective rate.

The **variable maintenance costs** are specifically indicated in monetary units per generated MWh of electricity. They can also be listed in detail in the sheets „Costs" and „Costs_M" over months and years (see previous Chapter).

The **fuel costs** are indicated as specific fuel costs in monetary units per Gigajoule (1 GJ =10^9 J = 10^6 kJ), a quantity that can easily be derived from other data, e.g. price per ton of fuel and its lower heat value according to the following formula:

$$\frac{Euro}{GJ} = 1000 \cdot \frac{price_{perTon}}{heat\ value} = \frac{Euro/t}{kJ/kg}$$

Formula 4-3 Specific fuel costs

The often used unit mBTU (million British Thermal Units) can easily be converted into GJ: 1 GJ = 0.9478169879134 mBTU.

All accessory fuel costs (e.g. transport costs) should be included in the fuel costs or as fixed costs (Other Costs A or B).

Fuel costs are a significant component of the overall costs of a fossil-fired power plant. They are calculated for each period (years or months) from the specific fuel costs (fuel price), electrical net power [MW], full load operating hours [h] and the electrical net efficiency [–] according to the formula below. For more information on the efficiency, see Chapter 4.3.2.

$$\text{fuel costs } [Euro] = 3{,}6 \cdot \frac{\text{spec fuel costs } [Euro/GJ] \cdot \text{power } [MW] \cdot \text{full load operating hours } [h]}{\text{efficiency}}$$

Formula 4-4 Absolute fuel costs

These specific fuel costs always refer to the thermal energy of the fuel employed.

The **consumables costs** are indicated as specific costs in monetary units per generated MWh. Typical consumables are limestone in coal-fired power plants, water or chemicals for flue gas washers.

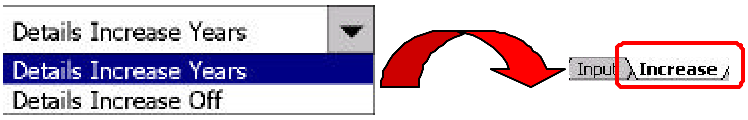
Consumables costs are calculated for each period (months or years) from the specific consumables costs, the electrical net power and the full load operating hours:

$$\text{consumables costs } [Euro] = \text{spec consumables costs } [Euro/GJ] \cdot \text{power } [MW] \cdot \text{full load operating hours } [h]$$

Formula 4-5 Absolute consumables costs

4.4.3 Details increase costs

On selection of „Details Increase" in the dropdown menu, the separate **Input sheet „Increase"** opens to enter the **increase rates for costs and revenues** individually for each year.



In this sheet the increase rates for all operating costs and revenues can be entered. The increase rates refer to the respective rate of the previous year.

Example: Initial value 1000 EUR in the year 2002. An increase by 4% in the second year results in 1040 EUR. An increase by 5% in the third year results in 1092 EUR.

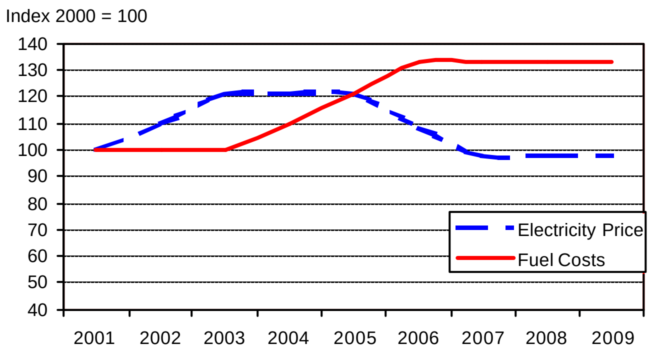
The entries in input sheet „Increase" have **priority** over the entries in sheet „Input". On selection of Details Increase Years, the increase rates in the sheet "Input" will no longer be taken into consideration.

Example: In the following, a diagram representing the increasing and decreasing rates of electricity revenues and fuel costs for a market awaiting its deregulation:

It is expected that the electricity tariffs will increase first, followed by a decrease in prices a few years later. A clear increase in fuel costs is expected first, followed by saturation.

A button allows the automatic transfer of the increase factors in sheet "Input".

	Fuel	Variable Rev. Electr.
2001		
2002		10,0%
2003		10,0%
2004	10,0%	
2005	10,0%	
2006	10,0%	-10,0%
2007		-10,0%



Graphic 4-9 Scenario for price and cost escalation

PG-ROI does not assume any further „inflation" apart from the increase rates. The calculations are generally made in real values. Since inflation is nothing else but the weighted average of increase rates of individual goods and services, the exactness of a calculation would deteriorate by including an additional rate of inflation.

The situation is different however in countries with hyper inflation which would have to be taken into consideration in any case but practice has shown that calculations are made in hard currencies anyway (USD or EUR).

4.5 Minimum- and maximum values / distribution

Many data described in the preceding Chapters are not exactly known and can only be estimated. For this purpose, PG-ROI offers the probability analysis, a special kind of a multi-dimensional sensitivity analysis. A more detailed description and interpretation is given in Chapter 5.4. The necessary data for the probability analysis are entered in sheet "Input".

The **base value** (corresponding to 100%) is entered into the first column ("Value") of the cells with colored background. These values should correspond to the best estimated value.

The cells **„Min%"** and **„Max%"** show the range in which the entered values can vary. They are entered as a percentage of the base value. When the base value is 2.5 for personnel costs and entering 90% as the minimum and 110% as the maximum value, the personnel costs vary between 2.25 and 2.75.

Power		**Value**	Min %	Max %
Electrical Net Power	MW	**720**	95%	103%
El. Full Load oper. Hours	h/a	**8000**	93%	101%
El. Net Efficiency	---	**56,50%**	99%	100%
Operating Costs		**Value**	Min %	Max %
Personnel	mill. EUR/a	**2,5**	90%	110%
Insurance	mill. EUR/a	**2**	90%	110%
Instandhaltung	mill. EUR/a	**13**	68%	127%
Other Costs A	mill. EUR/a			
Other Costs B	mill. EUR/a			
Variable Maintenance	EUR/MWh	**0,1**	100%	110%
Fuel	EUR/GJ	**2,6**		
Consumables	EUR/MWh	**0,25**		

Graphic 4-10 Input of min and max values

In the probability analysis many calculations are done where the input data vary statistically independent between the minimum and maximum value. Since all values change simultaneously, and carrying out a large number of calculations, the whole field of possible entries is covered thus creating a field of results.

With the Delta calculating method the question arises to what extent the entries should vary really independently of each other. This is shown by an example:

Let us assume that Option A is the plant with a powerful turbine (720 MW) and Option B is the same plant with a less powerful turbine (640 MW) but requiring a lower investment. The Delta calculation then gives an answer to the question whether the difference in prices between the expensive and less expensive turbine will repay, that is whether the sale of additionally produced power justifies the investment.

The additionally generated electricity and thus the profitability depend largely on the number of operating hours, of course. Assuming the number of operating hours may vary between 5000 and 8000 per year, the following entries would have to be made:

Details Power Off	Pay Off Time from NPV accumulated									
Details Costs/Rev Off	New Plant		**F-Class Turbine**				**E-Class Turbine**			
Details Increase Off	Without Heat Production									
Power			**Value**	Min %	Max %	Distr.	**Value**	Min %	Max %	Distr.
Electrical Net Power		MW	**720**				**640**			
El. Full Load oper. Hours		h/a	**8000**	62,5%	100%		**8000**	62,5%	100%	
El. Net Efficiency		---	**56,50%**				**52,00%**			

Graphic 4-11 Statistically independent distribution

In reality, the number of operating hours does not depend on the type of turbine but on the market so that it would make no sense to compare the 5000 operating hours of Option A with the 8000 operating hours of Option B. In this case it would be suitable to apply the same value for both options and calculating the Delta so that there is a Delta for 5000h, for 5100h and so on, up to 8000h.

This functionality (which is exclusively needed for Delta calculation) is offered by PG-ROI by entering "F" in column „Distribution" of Option B.

Power		**Value**	Min %	Max %	Distr.	**Value**	Min %	Max %	Distr.
Electrical Net Power	MW	**720**				**640**			
El. Full Load oper. Hours	h/a	**8000**	62,5%	100%		**8000**	62,5%	100%	F
El. Net Efficiency	---	**56,50%**				**52,00%**			

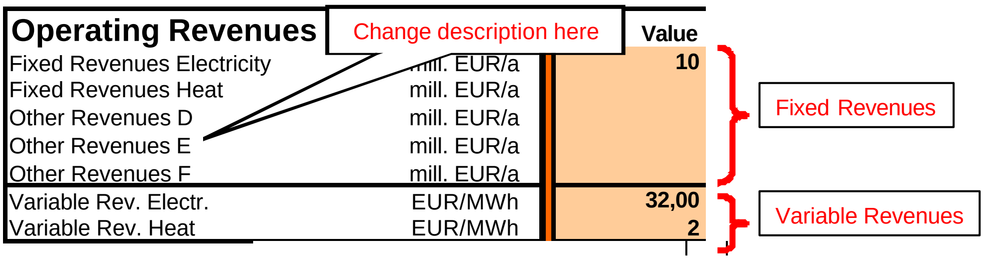
Graphic 4-12 Statistically dependent distribution

This makes sure that both options change by the same percentage (of their respective base value) upwards or downwards in the probability analysis applying the values „Min%" and "Max%" of Option A to Option B.

4.6 Operating revenues

The operating values consist of fixed and variable components:

Fixed operating revenues are hardly to be found; it is only in certain markets or in the case of peak load power plants that a price is paid for the provision of capacity, for example. Just as rare are the cases where fixed revenues are achieved by the production of heat. For the sake of flexibility in modeling, another three types of fixed revenues ("Other Revenues D, E, F") can be designated. These designations are then entered into all input and output sheets.



Graphic 4-13 Overview operating revenues

A special case for Other Revenues would be, for example, revenues from selling the plant at the end of the time under review (residual value) making it possible to compare options with different lifetimes.

The fixed operating revenues of each year are equally distributed to the months from the start of commercial operation over the total lifetime. When commercial operation starts in May 2002 and the lifetime is 10 years, the Fixed Revenues Electricity from May 2002 to April 2011 would be 1/12 of the entered value for each month.

This does not apply to Other Revenues, if detailing of revenues is activated (analogously to the operating costs, see Chapter 4.4.1).

The **variable operating values** are primarily the revenues achieved by the generation of electricity indicated in monetary units per MWh. Moreover, variable revenues from the production of heat are provided for.

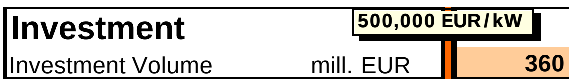
The variable revenues are entered as a specific quantity per generated MWh of electricity or heat. The absolute amount of revenues is obtained by multiplying the variable revenues by the generated electricity [MWh] of each month.

All revenues are subject to their respective annual **increase rates**, which are entered into the cells beside the revenues (analogously to the operating costs, see Chapter 4.3.1).

4.7 Investment

The **investment volume** includes all direct investment costs of the power plant (materials and wages etc.) as well as the costs for preparation, planning, construction and commissioning and the owner's expenses (e.g. estate and development costs, fees), which do not belong to the investment costs in a stricter sense.

The sum of these costs is indicated in million monetary units. Another frequently used unit is the specific investment volume per installed Kilowatt. The absolute value is obtained by multiplying this quantity by the electrical net power. The specific price is shown in the comments to the investment volume.



Graphic 4-14 Specific investment volume

The investment volume does not include the **interest during construction**. This interest is not considered until the calculation of the capital requirement in the profitability calculation:

- Investment volume + interest during construction = capital requirement

The interest during construction on the investment volume can be selected via the dropdown menu. In addition, it is possible to choose between interest during construction with or without compound interest.

Interests during construction apply only to the debt share but not to the equity share. This interest increases the credit volume until the start of debt service, as well as it increases assets. The distribution between equity capital and credit shifts slightly by including the interest during construction because they only increase the credit share.

The interest during construction is calculated on a monthly basis (see equation for any period j) and is cumulated up to the start of debt service. For calculation of the compound interest, the accrued interest is added to the cumulated debt. On this basis, the new interest is calculated.

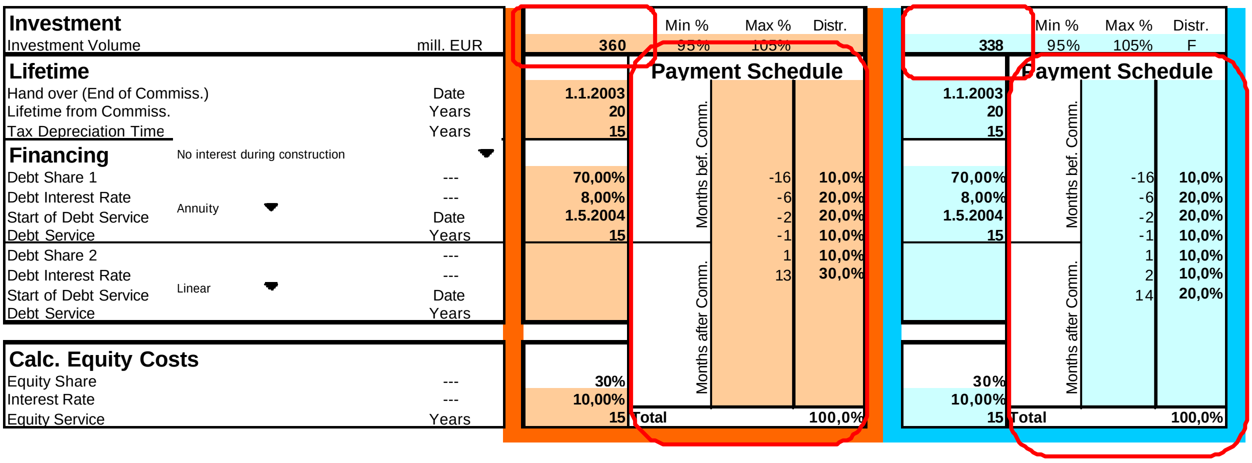
$$\text{interest}_j = \text{accumulated credit}_j \cdot \left[(1 + \text{interest for credit})^{1/12} - 1 \right]$$

Formula 4-6 Interest during construction

There is a so-called **price formula** that is used to consider the increase in the investment volume from the start date to the date of payment during the construction period. It is used to include an increase in costs during the construction of a plant (costs of materials, personnel costs) in price formation. However, practice has shown that it is easier to determine price increases in a by-calculation and to integrate it in the absolute investment volume and the percentage payment schedule. Accordingly, PG-ROI does not offer a price formula.

4.8 Payment schedule

In general, investment payments are not to be effected at once neither are distributed continuously over the period of construction. They depend on a negotiated **payment schedule**. It is entered into the input matrix „Payment Schedule“ for Option A and B respectively.



Graphic 4-15 Payment schedule

In the left column, the dates of payment are relative to the date of handover (upper part: in months <u>before</u> handover with negative sign, lower part: in months <u>after</u> handover). When the date of handover is 1.1.2003, then „-1 month“ = December 2002 and „+1 month“ = February 2003. On the right of this column definite payment rates (as a percentage of the investment volume) are assigned to a maximum of 16 dates.

Of course, the total sum of all part payments must be 100% and lie within the period under review, that is the first payment must be effected after the start date (see Chapter 4.2).

The physical **time of construction** is therefore not important in a profitability analysis. For the investor, it is the dates of payment and the start of commercial operation, which count.

PG-ROI assumes all investment payments to be at the end of month, like all other payments.

4.9 Lifetime

The day of **handover** (= end of commissioning or start of commercial operation) is entered as a date and must always be the first day of a calendar month.

Graphic 4-16 Lifetime

The **lifetime from handover** is calculated from the date of handover until the end of commercial operation. It does not automatically correspond to the technical lifetime. With PG-ROI, the economic lifetime is decisive; the technical lifetime may be longer.

The lifetime is entered in years. If a plant is put into operation in May 2002 and is operated for ten years the lifetime will end in April 2011.

The fixed annual operating costs and operating revenues are equally distributed to the months from the start of commercial operation over the total lifetime. When commercial operation starts in May 2002, for example, and the lifetime 10 years, the costs and revenues from May 2002 until April 2011 would be 1/12 of the annual value for each month.

This does not apply to the Other Costs and Revenues, if the detailing of costs is activated (see Chapter 4.4.1).

The **tax depreciation time** can distinctly deviate from the time of commercial use. It is entered in years starting from the date of handover.

The tax depreciation time is important for determining the profitability because it leads to deductible costs thus reducing the profits and the tax burden. This tax diminution influences the cash flow although no payment is made by (straight-line) depreciation.

If there is no general 100% linear depreciation, as components might have different depreciation periods, PG-ROI offers a detail input sheet., please see the following chapter.

4.10 Details Investment

The payment schedule might be sufficient detailed at an early stage of the project, and for many projects they payment schedule data are not known at all (e. g. for market studies). On the other hand it can be useful to describe the payment schedule and the schedule for the credit line more detailed for specific projects. If major components such as land, buildings, machinery etc the project schedule is known, and the progress in construction reflects in the payment schedule, then PG-ROI in its sheet “Invest_M”, offers the possibility to put in the data for payment schedule and credit schedule in a very detailed way.

Graphic 4-17 Sheet „Invest_M“

Category	Land	Buildings	Access roads	Plant (civil works)	Plant (mechanical)	Plant (electr., I&C)	Other Invest A	Other Invest B	Other Invest C	Other Invest D	Credit 1	Credit 2	% Credit
mill. EUR	20	30	10	100	120	20	30				60	100	
% Depreciation		100%		100%	100%	100%	50%						
Years deprec.		50		25	20	10	20						
2005-01	50,0%		20,0%								20,0%		100%
2005-02	50,0%	10,0%									20,0%		96%
2005-03		10,0%	50,0%								20,0%		109%
2005-04		10,0%					50,0%				20,0%		94%
2005-05		10,0%					50,0%				20,0%		87%
2005-06		20,0%		10,0%									71%
2005-07		20,0%										20,0%	88%
2005-08		10,0%		10,0%									77%
2005-09		10,0%		10,0%	30,0%							20,0%	65%
2005-10				10,0%		20,0%							60%
2005-11				10,0%								20,0%	68%
2005-12				30,0%	30,0%	40,0%							48%
2006-01			30,0%									20,0%	55%
2006-02						30,0%							54%
2006-03				10,0%	30,0%							20,0%	52%
2006-04													
2006-05													
2006-06				10,0%	10,0%	10,0%							48%
2006-07													
2006-08													

When the sheet „Invest_M“ is visible, the payment schedule in sheets „Input“ is disregarded (they are just invisible but not deleted, so that a formula link between „Input“ and „Invest_M“ is still possible). On the other hand, the automatic rule of 100% depreciation and interest during construction are not regarded anymore.

In the first line of sheet „Invest_M“) the absolute amount of the major components is put in. The titles can be changed in case of „Other Invest A, B, C, D“), directly overwriting the text in the cells.

The lines „% Depreciation“ and “Years Depreciation” refer to the tax depreciation of components. Land and access roads might not be considered in depreciation at all, Buildings over a longer period than machinery components. From the single depreciation of each component, the total depreciation is summed, always regarding a linear type depreciation over the years. Nonlinear deprecation is not foreseen in this model.

In the following cells there are the percent portions of payments for each component in a monthly schedule. The sum of percentages should always result in 100%, otherwise the calculation would be incomplete. These percentages then indicate, in which month a certain portion of the component’s price is to be paid.

A similar approach is taken for the two lines of credit that might be drawn in portions. Here the sum of percentages in each column should be 100%, too. Start and duration of payback are defined in sheet “Input”.

As outlined before, the monthly detail for Investment does not allow interest during construction, and the dropdown menu in the sheet „Input“ automatically changes to „no interest during construction“. Even though it might seem to be a restriction of the program, it is still possible to integrate highly complex interest rates into the calculation. In this case, a side calculation should provide the real credit volume (basic credit plus interests). This value is put in the first line of “credit volume”, and the percent portions of credit line drawn per month is to be calculated by the simple formula, in which the real drawn credit volume is divided by the real credit volume including interest (e. g. for the first cell in the above example: The formula ‘=12/N$6”, results in 20% for a credit volume of 60 and no interest during construction, but drops to 18.46% in credit plus interest sum 65). The sum of percentages in the column in the latter case does not sum 100% but remains lower, because the interest during construction are not part of the credit payment to the debtor.

In the right column “% credit”, the accumulated credit share is listed as information. Calculated by the accumulation of all payments from credit line divided by the accumulation of all payments for project components. In the figure can be derived for July 2005, that 88% of all payments until the moment are covered by credits. Of course it is possible to achieve an overpayment of credits, which occurs whenever there are more credits drawn than payments made for the project. In the above example this is the case only once in March 2003.

4.11 Financing

The investment volume is financed by equity capital and external capital (credit or debt). If the debt share is 0%, the investment is exclusively financed by equity capital, if it is 100%; the investment is exclusively financed by credits.

Advantage of PG-ROI: The financing data can be individually entered and thus prove to come close to reality. The user can enter even two debt shares separately from each other (debt share 1 and debt share 2). The interest rate for both debt shares can be entered separately. Moreover, the **start of debt service** and the **debt service** period can be fixed independently of each other. In addition, the dropdown menu allows to enter the **type of payback** for the two credits: annuity or linear payback.

It goes without saying that the sum of both debt shares must not exceed 100%.

The **debt share** in the total investment volume is given in percentage (between 0% and 100%). If the debt share is zero, the investment is exclusively financed by equity capital, if it is 100% no equity capital is used.

The **debt interest rate** reflects the weighted medium interest rate for the credit which is to be paid to the lender. The value is entered in percentage for each year. As a rule, the higher the risk of a project the higher the interest rate.

Financing	No interest during construction		
Debt Share 1		---	70,00%
Debt Interest Rate	Annuity	---	8,00%
Start of Debt Service		Date	1.5.2004
Debt Service		Years	15
Debt Share 2		---	10,00%
Debt Interest Rate	Linear	---	5,00%
Start of Debt Service		Date	1.8.2004
Debt Service		Years	4

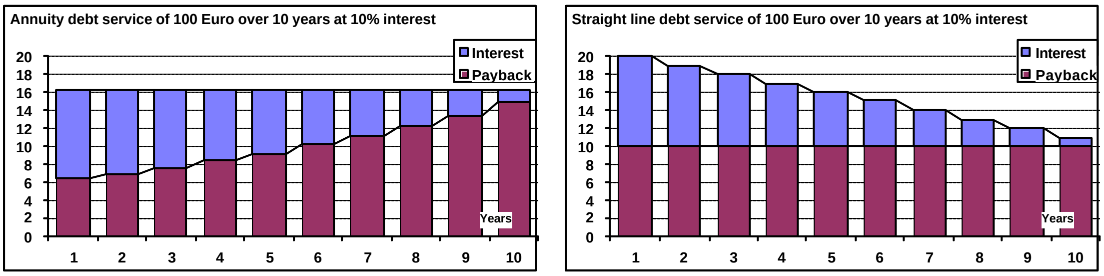
Graphic 4-18 Input data financing

The **start of debt service** is entered as a date. In many cases, debt service starts in the first operating year but it can also be fixed to a later start date so that there is a period of time during which no payments are to be made other than interest. By it, the lender allows the investor to bridge a lower cash flow at the beginning of operation.

The **debt service** is entered in years from the start of debt service. It is determined by the terms set forth in the credit agreement. As a rule: the higher the lender's risk the shorter the debt service time. Debt service consists of payback and interest.

The most important **types of payback (redemption)** for credits are the annuity payback and straight-line payback methods. With the **annuity payback** method the debt service remains constant over the whole period. While the payback share increases in the course of the years, the interest share decreases.

With the **straight-line payback** method, a constant portion of the initial amount of credit is paid back each year during the debt service period and interest is paid on the remaining amount of credit, thus the interest share decreases. The total debt service, i.e. the sum of interest and payback, decreases in the course of the years.



Graphic 4-19 Annuity and straight line payback

Similar to the operating costs and revenues, all payments, interest and payback, are assumed to be at the end of each calendar month.

There is no equity capital service provided for in the profitability calculation. As no payment is effected the equity service would not affect the monetary asset or cash flow. In a certain way, the cash flow itself could be regarded as a kind of equity capital service but this would be the result of the calculation only, not yet an input parameter.

4.12 Calculatory equity costs

The input cells for the calculatory equity costs are only used for calculating the electricity production costs (full costs calculation), they are not necessary for calculating the cash flow and the resulting profitability of the investment (for more information see Chapter 6.1 Balance and Cash flow).

For determining the electricity production costs, a capital service is provided for the remaining equity share apart from the capital service for credits. Since no payments are made it is mere calculatory.

Calc. Equity Costs		
Equity Share	---	20%
Interest Rate	---	10,00%
Equity Service	Years	15

Graphic 4-20 Calculatory equity costs

The **equity share** of the plant is automatically calculated on the basis of the debt share (equity = 100% minus debt). When the debt share is zero, the equity share is 100% meaning purely an equity capital financing.

The **equity capital interest rate** is not used for calculating the profitability. However, it is included in the calculation of the electricity production costs for determining the calculatory equity costs. The rate of interest should reasonably equal the discount rate.

The period of **equity service** is entered in years from handover (start of commercial operation). In any case, it should be shorter than the lifetime. For calculating the electricity production costs, it is always assumed that the annuity payback method is used.

5 Results - output

The calculation of economic benefits of each project leads over many steps to results that primarily are displayed in detailed tables for each month and year, then graphically shown in diagrams and finally condensed into RoI figures.

PG-ROI contains several output sheets as shown in the following list:

Content	Details	Output sheets
RoI figures and charts	Cash flow A/B/D	Results CF A/B/D
	Electricity production costs A/B/D	Results EPC A/B/D
Tables	Operating result A/B/D	OR A/B/D OR_M A/B/D
Tables	Cash flow A/B/D	RoI A/B/D RoI_M A/B/D
	Electricity production costs A/B/D	EPC A/B/D EPC_M A/B/D
Sensitivity analysis	Probability analysis A/B/D	Sens A/B/D/A B
	Multiple sensitivity analysis A/B/D	Multi A/B/D Multi-Tab
	Single sensitivity analysis	SingleSens A/B/A B
Evaluation criteria	Four derivation A	Eval Case
	Sensitivity analysis A	Eval Table

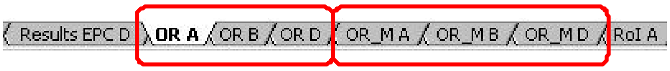
Graphic 5-1 Overview output sheets

The following description of output sheets only describes Option A; the information for Option B and the Delta option are similar and the output sheets are neighbored.

Data base for the charts are generally the respective tables (only the data for the probability analysis are invisible).

- Table „EPC A“ is the data base for the upper chart in „Results EPC A“
- Table „EPC_M A“ is the data base for the lower chart in „Results EPC A“
- Table „RoI A“ is the data base for the upper chart in „Results CF A“
- Table „RoI_M A“ is the data base for the lower chart in „Results CF A“
- Table „Multi-Tab“ is the data base for the chart „Multi A“
- Table „SingleSens A“ is the data base for the charts on the same sheet
- Table „Eval Table“ is the data base for the charts that can be called via the button on the same sheet

5.1 Operating results

The Operating Result of each option is displayed in 

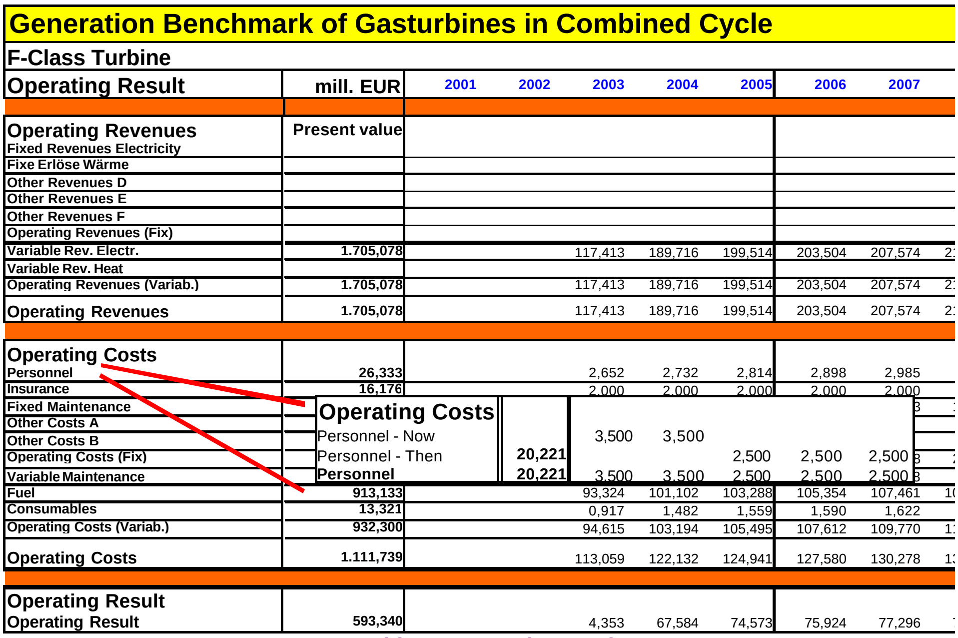
detailed output tables.

The components of the operating result are listed on a yearly base in the sheet "OR A". If the data for operating hours and/or costs are entered on a monthly base (see Chapter 4.3.4 and 4.4.3), then the first five years from start date are listed on a monthly base in the additional sheet „OR_M A“.

The upper part of the table are the operating revenues, then the operating costs and in the last row the operating result. All data are million monetary units with three digits.

The nominal values are displayed in single columns for each year. The resulting present value is accumulated over the period under review and shown in the second column (for present value, see Chapter 6.2.1). There are also subtotals for all variable and fixed operating costs and revenues.

If for a modernization project the existing plant takes part (see Chapter 3.2), then the values of the "today plant" and the "new plant" are shown up in two additional lines and then are summed up in a single line, as shown in the small window inside the table.



Generation Benchmark of Gasturbines in Combined Cycle

F-Class Turbine

Operating Result	mill. EUR	2001	2002	2003	2004	2005	2006	2007
Operating Revenues	Present value							
Fixed Revenues Electricity								
Fixe Erlöse Wärme								
Other Revenues D								
Other Revenues E								
Other Revenues F								
Operating Revenues (Fix)								
Variable Rev. Electr.	1.705,078			117,413	189,716	199,514	203,504	207,574
Variable Rev. Heat								
Operating Revenues (Variab.)	1.705,078			117,413	189,716	199,514	203,504	207,574
Operating Revenues	1.705,078			117,413	189,716	199,514	203,504	207,574
Operating Costs								
Personnel	26,333			2,652	2,732	2,814	2,898	2,985
Insurance	16,176			2,000	2,000	2,000	2,000	2,000
Fixed Maintenance								
Other Costs A								
Other Costs B								
Operating Costs (Fix)								
Variable Maintenance								
Fuel	913,133			93,324	101,102	103,288	105,354	107,461
Consumables	13,321			0,917	1,482	1,559	1,590	1,622
Operating Costs (Variab.)	932,300			94,615	103,194	105,495	107,612	109,770
Operating Costs	1.111,739			113,059	122,132	124,941	127,580	130,278
Operating Result								
Operating Result	593,340			4,353	67,584	74,573	75,924	77,296

Operating Costs						
Personnel - Now		3,500	3,500			
Personnel - Then	20,221			2,500	2,500	2,500
Personnel	20,221	3,500	3,500	2,500	2,500	2,500

Graphic 5-2 Operating result

The data of the operating result are not displayed directly in a chart. If needed, then the user easily can create a new chart with link to the tables "OR A“ or "OR_M A“.

All payments (revenues, costs and financing) are assumed to be at the end of each month.

5.2 Return on investment (RoI)

The concept "Return on investment (RoI)" applies within PG-ROI for the calculation of the cash flow, its present value, the Net Present Value (NPV), the Internal Rate of Return (IRR), the Pay-off Time (POT), i. e. the three important RoI figures that can be derived from the cash flow and that allow the assessment of an investment. None of the three figures totally overrules the others, so that they should be used in combination for any investment decision.

Basis of return on investment calculation is the cash flow (i. e. the change of cash in the balance sheets between two periods) that includes all positive payments to the investor and all negative payments by the investor. Insofar, PG-ROI is a cash flow model. See Chapter 6.1 for the definition and calculation of cash flow and 6.2 for an introduction to dynamic investment theory.

All payments (revenues, costs and financing) are assumed to be at the end of each month.

The results of cash flow calculations are listed in tables and in charts. The RoI investment figures appear in the overview output sheet "Results RoI A" together with the diagrams. See the following sub-chapters for detailed description of the PG-ROI output sheets.

5.2.1 Return on investment tables

The components of the RoI calculation are listed on a yearly base in the output sheet "RoI A". If the data for operating hours and/or costs are entered on a monthly base (see Chapter 3.4 and 4.4.3), then the first five years from start date are listed on a monthly base in the additional sheet "RoI_M A".

All values are in million monetary units. The nominal values are in the columns for each year and the cumulated present value over the whole period is shown in the second column (see Chapter 6.2.1 for the definition of present value).

Investment and financing

The **first part of the table** contains investment and financing: the components of the investment volume of equity and debt, the interest during construction and the resulting capital requirement.

The debt is drawn according to the debt share from one or two credit lines and according to the payment schedule of the investment.

The **payment schedule** is detailed on a monthly basis in sheet "Input" and PG-ROI calculates it always with a monthly resolution. The yearly based table in sheet "RoI A" is only a summary of the monthly table "RoI_M A", as displayed in the small window in the graphic.

Return on Investment	mill. EUR	2001	2002	2003	2004	200
Investment	**Present value**					
Equity	**64.748**	7.200	36.000	7.200	21.600	
Debt	**258,991**	28,800	144,000	28,800	86,400	
Interest during construction						
Investment Volume	**323,739**	36,000	180,000	36,000	108,000	
Debt Service						
Debt Payback	**130,218**				14,950	25,80
Debt Interest	**81,817**				13,897	20,05
Debt Service	**212,035**				28,847	45,85

2002-07	2002-08	2002-09	2002-10	2002-11	2002-12	2003-01	2003-02	2003-03
14,400				14,400	7,200		7,200	
57,600				57,600	28,800		28,800	
72,000				72,000	36,000		36,000	

Graphic 5-3 Investment volume and debt service

The **debt service** consists of payback and interests, adding the payments of both credits.

Win/loss and taxes

Any calculation of profitability without regarding taxes is incomplete, as the taxes on profit (win) are a payment that reduces the cash flow directly. In the **second part of the table** the **profit** before and after **taxes** is calculated. PG-ROI assumes that there are no further bookings affecting taxes that do not come from the power plant itself.

The **profit before tax** (also called gross profit or earning before taxes) is calculated by subtracting the depreciation and credit interests from the operating result. Debt payback does not affect the taxable profit (only the debt volume), but certainly affects the cash flow. If the profit before tax is positive in the period, then a percentage of it must be paid as income tax[2] (see Chapter 4.2).

The remaining **profit after tax** (net profit, earning after interest and taxes) is not needed for cash flow calculation, but can be used for further needs and especially serves to explain the difference between cash flow and profit.

The tax itself is part of the cash flow and reduces it directly.

Other taxes than the ones on profit can be considered as additional costs, as long as their absolute amount can be fixed.

Return on Investment	mill. EUR	2003	2004	2005	2006	2007
Income Tax Rate and Profit						
Operating Result	**355,908**	-17,500	-17,500	-17,500	69,382	69,382
Depreciation	**-173,426**	-24,000	-24,000	-24,000	-24,000	-24,000
Debt Interest	**-81,817**		-13,897	-20,054	-18,260	-16,466
Profit before Tax	**100,664**	-41,500	-55,397	-61,554	27,121	28,915
Income Tax	**-78,320**				-9,493	-10,120
Profit after Tax	**22,345**	-41,500	-55,397	-61,554	17,629	18,795

Graphic 5-4 Result before and after taxes

[2] Including tax payments affects definitely the profitability of a project, but is very complex and bundled with mathematical problems. However, an estimation of taxes at least covers big part of its influence.

Tax depreciation reflects the decrease of assets by usage, so that a plant over the years looses its value until it reaches zero.

The depreciation in PG-ROI is considered linear, i. e. the amount of depreciation for each period is equal, starting from handover during the depreciation period. A typical period for a new plant could be 15 to 20 years, for a modernized plant 5-10 years or its components (turbine, boiler etc.).

Cash flow

In the **third part of the table** the **cash flow** is derived. All detailed payments from **operating result** count in the cash flow. The **investment volume** affects the cash flow negatively, while the draw of a credit line according to the debt share has a positive effect. The credit later on is paid back and charges the cash flow, just like the tax on profit.

The resulting **cash flow** is a nominal amount for each period; it serves as basis for calculating the **internal rate of return** of each period, of which only the IRR at the end of all periods is really interesting. The **present value** of the cash flow is calculated for each period and accumulated to the **Net Present Value**. The present value method and the NPV are discussed in Chapter 6.2.1 in detail.

Return on Investment	mill. EUR	2001	2002	2003	2004	2005	2006	2007
Cash Flow								
Variable Rev. Electr.	1.055,346						184,320	184,320
Operating Revenues (Variab.)	1.055,346						184,320	184,320
Operating Revenues	1.055,346						184,320	184,320
Personnel	-20,221			-2,500	-2,500	-2,500	-2,500	-2,500
Insurance	[illegible]			-2,000	-2,000	-2,000	-2,000	-2,000
Fixed Maintenance	[illegible]			-13,000	-13,000	-13,000	-13,000	-13,000
Operating Costs (Fix)	-141,544			-17,500	-17,500	-17,500	-17,500	-17,500
Variable Maintenance	-3,298						-0,576	-0,576
Fuel	-546,352						-95,422	-95,422
Consumables	-8,245						-1,440	-1,440
Operating Costs (Variab.)	-557,895						-97,438	-97,438
Operating Costs	-699,439			-17,500	-17,500	-17,500	-114,938	-114,938
Investment Volume	-323,739	-36,000	-180,000	-36,000	-108,000			
Income from Credit	258,991	28,800	144,000	28,800	86,400			
Debt Service	-212,035				-28,847	-45,854	-44,060	-42,266
Income Tax	-78,320						-9,493	-10,120
Cash Flow	0,805	-7,200	-36,000	-24,700	-67,947	-63,354	15,829	16,995
Cash Flow, accumulated		-7,200	-43,200	-67,900	-135,847	-199,202	-183,373	-166,378
Internal Rate of Return	10,1%							
Present Value of Cash Flow	0,805	-7,374	-33,362	-21,557	-53,560	-45,231	10,265	10,020
Net Present Value	19,8 a	-7,374	-40,736	-62,292	-115,852	-161,083	-150,818	-140,798

Operating Result

Graphic 5-5 Cash flow and its components

Debt service cover ration

In the **fourth part of the table** the **debt service cover ratio** shows, how secure the debt service is covered by the cash flow. The DSCR is a key figure during credit negotiations, as the higher the DSCR, the better the chances of pay back even in difficult market situations and hence the better the credit conditions. Some banks require a minimum DSCR (>1,5) for each year of operation.

The debt service cover ratio comes from the operating result minus taxes and then is put into relation to the debt service (payback and interest).

In the example below, the profit after tax in 2006 is 63.807 mill Euro. If compared with the debt service of 34,104 Mio. Euro, the resulting DSCR is 1,87.

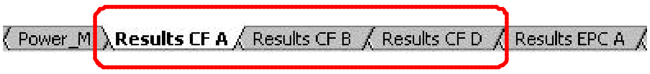
A ratio lower than one means that the credit cannot be paid from current incomes.

Return on Investment	mill. EUR	2001	2002	2003	2004	2005	2006	2007
Debt Service Cover Ratio								
Operating Result				4,353	67,584	74,573	75,924	77,296
Income Tax					-11,187	-11,174	-12,117	-13,068
Cash Flow for DSCR				4,353	56,397	63,399	63,807	64,228
Debt Service					24,379	35,448	34,104	32,760
Debt Service Cover Ratio					2,31	1,79	1,87	1,96

Graphic 5-6 Debt service cover ratio

5.2.2 Charts and RoI figures

The different charts show the results in an understandable way and the key RoI figures condense the information into single values, all to be issued in the sheet "Results CF".



RoI figures

The overview sheets show the common RoI figures. Their derivation is discussed in detail in Chapter 0.

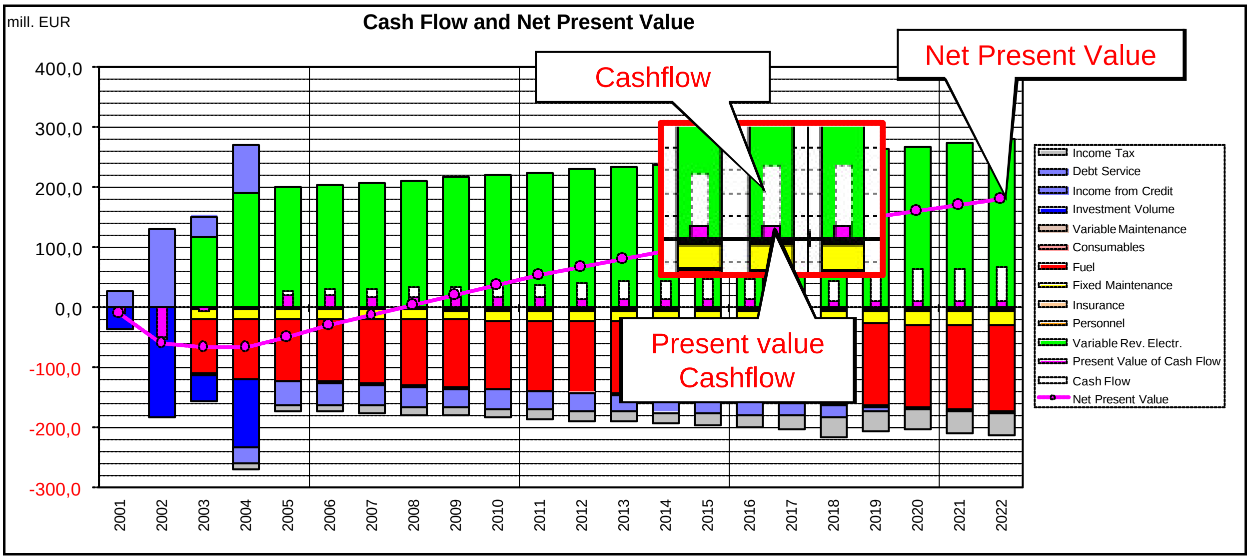
- Capital requirement, sorted by internal and external payments
- Net Present Value of the whole project
- Internal Rate of Return after 10 years and at the end of the project (optional the use of Modified IRR)
- Pay-off Time in years (according to Chapter 6.2.4)

Investment			**Net Present Value (10,0%) at 1.1.2002**	**mill. EUR**	**184,400**
Debt	mill. EUR	252,000	Internal Rate of Return till 2011	% / a	22,5%
Equity	mill. EUR	108,000	**Internal Rate of Return till 2022**	**% / a**	**28,4%**
Capital Requirement	**mill. EUR**	**360,000**	**Pay Off Time from 1.1.2003 (a)**		**5,5**

Graphic 5-7 RoI investment figures

Chart cash flow

The chart with cash flow allows the best **overview** about the return on investment of the project and the best hints for interpretation:



Graphic 5-8 Chart cash flow and net present value

During the whole period under review this chart displays the **income or revenues** (positive = bars above zero-line) and the **payments** (negative = below zero-line), separated into the different cash flow components as stated in the legend (see previous Chapters for details of components).

The sum of income and payment is the **cash flow** (white bar), with its discounted **present value** (pink bar).

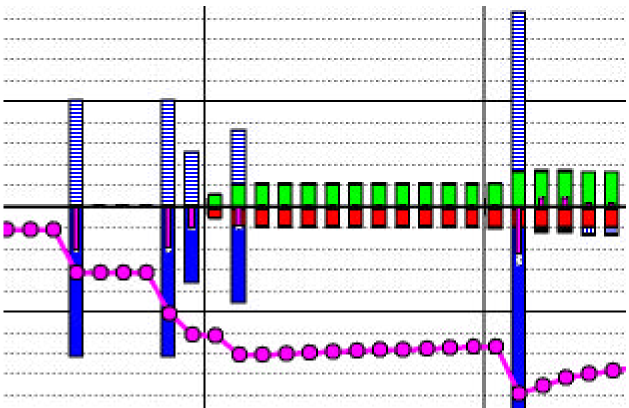
The accumulated present values are represented in the pink line, called net present value curve that gives the best impression about the timely development of the project. The last point of the curve is the **net present value (NPV)**.

When the net present value curve hits the x-axis, the end of the **Pay-off Time (POT)** is reached (there are also other definitions of the pay-off time that are described in Chapter 0).

Chart cash flow months

If the costs and revenues or the operating hours are detailed per months (see Chapters 4.3.4 and 4.4.1), then the first five years from start date are shown in an additional chart.

In this chart one can easily see the distribution of payments (blue bars) and the step-by-step commissioning of the power plant that results into steps in revenues (green bars of electricity sales).



Graphic 5-9 Chart cash flow with monthly resolution

5.3 Electricity production costs

The calculation of the electricity production costs is a full costs calculation adding up the real costs of operating the plant and the calculatory capital costs of the investment. The full costs correspond to the minimum price, which the electricity producer would demand to be paid by his customer to cover his costs and to achieve the desired interest on the invested capital.

Aside from the fuel costs, the capital costs are a second important share in the overall costs of power plants. On calculating the electricity production costs they consist of the real capital service for credits and the calculatory capital service for the equity capital, i.e. annuity, interest and payback, of the total investment volume.

The depreciation for usage is not integrated in the (calculatory) calculation of electricity production costs. The reason for it is, that the tax depreciation time often does not reflect the decrease of assets by usage but is governed by fiscal policy aspects (e.g. special depreciation period). Instead of the tax related depreciation, PG-ROI uses the financing costs in the form of the capital service for determining the electricity production costs.

The results obtained by the electricity production costs calculation are shown in tables and diagrams (Results EPC = Results Electricity Production Costs).

5.3.1 Electricity production costs tables

RoI_M D | EPC A | EPC B | EPC D | EPC_M A | EPC_M B | EPC_M D | Sens A

The components of the electricity production costs are shown with an annual resolution in the sheet „EPC A“. If the data for costs/revenues or power are entered **on a monthly basis** (see Chapters 4.3.4 and 4.4.1), then the first five years from the start date are listed on a monthly basis in the additional sheet „EPC_M A“.

Absolute electricity production costs

The **upper par t of the table** are the **absolute costs** in million monetary units, divided into capital costs and operating costs. In the third column are the present values of costs accumulated over the period under review (see Chapter 6.2.1).

Electricity Production Cost			2001	2002	2003	2004	2005	2006	2007
Capital Costs		Present value							
Equity	mill. EUR	88.627				9.285	13.927	13.927	13.927
Debt	mill. EUR	198,194				25,949	37,731	36,300	34,870
Capital Costs	mill. EUR	286,821				35,233	51,658	50,227	48,797
Operating Costs									
Personnel	mill. EUR	26,333			2,652	2,732	2,814	2,898	2,985
Insurance	mill. EUR	16.176			2.000	2.000	2.000	2.000	2.000
Fixed Maintenance	mill. EUR	136,929			13,792	14,205	14,632	15,071	15,523
Operating Costs (Fix)	mill. EUR	179,438			18.444	18.937	19.445	19.969	20.508
Variable Maintenance	mill. EUR	5,846			0,374	0,610	0,648	0,668	0,688
Fuel	mill. EUR	913,133			93.324	101.102	103.288	105.354	107.461
Consumables	mill. EUR	13,321			0,917	1,482	1,559	1,590	1,622
Operating Costs (Variab.)	mill. EUR	932,300			94.615	103.194	105.495	107.612	109.770
Operating Costs	mill. EUR	1.111,739			113,059	122,132	124,941	127,580	130,278
Electricity Production Cost									
Electricity Production Cost	mill. EUR	1.398,559			113,059	157,365	176,598	177,808	179,075

2004-01	2004-02	2004-03	2004-04	2004-05	2004-06	2004-07	2004-08	2004-09	2004-10	2004-11	2004-12
				1,161	1,161	1,161	1,161	1,161	1,161	1,161	1,161
				3,278	3,268	3,258	3,249	3,239	3,229	3,219	3,209
				4,439	4,429	4,419	4,409	4,399	4,389	4,379	4,369
0,228	0,228	0,228	0,228	0,228	0,228	0,228	0,228	0,228	0,228	0,228	0,228
0,167	0,167	0,167	0,167	0,167	0,167	0,167	0,167	0,167	0,167	0,167	0,167

Graphic 5-10 Absolute electricity production costs

In order to get a significant sum of costs over the lifetime the present value method is used instead of summing up the values: All costs of each month are discounted to their present values. The individual present values are then summed up. The result is the present value of the absolute electricity production costs over the period under review. For this, the following formula is used in general.

The calculation of the present value allows to compare rows of costs of different options. The **present value of the absolute electricity production costs** can be used as a criterion for comparing alternatives: The most favorable alternative is the option with the lowest present value of the complete costs.

$$\text{present value} = \sum_{j=1}^{\text{period under review}} \left[\frac{\text{Sum costs}_j}{(1+i)^j} \right]$$

Formula 5-1 Present value of absolute prod. costs

If two options do not have the same output, i.e. if the power or the full load operating hours are different, or if the lifetime is different, it would be unreasonable to compare the present values. In this case, the specific electricity production costs per Kilowatt hour are used as a criterion.

Remaining costs with heat production

If a power plant produces heat as a by-product of electricity, it would be reasonable to divide the costs into the electricity and heat production costs. However, the costs of both products arise at the same time, meaning that fuel is consumed also without heat production. Therefore, a direct division is not possible so that the remaining costs calculation[3] method is applied instead.

For calculating the remaining costs of two products, (electrical and thermal energy), they are hierarchically classified, the electrical energy being the main product and the thermal energy the by-product. All costs are added to the electricity costs and the revenues achieved by selling the thermal energy are then subtracted from the calculated sum. In this way, no result for the heat production costs is obtained but a useful value for the electricity production costs, the so-called remaining costs.

Please note however, that the revenues gained from heat are credited to the electricity production costs with negative sign in the calculation because they reduce the (positive) full costs.

Electricity Production Cost	2003	2004	2005
Total Costs			
Capital Costs + Operating Costs	113,059	155,795	174,315
Credit Note from Heat			
Fixed Revenues Heat	-2,500	-2,500	-2,500
Variable Rev. Heat	-25,000	-30,000	-30,000
Revenues from Heat	-27,500	-32,500	-32,500
Electricity Production Cost			
Electricity Production Cost	85,559	123,295	141,815

Graphic 5-11 Remaining costs with heat production

The credit entry of the revenues from heat appears only in the electricity production costs calculation and is of the same amount as the revenues from heat in the profitability calculation.

Specific electricity production costs

In the lower part of the table are the **specific electricity production costs** per MWh, which are calculated on the basis of the absolute costs divided by the produced amount of electricity.

Electricity Production Cost			2001	2002	2003	2004	2005	2006	2007
Capital Costs		**Levelized**							
Equity	EUR/MWh	**1,991**				1,662	2,418	2,418	2,418
Debt	EUR/MWh	**4.453**				4.645	6.551	6.302	6.054
Capital Costs	**EUR/MWh**	**6,444**				6,307	8,968	8,720	8,472
Operating Costs		**Levelized**							
Personnel	EUR/MWh	**0.592**			0.752	0.489	0.489	0.503	0.518
Insurance	EUR/MWh	**0,363**			0,567	0,358	0,347	0,347	0,347
Fixed Maintenance	EUR/MWh	**3.076**			3.911	2.543	2.540	2.616	2.695
Operating Costs (Fix)	**EUR/MWh**	**4,031**			5,230	3,390	3,376	3,467	3,560
Variable Maintenance	EUR/MWh	**0,131**			0.106	0.109	0.113	0.116	0.119
Fuel	EUR/MWh	**20,515**			26,462	18,097	17,932	18,291	18,656
Consumables	EUR/MWh	**0,299**			0.260	0.265	0.271	0.276	0.282
Operating Costs (Variab.)	**EUR/MWh**	**20,945**			26,829	18,472	18,315	18,683	19,057
Operating Costs	**EUR/MWh**	**24,977**			32,058	21,861	21,691	22,149	22,618
Electricity Production Cost		**Levelized**							
Electricity Production Cost	**EUR/MWh**	**31,420**			32,058	28,168	30,659	30,869	31,089

Graphic 5-12 Specific electricity production costs

The nominal specific electricity production costs in the first year of operation are often used to compare different plants; this procedure is only of use, if all costs are already included in that year. When entering the payback periods, divided into debt and equity, the electricity production costs will change abruptly: since the capital costs are part of the electricity production costs calculation, the costs during the payback period are higher than after it.

The remaining costs for revenues from heat reduce the specific electricity production costs analogously to the absolute costs.

Levelized electricity production costs

The specific electricity production costs are calculated for each year by dividing the (nominal) full costs of the month by the electrical energy (MWh) produced during the respective period. In order to obtain a characteristic figure for the whole period under review, the **levelized electricity production costs** were created.

It is not useful to compute the arithmetical average of the specific electricity production costs because periods with different electricity production would be equally handled; exactly this weighting is achieved with the present value calculation method. Analogously to the capital value in the cash flow calculation, the levelized electricity production costs are defined as the present value of the absolute electricity production costs divided by the present value of the produced electricity according to the formula (at the discount rate i from the profitability calculation):

$$\frac{\sum_{j=1}^{\text{period under review}} \left[\frac{\text{Sum costs}_j}{(1+i)^j} \right]}{\sum_{j=1}^{\text{period under review}} \left[\frac{\text{elec power}[MW] \cdot \text{operating hours}_j}{(1+i)^j} \right]}$$

Formula 5-2 Levelized electricity production costs (LEPC)

The levelized electricity production costs should be used only as a comparative figure between alternatives because they cannot be reasonably derived from a technical-economic aspect. In any case, they cannot be interpreted as initial electricity production costs at the start nor as average price the electricity producer should receive from his customers to cover his costs and to achieve the desired interest on the invested capital. These figures should be found using the goal seek function for electricity revenues.

Produced electrical energy

Additional data are given at the end of the table with the amount of electrical energy produced in each period and the variable revenues per MWh from electricity including the increase.

		2003	2004	2005
Electricity Production	**MWh**	3.526.667	5.586.667	5.760.000
Variable Rev. Electr.	**EUR/MWh**	33,293	33,959	34,638

Graphic 5-13 Electricity production

[3] The remaining costs calculation has nothing to do with the remaining value of the plant at the end of the period under review.

5.3.2 Charts and LEPC figures

LEPC figures electricity production costs

In the upper part is an overview of the specific electricity production costs per MWh. For the first five years, the respective values of capital costs as well as variable and fixed operating costs, as well as the levelized electricity production costs over the period under review (Life Cycle Costs) are indicated.

Electricity Production Cost		Levelized	2001	2002	2003	2004	2005
Capital Costs	EUR/MWh	6,444				6,307	8,968
Fixed Operating Costs	EUR/MWh	4,031			5,230	3,390	3,376
Variable Operating Costs	EUR/MWh	20,945			26,829	18,472	18,315
Electricity Production Cost	**EUR/MWh**	**31,420**			**32,058**	**28,168**	**30,659**

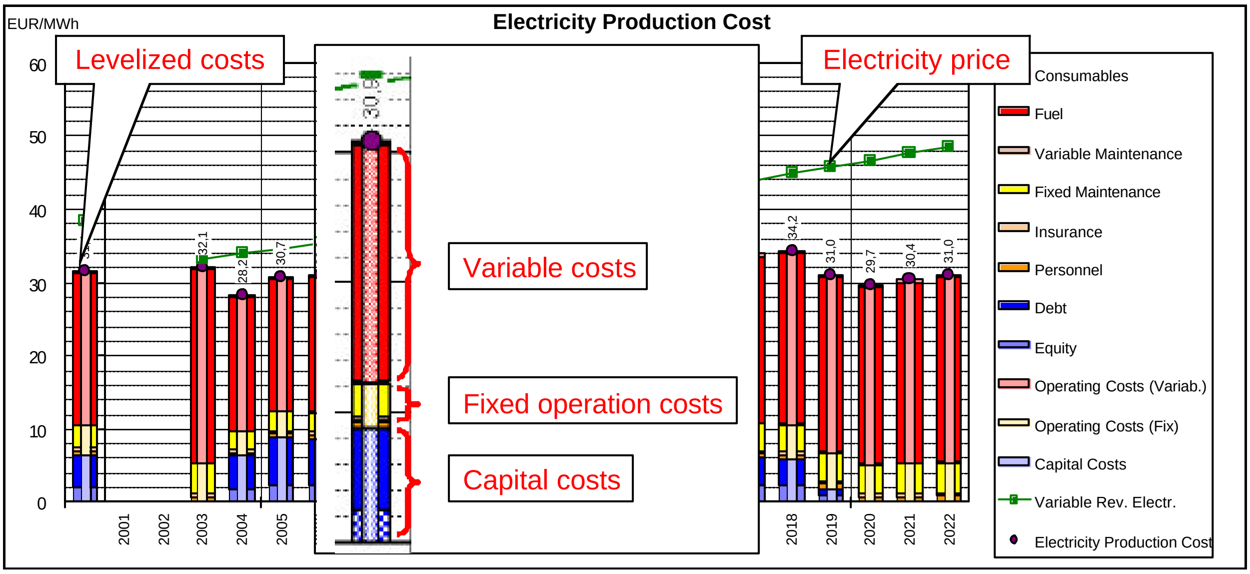
Graphic 5-14 Levelized and yearly production costs

Chart electricity production costs

The diagram below shows the electricity production costs over the period under review with indication of the **individual types of costs** (see legend). The **levelized electricity production costs** are depicted on the very left and the individual years on the right.

The narrow bars inside show the division of the costs into capital costs, fixed and variable operating costs.

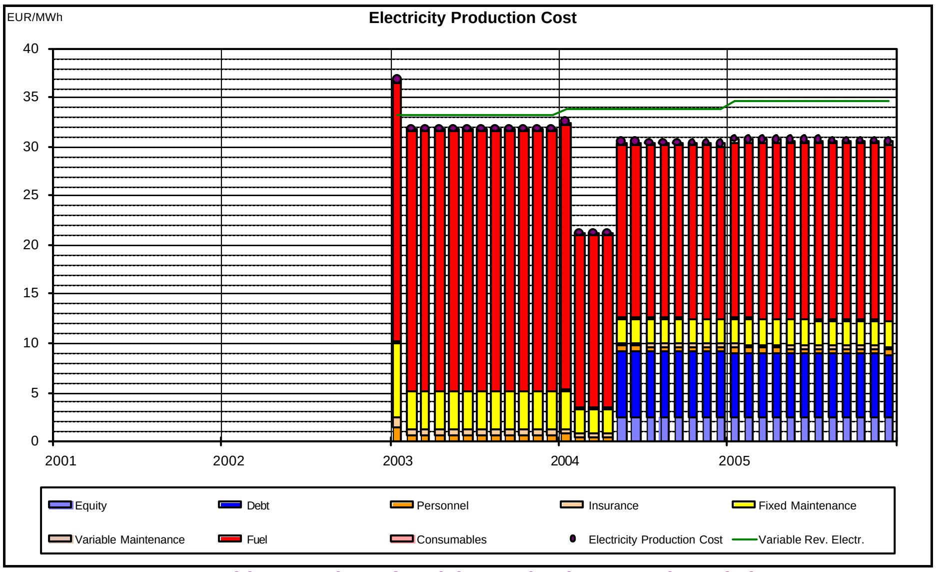
The **variable revenues from electricity** are reference values and integrated into this chart as green line.



Graphic 5-15 Chart electricity production costs (years)

Chart electricity production costs months

If the data for costs/revenues or power are detailed **per month** (see Chapters 4.3.4 and 4.4.1), then the first five years from start date are shown on a monthly basis in an additional diagram.

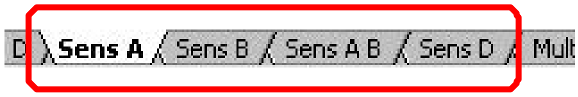


Graphic 5-16 Chart electricity production costs (months)

5.4 Probability analysis

The probability analysis shows the dependence of the four key RoI figures

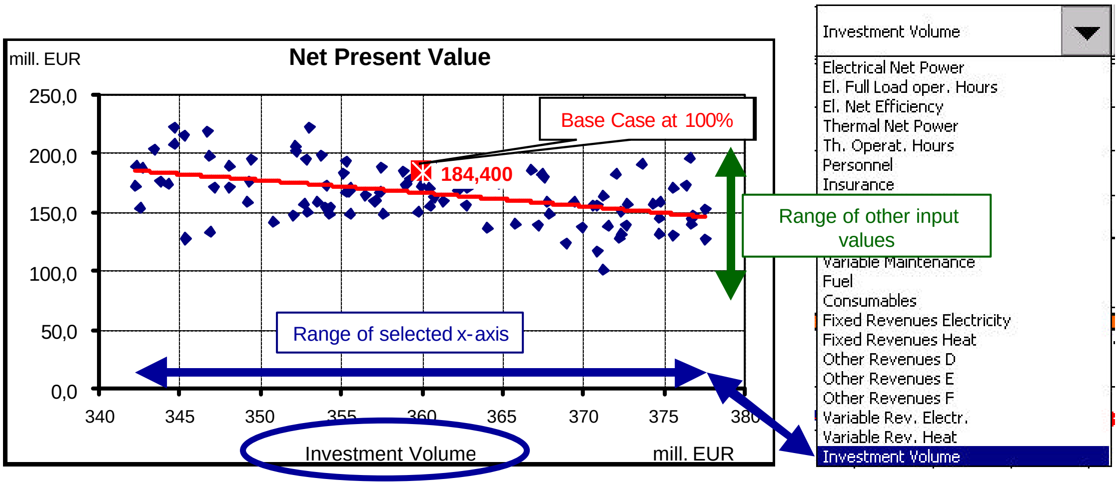
- Net Present Value
- Internal Rate of Return
- Pay-off Time
- Electricity Production Costs



on different input data.

Note: The data of the probability are not updated automatically, if in sheet „Input" a new calculation has been triggered because dependent on the number of selected calculations, this calculation takes a few minutes, instead an update is carried out by clicking on the **Button** „Calculate".

A special feature of this assessment is that all input data vary within their range (see „Min%" and „Max%" in sheet „Input", Chapter 4.5). Due to the multitude of calculations with statistically distributed values quite a great number of results are produced that can be best presented in a chart. The two diagrams below show the evaluation with reference to the net present value:



Graphic 5-17 Probability analysis: investment

The resulting so-called star field shows the dependence of each one of the four key figures on the input quantity on the x-axis. In the diagram above, it is the investment volume.

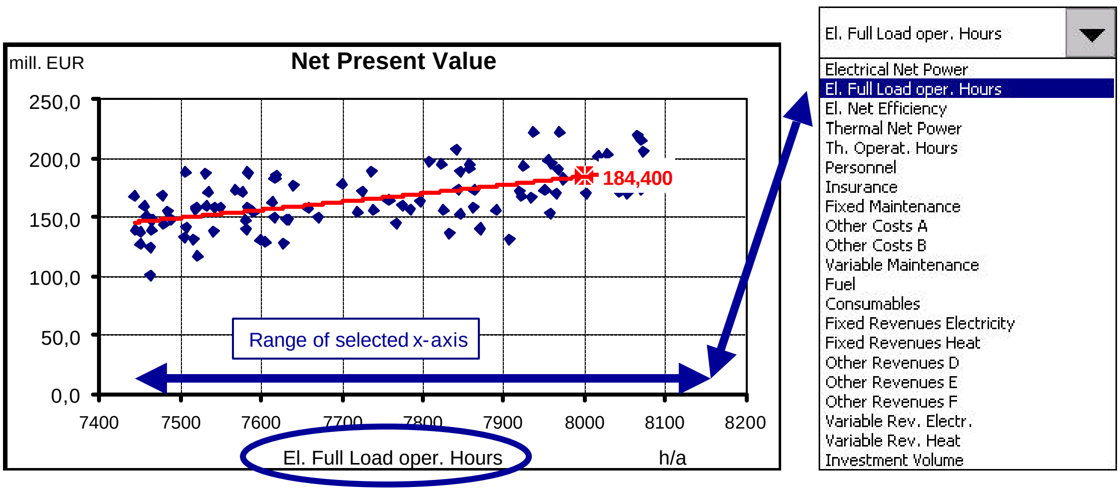
In the middle of the data there is a **trend line** of the star field, which does not necessarily reflect the most probable values, however. The base value, when all input data are at 100%, is set off and colored red.

The steeper the **course of the curve**, the greater is the influence by a change of the x-axis on the result. The wider the vertical scattering around the trend line, the greater is the collective influence of the remaining input data. From the diagram above it can be seen that the net present value

- at an investment volume of 345 mill. EUR lies between 125 and 225 mill. EUR
- at an investment volume of 375 mill. EUR lies between 100 and 200 mill. EUR.

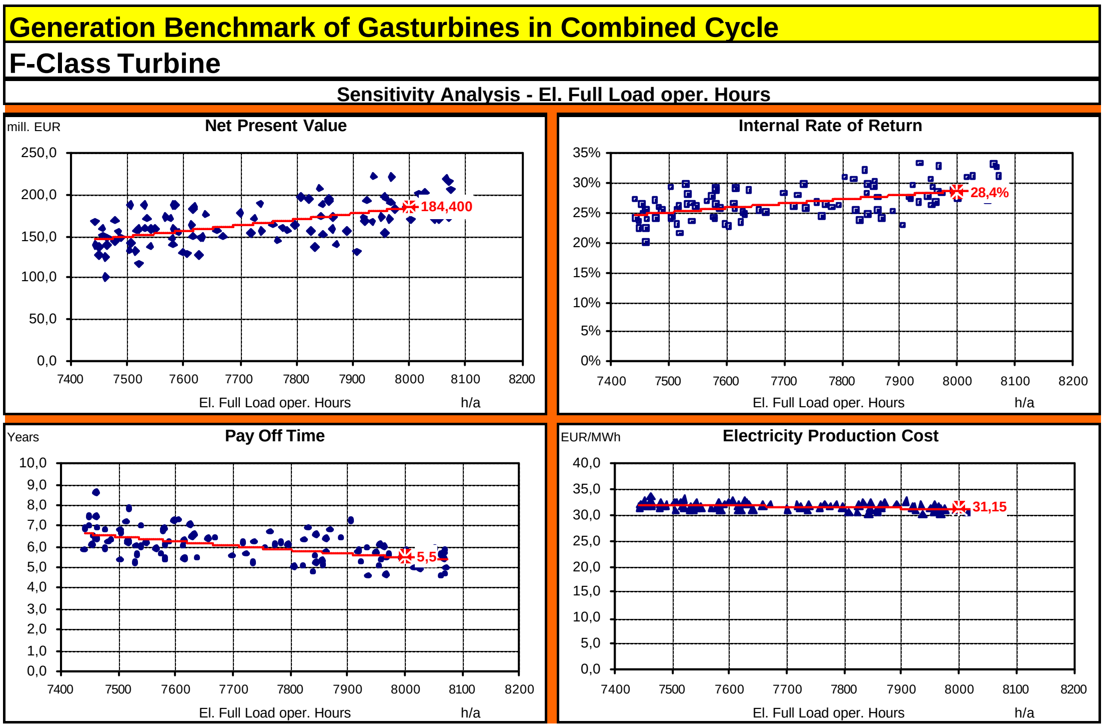
Aside from the trivial statement that the net present value decreases along with an increase in investment, the diagram clearly shows that the collective influence of the variation of all other parameters is greater than the influence of the investment volume itself. Therefore, the exact price of the power plant is not the **decisive criterion** for or against an investment as long as there are no detailed data available for the market and operation.

The same data can also be plotted as a function of the operating hours, for example. There are 25 different x-axes to choose from:



Graphic 5-18 Probability analysis: operating hours

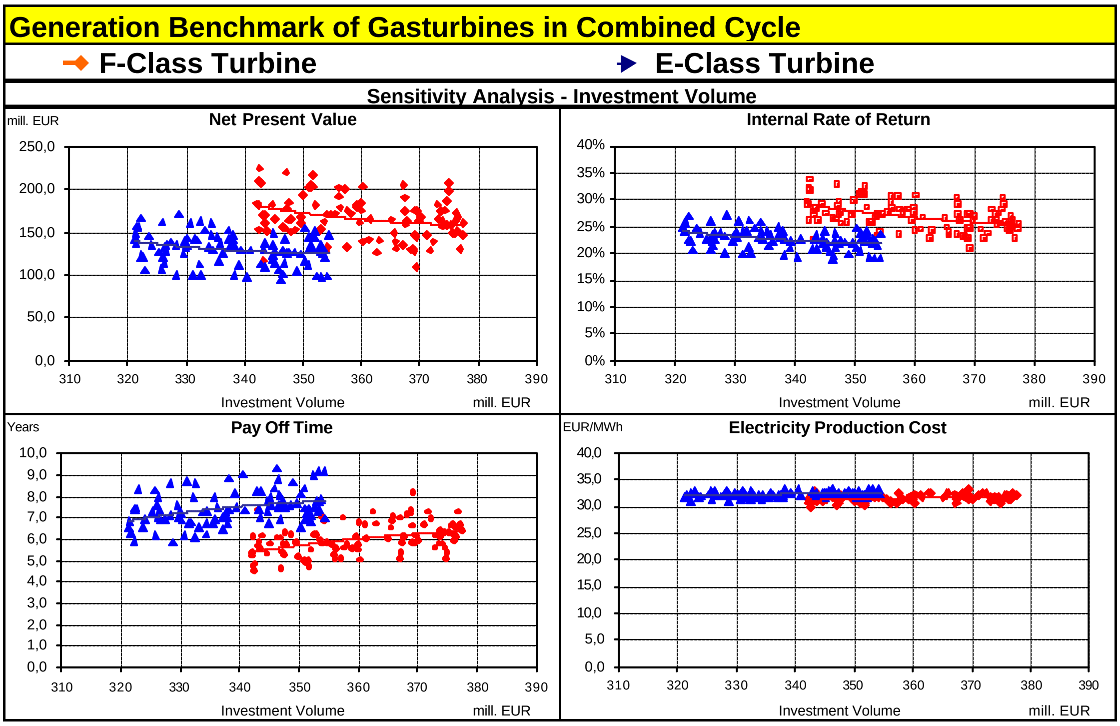
Next to the net present value there are also corresponding diagrams for the other three key figures combined in sheet „Sens A“:



Graphic 5-19 Probability analysis with all RoI figures

The net present value and the internal rate of return increase clearly along with the number of operating hours, the pay-off time decreases accordingly. While the pay-off time is 6.5 hours at 7500 operating hours it decreases to 5.5 years at 8000 operating hours, however with a range of variations of ± 1.5 years. In contrast to that the electricity production costs change hardly. For this key figure, the investment volume and other fixed values are not of great importance, it is the variable costs (fuel) that count. The variable costs do not change in this example.

The user can choose between Option A and Option B, a combination of A and B and the Delta option. The following is sheet „Sens A B“ containing separate results of both options.



Graphic 5-20 Probability analysis options A and B

Obviously Option A „F-Class Turbine“ (red dots) is the better choice. Even in unfavorable cases for A the key figures are still better than in the most favorable cases for B. The advantage of A is thus proven for the whole range of input data.

5.5 Multiple sensitivity analysis

The multiple sensitivity analysis is used to show the dependence of the key figures

- Net Capital Value
- Internal Rate of Return
- Pay-off Time
- Electricity Production Costs

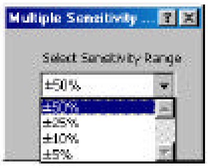
on variations of individual input values. In contrast to the probability analysis only one parameter is changed at a time so that several sensitivity analyses are automatically calculated one after the other. The results are depicted in diagrams in sheets „Multi A", „Multi B" and „Multi D"; the respective data are listed in sheet „Multi-Tab".

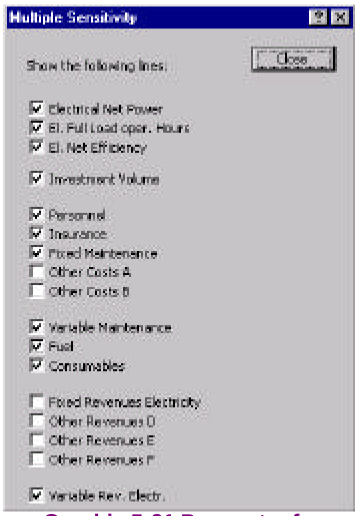
The data of the multiple sensitivity analysis are not updated automatically, if in sheet „Input" a new calculation has been triggered, because the calculation takes a few minutes dependent on the number of selected lines. Any of the buttons „Multiple sensitivity analysis" starts the updating.

Before carrying out the calculation, the parameters to be calculated are selected in the dropdown menu „**Show and Hide Lines**". On clicking on the parameters they are checked off, so that individual lines in the tables and diagrams are displayed or hidden. The fewer parameters are checked off, the faster the calculation.

The input parameters are variable during the calculation in eleven steps within a selectable **range**. The narrower the range, the more detailed the resolution (values ±5% and ±50%). During the calculation the status bar down on the left indicates the status of the calculation.

The result of each individual calculation is indicated in the sheet „Multi-Tab". This table is subdivided into several parts.





Graphic 5-21 Parameter for multiple sensitivity analysis

Variation by one unit or one percent

In the left part are the input quantities; their respective base value and the unit as well as the variation of the net present value or the levelized electricity production costs, if the input value increases by one unit or one percent. The marked line in the next graphic thus answers the following questions

- What is the increase in the net present value and the levelized electricity production costs when the number of operating hours increases by 1 unit from 8000 to 8001?
  The net present value increases by 0.064 mill EUR.
  The electricity production costs decrease by 0.00128 EUR/MWh.
- What is the increase in the net present value and the levelized electricity production costs when the number of operating hours increases by 1% from 8000 to 8080?
  The net present value increases by 5.098 mill. EUR.
  The electricity production costs decrease by 0.10105 EUR/MWh.

The other lines are evaluated analogously.

F-Class Turbine			Delta NPV mill. EUR		Delta LEPC EUR/MWh	
Titel		Basis	+1 unit	+1 Perc.	+1 unit	+1 Perc.
Electrical Net Power	MW	720,0	0,678	4,885	-0,01372	-0,09798
El. Full Load oper. Hours	h/a	8000,0	0,064	5,098	-0,00128	-0,10105
El. Net Efficiency	---	56,5%	9,336	5,315	-0,32269	-0,18371
Personnel	mill. EUR/a	2,5	-7,193	-0,180	0,23664	0,00592
Insurance	mill. EUR/a	2,0	-5,584	-0,112	0,18171	0,00363
Fixed Maintenance	mill. EUR/a	13,0	-7,193	-0,935	0,23664	0,03076
Variable Maintenance	EUR/MWh	0,1	-39,225	-0,039	1,31342	0,00131
Fuel	EUR/GJ	2,6	-246,294	-6,241	7,89023	0,20515
Consumables	EUR/MWh	0,3	-35,835	-0,090	1,19708	0,00299
Variable Rev. Electr.	EUR/MWh	32,0	35,835	11,467		

Graphic 5-22 Multi-Tab with Delta NPV and Delta LEPC

Variation by ranges

In the right part of the „Multi-Tab" table are (from left to right for net present value, pay-off time, internal rate of return and levelized electricity production costs) the results for different percentage changes of the input data. The part for the net present values is shown on the next page as an example. The figures within the red marking can be interpreted as follows:

- What is the increase in the net present value when the variable revenues change between 90% and 104% at a base value of 32.0 EUR/MWh (corresponds to 28.8 – 33.28 EUR/MWh)?
  At 90% (28.8 EUR/MWh) the net present value is 69.728 mill. EUR
  At 100% (32.0 EUR/MWh) the net present value is 184.4 mill. EUR
  At 104% (33.28 EUR/MWh) the present value is 230.268 mill. EUR etc.

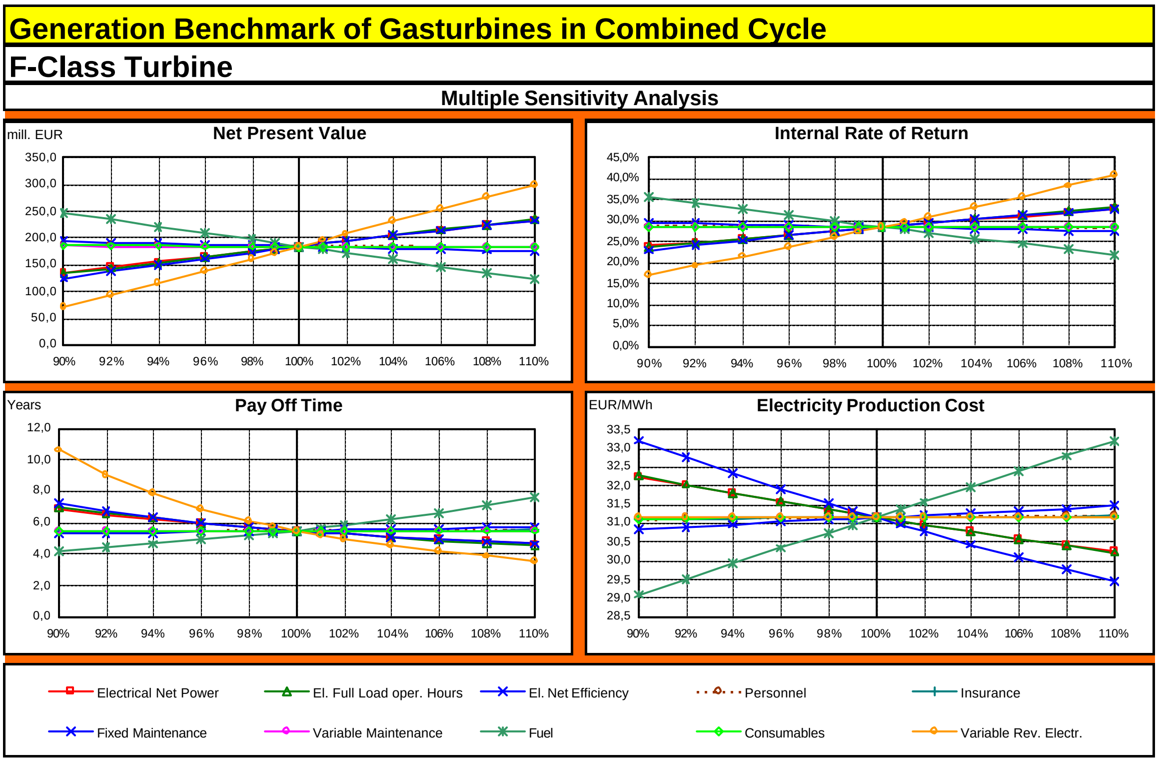
The figures within the blue marking show the net present value at 100% (184.4 mill. EUR) and 101% (189.497 m. EUR) of electrical full load operating hours. Except for rounding errors, the difference between both values (5.098 mill. EUR) corresponds exactly to the Delta value for the 1% increase calculated in the previous example.

F-Class Turbine			Net Present Value						184,4		mill. EUR	
Titel		Basis	90,0%	92,0%	94,0%	96,0%	98,0%	99,0%	100,0%	101,0%	102,0%	104,0%
Electrical Net Power	MW	720,0	135,554	145,323	155,092	164,862	174,631	179,515	184,400	189,284	194,169	203,938
El. Full Load oper. Hours	h/a	8000,0	133,423	143,619	153,814	164,009	174,204	179,302	184,400	189,497	194,595	204,790
El. Net Efficiency	---	56,5%	124,751	137,718	150,134	162,032	173,444	178,977	184,400	189,715	194,926	205,047
Personnel	mill. EUR/a	2,5	186,198	185,838	185,479	185,119	184,759	184,580	184,400	184,220	184,040	183,680
Insurance	mill. EUR/a	2,0	185,516	185,293	185,070	184,846	184,623	184,511	184,400	184,288	184,176	183,953
Fixed Maintenance	mill. EUR/a	13,0	193,751	191,881	190,010	188,140	186,270	185,335	184,400	183,465	182,529	180,659
Variable Maintenance	EUR/MWh	0,1	184,792	184,714	184,635	184,557	184,478	184,439	184,400	184,360	184,321	184,243
Fuel	EUR/GJ	2,6	246,807	234,325	221,844	209,362	196,881	190,640	184,400	178,159	171,918	159,437
Consumables	EUR/MWh	0,3	185,296	185,116	184,937	184,758	184,579	184,489	184,400	184,310	184,221	184,041
Variable Rev. Electr.	EUR/MWh	32,0	69,728	92,663	115,597	138,531	161,465	172,933	184,400	195,867	207,334	230,268

Graphic 5-23 Multi-Tab with net present value

Some results are not linear so that extrapolation beyond the calculated range does not always lead to correct results.

The results can be shown much more clearly in diagrams, which refer exactly to the tables. The steeper the course of the curve, the greater is the influence of the parameter on the net capital value and internal rate of return. Rising curves have a positive effect, falling curves a negative effect. The inclination of the respective curves of pay-off time and electricity production costs is reverse.



Graphic 5-24 Charts multiple sensitivity analysis

The respective curves for the four criteria allow for a good and quick overview as to which parameters have great or little effect on the profitability and the electricity production costs. Typical statements in this case (not in any case!) are:

The higher the fuel costs, the investment volume and other costs,

- the lower the net present value,
- the lower the internal rate of return,
- the longer the pay-off time,
- the higher the electricity production costs.

The higher the electricity price, the efficiency or number of full load operating hours,

- the higher the net present value,
- the higher the internal rate of return,
- the shorter the pay-off time,
- the lower the electricity production costs.

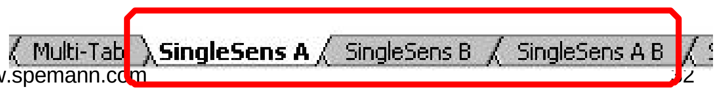
In simple evaluations, the curves for power and operating hours lie one upon another because they are used only as the product of power and hours [MWh] in all calculations so that it does not matter whether the power or the operating hours are increased by one percent.

The influence of personnel and insurance costs is very little (curve runs almost parallel to the x-axis) because the absolute height is small so that an increase would hardly show any effect. In consequence it is not important to know the exact value for any decision.

In the case of Delta analysis, in which many quantities cancel out during calculation, the interpretation and order of importance may differ widely from the analysis described here.

5.6 Single sensitivity analysis

Like the multiple sensitivity analysis, the single sensitivity analysis is used to show the dependence of the four key figures on a certain input value.



- Net Capital Value
- Internal Rate of Return
- Pay-off Time
- Electricity Production Costs

The options under review are Option A (**SingleSens A**), Option B (**SingleSens B**) or both options (**SingleSens A B**) and the Delta option (**Single Sens D**).

The data of the single sensitivity analysis are not updated automatically, if in sheet „Input" a new calculation has been triggered because the calculation takes a few minutes. Any of the buttons „Single Sensitivity" starts the updating. Note: The buttons „Single Sensitivity" in the four table sheets work in parallel, so it does not matter, in which sheet the button is clicked.

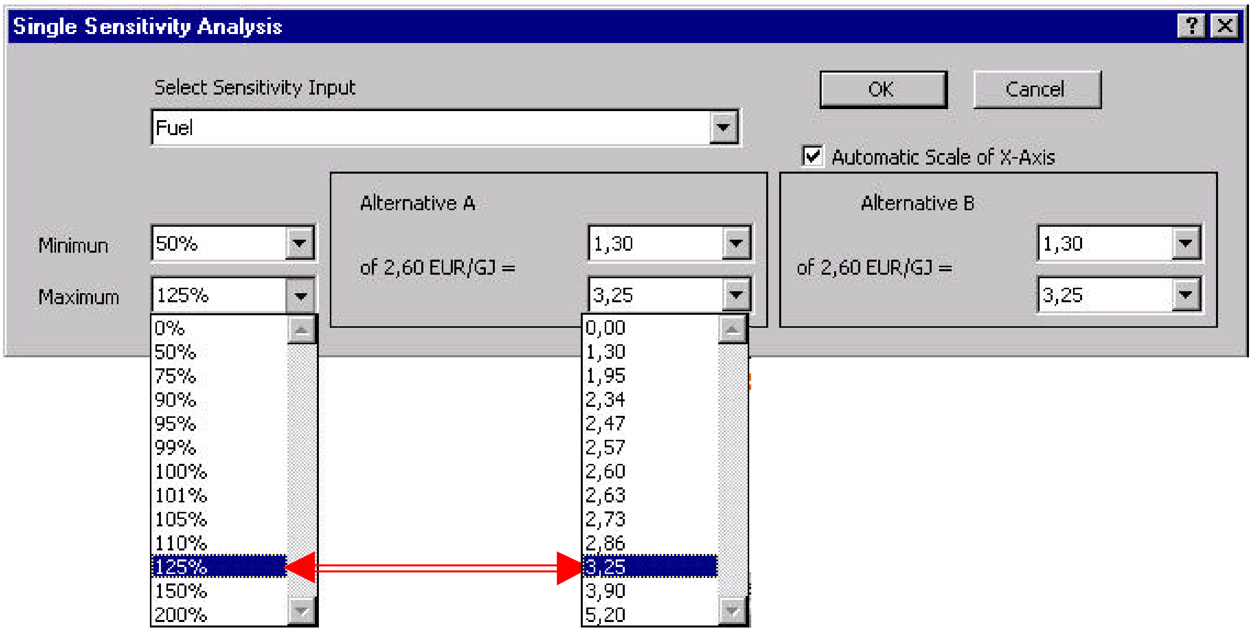
First the x-axis is selected in the dialog window that is the input value to be changed. The following input values are available with their respective x-axis.

Input Value	Unit
Electrical Net Power	MW
Electrical Full Load Operating Hours	h/a
Electrical Net Efficiency	%
Investment Volume	mill. EUR
Personnel	mill. EUR/a
Insurance	mill. EUR/a
Fixed Maintenance	mill. EUR/a
Other Costs A	mill. EUR/a
Other Costs B	mill. EUR/a
Variable Maintenance	EUR/MWh
Fuel	EUR/GJ
Consumables	EUR/MWh

Input Value	Unit
Fixed Revenues Electricity	mill. EUR/a
Other Revenues D	mill. EUR/a
Other Revenues E	mill. EUR/a
Other Revenues F	mill. EUR/a
Variable Revenues Electricity	EUR/MWh
Debt Interest Rate	%
Discount Rate	%
Handover (=End of Commissioning)	Date
Debt Share 1	%
Thermal Net Power	MW
Thermal Full Load Operating Hours	h/a

Graphic 5-25 Input data for sensitivity analysis

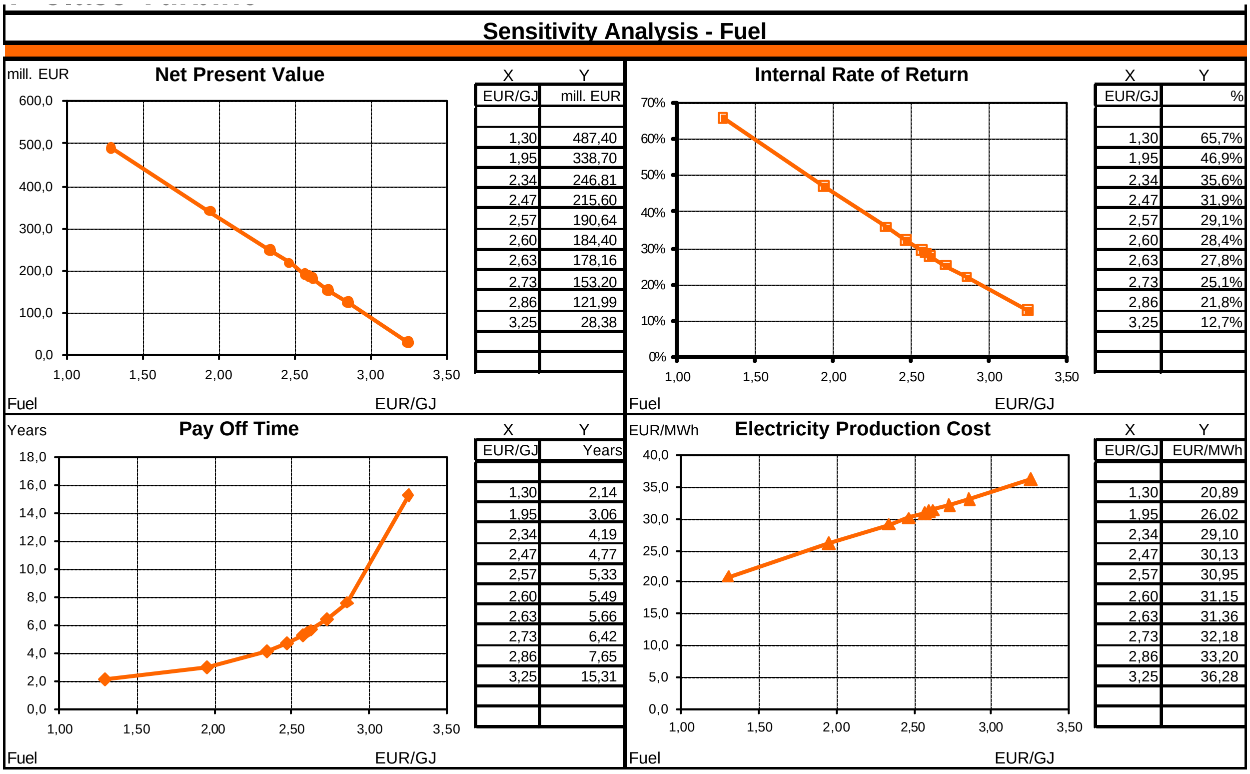
In addition, the range under review is selected by means of percentage values or absolute values, which correspond to each other:



Graphic 5-26 Dialog for sensitivity analysis

When checking off the window „Automatic Scale of x-Axis" the scale of the x-axis is centered, otherwise the x-axis reaches exactly from the lower v alue up to the upper value.

The results are shown in one sheet for all four key figures. The corresponding numerical values are indicated opposite on the right (they can simply be pasted for further evaluations).



Net Present Value

X	Y
EUR/GJ	mill. EUR
1,30	487,40
1,95	338,70
2,34	246,81
2,47	215,60
2,57	190,64
2,60	184,40
2,63	178,16
2,73	153,20
2,86	121,99
3,25	28,38

Internal Rate of Return

X	Y
EUR/GJ	%
1,30	65,7%
1,95	46,9%
2,34	35,6%
2,47	31,9%
2,57	29,1%
2,60	28,4%
2,63	27,8%
2,73	25,1%
2,86	21,8%
3,25	12,7%

Pay Off Time

X	Y
EUR/GJ	Years
1,30	2,14
1,95	3,06
2,34	4,19
2,47	4,77
2,57	5,33
2,60	5,49
2,63	5,66
2,73	6,42
2,86	7,65
3,25	15,31

Electricity Production Cost

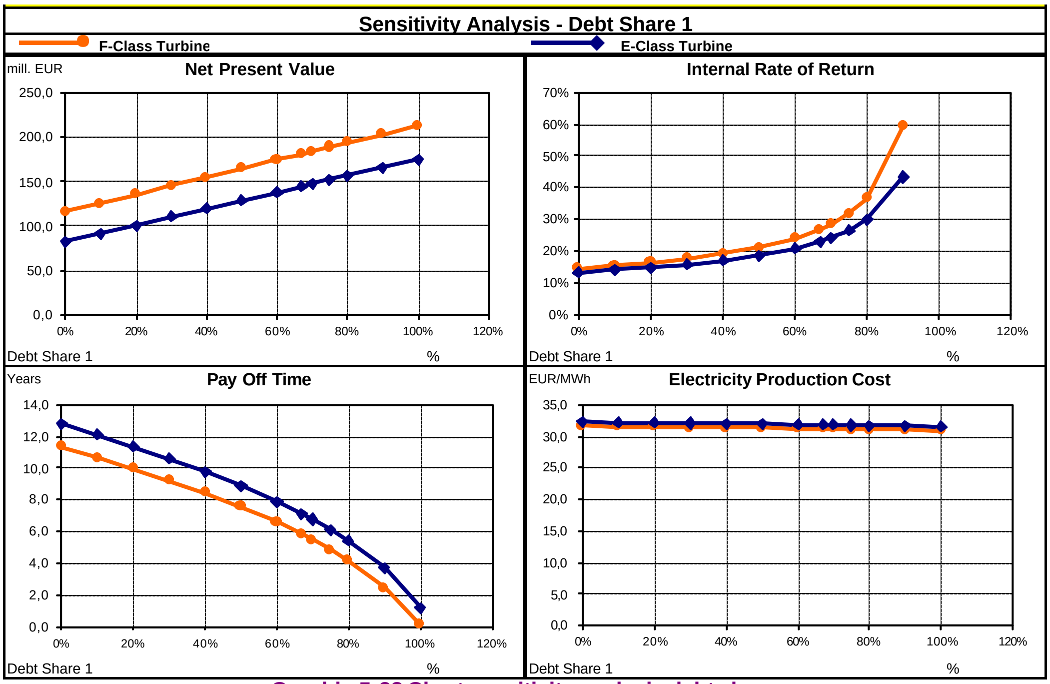
X	Y
EUR/GJ	EUR/MWh
1,30	20,89
1,95	26,02
2,34	29,10
2,47	30,13
2,57	30,95
2,60	31,15
2,63	31,36
2,73	32,18
2,86	33,20
3,25	36,28

Graphic 5-27 Chart for sensitivity analysis with all RoI figures

The steeper the course of the curve the greater the effect of the parameter under review on the key figures. It is rather easy to determine values within the calculated range by interpolation, an extrapolation of results can lead to incorrect results because of the non-linearity of many curves.

The sensitivity analysis gives also important information on financing. The following diagram shows the key figures as a function of the debt share, which varies between zero and 100% in this case. In sheet „SingleSens A B“ the results of the two options A and B are directly compared with each other.

It becomes obvious that the debt share has an essential effect on the three profitability key figures net present value, internal rate of return and pay-off time, so that it is possible to answer the question, for example, how much may the debt share be in order to achieve a certain internal rate of return.



Graphic 5-28 Chart sensitivity analysis debt share

The debt share has little effect on the electricity production costs, because the calculatory equity share is also included in the costs. It is due to the type of payback, lifetime and interest, if the course of the curves is not exactly horizontal, which would mean constant values independent of financing.

The key figures can also be calculated as a function of the date of handover to show the advantages of speeding up construction. For this calculation, please do not detail the power in years or months but enter the values only in sheet "Input" for the total lifetime.

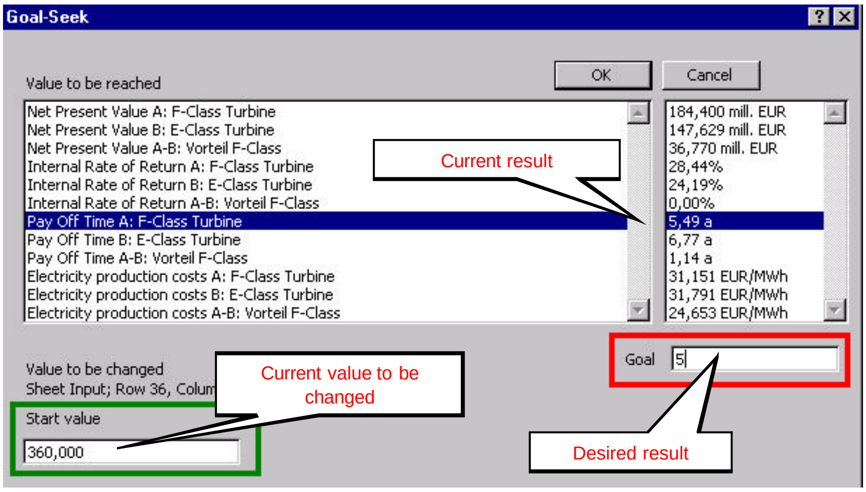
5.7 Goal Seek

The goal seek function adapts a selected input value until the **desired result** is reached, hence it is the reverse calculation for answering the following questions (e.g.):

- What is the allowed investment volume that leads to a 5-year pay-off time?
- How many hours must the plant operate so that the internal rate of return is exactly 25 %?

Goal seek can be carried out in all input sheets: „Input“, „Increase“, „Costs“ and „Costs_M“ as well as „Power“ and „Power_M“.

First select the cell of the input value to be changed. When searching for the investment volume (current value to be changed is 360m. EUR) leading to a pay-off time of 5 years for Option A (current value 5.49 years) the cursor is moved onto “Investment volume”. The following window opens with the button “Goal Seek”:



Graphic 5-29 Goal seek dialog

In the upper part, the value to be changed is selected, the current result is shown on the right. The desired result is entered into the field marked with a red frame, in this case the desired result is 5 years.

Down on the left within the green frame, the current value to be changed is displayed, indicating the start value for searching the desired result. PG-ROI starts to search nearby the start value at first and extends the range (0 – 200%) step by step to find a value, which comes near the desired result. It is useful to enter an estimated value as exact as possible so that PG-ROI can find the best solution quickly.

If the found solution differs by less than 0.001 from the desired value, search is stopped and the found value is displayed in a dialog window. The user can decide, whether he wants to insert the new value instead of the previous one.

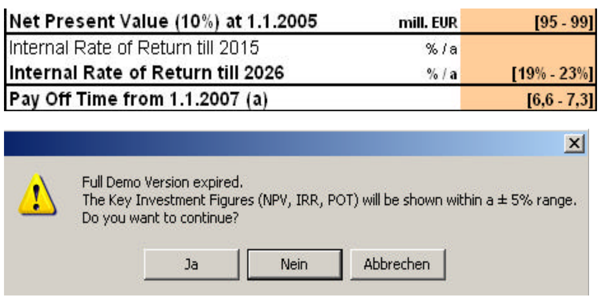
Graphic 5-30 Goal seek results

The answer to the question „What is the allowed investment volume that leads to a 5 years pay-off time? “ is: 338,117 m. EUR instead of 360 m. EUR at present.

Please refer to the examples in Chapter 7 for further details on the use of the goal seek function.

5.8 DEMO Version

All functions described in the present manual are available in the licensed full version of PG-ROI. Users of the DEMO-Version cannot access some of these functions. Either they might be disabled, or the results are displayed with an artificial uncertainty, for example they are given as range or with a random uncertainty of +/- 5%. In this case, the results of repetitive calculation will prove to be different, even though they were performed with identical input parameters.



Graphic 5-31 Ranges of results in DEMO Version

The meaning of the DEMO-Version is to demonstrate the functions of the program, not obtaining exact results for real projects. For the latter purpose, exclusively the licensed full version is to be used.

5.9 Evaluation Criteria

During many development projects the question raises, in how far an incremental improvement of a technical parameter influences the economic result of the whole power plant. There are different ways to create a concrete question on that problem, so that PG-ROI could calculate the result.

Some examples are:

- How much reduces the pay off time, if the power plant produces an additional 1MW?
- How much increases the Net Present Value, if the availability rises by 1%?
- How much increases the internal rate of return, if the efficiency increases by 1%?

Or regarding the investment volume

- How much higher the investment could be, so that the above-mentioned improvements lead to an internal rate of return of the additional investment reaches 20% (independent of the rate of return of the whole project)?

The answer to the last question is named evaluation criterion within PG-ROI. In practice, it only can be calculated using the goal seek function, that was described in the previous chapter. The example in chapter 7.1 describes goal seek function, too, as it calculates the difference of two alternative power plant options.

The method to obtain evaluation criteria is as follows: The basic data of a power plant are put into Option A and then automatically transferred to Option B, so that both options have the same data. Then the calculation is started, giving identical results for both options A and B, consequently the cells of Delta option remain empty.

As a next step, an improvement of the option A is put in by changing one input parameter, e. g. increasing the power output by 1 MW, and a new calculation is performed. The sheets now show two different results for the two options, generally option A will outperform option B. The superiority of option A can best be seen in the Delta/option D, as it represents a positive Net Present Value.

No additional investment

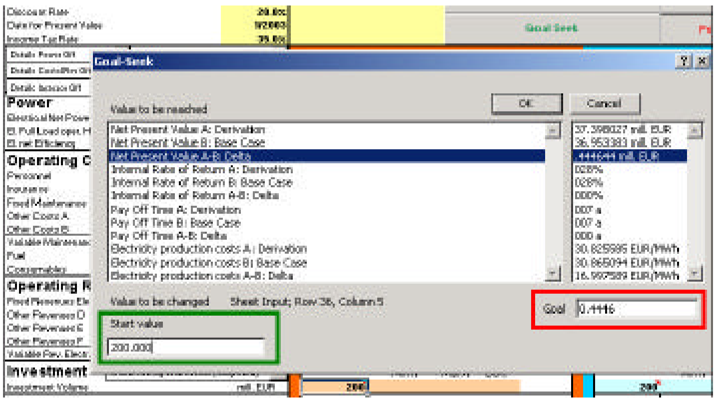
Investition			**Net Present Value (20%) at 1.1.2003**	**mill. EUR**	**0.445**
Fremdkapital	mill. EUR	0.000	Internal Rate of Return till 2013	% / a	0.0%
Eigenkapital	mill. EUR	0.000	**Internal Rate of Return till 2025**	**% / a**	**0.0%**
Kapitalbedarf	**mill. EUR**	**0.000**	**Pay Off Time from 1.1.2005 (a)**		**0.0**

Graphic 5-32 Net Present Value without investment

As a next step, the goal seek function for the investment volume of option A is employed. There are two ways to calculate a 20% internal rate of return for the Delta/option:

- Leaving discount rate at normal value (e. g. 10%) and setting destination value „Internal Rate of Return A-B: Delta“ on 20%.
- Changing discount rate to 20% and setting destination value „Net Present Value A-B: Delta“ on 0.

Both methods lead exactly to the same result, but due to the strong non/linearity of the internal rate of return, the second method is recommended, as it leads faster and more easily to the desired goal.



Graphic 5-33 Goal seek for evaluation criteria

PG-ROI finds the investment volume for the improved option A that leads to a 20% internal rate of return for the additional 0.882 mi EUR:

0.882 mill additional investment

Investition			**Net Present Value (20%) at 1.1.2003**	**mill. EUR**	**0.000**
Fremdkapital	mill. EUR	0.457	Internal Rate of Return till 2013	% / a	13.2%
Eigenkapital	mill. EUR	0.425	**Internal Rate of Return till 2025**	**% / a**	**20.0%**
Kapitalbedarf	**mill. EUR**	**0.882**	**Pay Off Time from 1.1.2005 (a)**		**20.9**

Graphic 5-34 NPV with additional investment

The criterion for the evaluation of an additional 1MW output is then calculated as 0.882 mi Euro.

This results changes with higher or lower electricity price, fuel costs, availability etc. In the multiple sensitivity analysis (chapter 5.5) some hints can be derived, which parameter has strong or soft influence on the result, anyway a higher number of calculation steps are required for a detailed analysis.

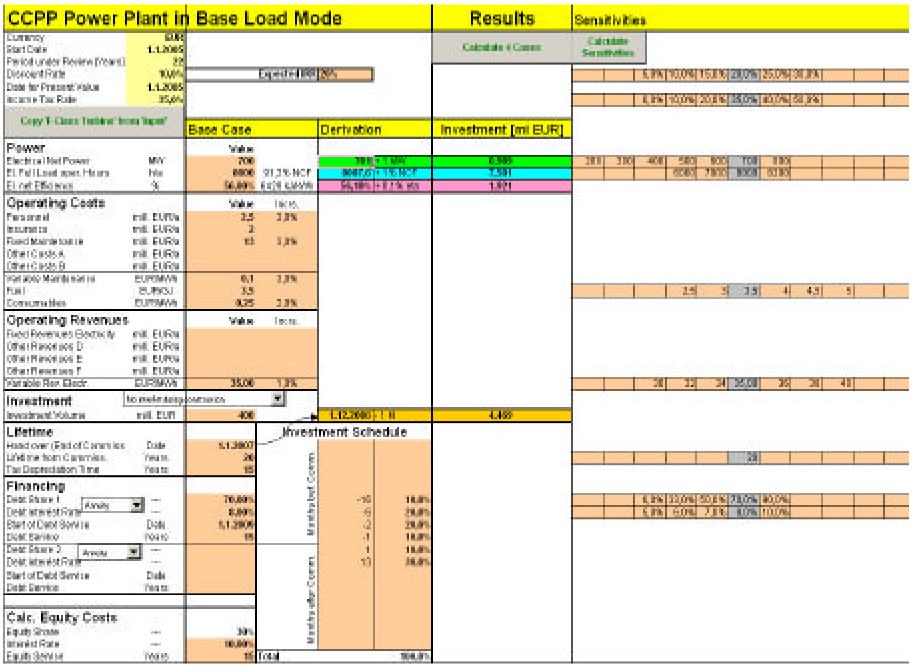
PG-ROI offers the fast and automated calculation as Add-on „Evaluation Criteria“ for new power plant projects, finding the justified additional investment for:

- Increase of power output by 1MW
- Increase of availability by 1% (87.6 full load operating hours)
- Increase of efficiency by absolute 0.1 %
- Shorter lead-time (construction period) by 1 month, while the absolute payment dates remain constant.

The data are transferred automatically into the sheet “Eval Cases” (Button Copy … from ‘Input’“. The so-called „Base Case“ and its four possible derivations correspond with the input data for the PG-ROI main program, but details on power and operating hours, costs and increase rates will not be considered, so that only simple cases of new power plants can be automatically evaluated.

The expected height of internal rate of return can be chosen, typical values range from 20 to 30%.

With button „Calculate 4 Cases“ PG-ROI calculates the four derivations of the base case. The results are shown in the colored cells.



Graphic 5-35 Input data evaluation criteria

For all the four described cases, the PG-ROI Add-On can also calculate sensitive analyses. The range of sensitivity is typed in directly into the cells on the right side of the sheet „Cases“. Empty cells are not considered, which speeds up the calculation. The grey filled cells should keep their formula as reference to the original value.

The results of the sensitivity analysis are displayed as table and in several charts. The button „Select Chart“ in sheet „Table“ leads the user directly to the chart according the selected cell in the table.

Variat Select Chart	Sensitivities + 1 MW					Start new Calcualation						Sensitivitie		
Expected IRR Delta		0.0%	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%					0.0%	
Delta Investment		0.924	0.657	0.498	0.397	0.328	0.278	0.240					17.484	1
Income Tax Rate	0.0%	10.0%	20.0%	25.0%	30.0%	35.0%	40.0%					0.0%	10.0%	2
Delta Investment	0.344	0.339	0.335	0.332	0.330	0.328	0.325					6.421	6.329	
Electrical Net Power														3
Delta Investment														
El. Full Load oper. Hours			5,000	6,000	7,000	7,000	8,000	8,200						5
Delta Investment			0.241	0.289	0.328	0.328	0.364	0.370						
Fuel	1.5	2	2.5	3	3.5	4	4.5	5				1.5	2	
Delta Investment	0.855	0.739	0.623	0.507	0.391	0.328	0.195	0.054				1.929	2.572	
Variable Rev. Electr.	30	31	33	35	37	35	41	43	45					
Delta Investment	0.113	0.157	0.247	0.328	0.387	0.328	0.496	0.569	0.643					
Lifetime from Commiss.			15	19	20	21								
Delta Investment			0.315	0.325	0.326	0.328								
Debt Share 1	0.0%	10.0%	20.0%	30.0%	40.0%	50.0%	60.0%					0.0%	10.0%	2
Delta Investment	0.193	0.236	0.269	0.289	0.308	0.328	0.349					3.611	4.258	
Debt Interest Rate		0.0%	2.0%	4.0%	6.0%	8.0%	10.0%	15.0%					0.0%	
Delta Investment		0.306	0.342	0.346	0.338	0.328	0.316	0.286					5.711	
Variation	Sensitivities + 1% NCF											Sensitivitie		
Expected IRR Delta		0.0%	5.0%	10.0%	15.0%	20.0%	25.0%	30.0%					0.0%	
Delta Investment		4.045	2.875	2.181	1.738	1.435	1.215	1.050					-0.202	
Income Tax Rate	0.0%	10.0%	20.0%	25.0%	30.0%	35.0%	40.0%					0.0%	10.0%	2

Graphic 5-36 Sensitivity analysis for evaluation criteria

6 Investment theory

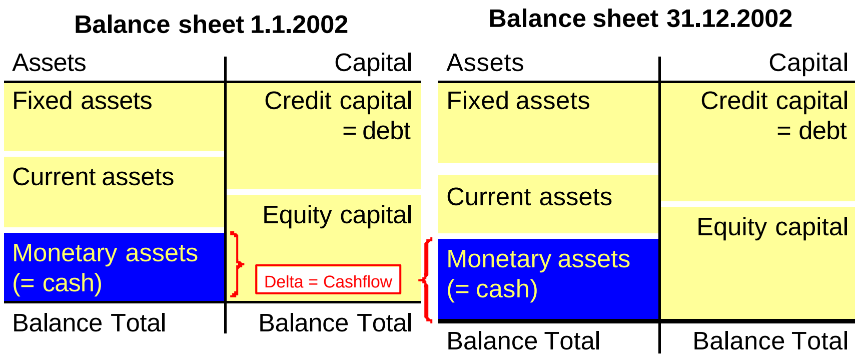
This Chapter describes the fundamentals of investment theory: The cash flow is a quantity used in industrial bookkeeping and accounting. It forms a row of payments, which are subjected to the present value calculating methods. The results of this calculation are the key figures: net present value, internal rate of return and pay-off time. The described methods have been generally accepted practices for decades and are used all over the world with little variation.

6.1 Balance and Cash flow

The cash flow is the basis of investment calculation. It reflects the change of cash resulting from an investment. The cash flow often is not calculated correctly and includes too many or too few components. This frequent lack of understanding is the reason why the cash flow is derived directly from the balance sheet in this chapter.

A balance sheet shows the assets on one side and the capital on the opposite side at a **POINT** of time (fixed date, e.g. at the beginning or end of the year).

- The capital side of a balance sheet shows where the money of a company came from (from equity capital[4] or from credit banks).



Graphic 6-1 Balance sheet: cash

- The asset side of the balance sheet shows where the money went to in the company, or what was bought with this money (fixed assets = machines, buildings etc., current assets = stock, claims etc.).
- Part of the current assets is the monetary asset, or simply called cash.
- Both sides of the balance sheet always equal in their totals.

The cash flow reflects the change of cash in the balance sheet between two fixed dates. It is positive, if the cash increased (income higher than payments, negative, if the cash decreased (income lower than payments).
Accordingly, only income and payments affect the cash flow.

Note: Four of the most important terms of accounting are often used as synonym although they are not at all identical in meaning:

- Payment / Expenditure / Expense / Costs or Income / Receipts / Earnings / Revenues

PG-ROI uses

- Payment and income for cash flow calculation because they affect the cash flow,
- Costs and revenues for profit and loss calculation because they affect the equity capital.

There are quite a number of payments that are at the same time costs, grouped as operating costs. On the other hand there are incoming payments that are at the same time revenues, grouped as operating revenues.

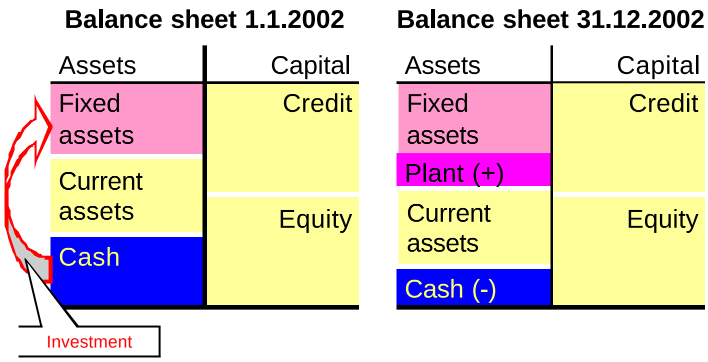
All costs and revenues are summarized in a separate **profit and loss calculation** over a **PERIOD** of time. The balance of this calculation is the profit or loss, which increases or decreases the equity capital.

Note: The term cash flow is often seen as a „change of equity" or is interpreted in a similar way. That is wrong. It is always the change of the monetary asset (or cash), which is to be understood by this term.

6.1.1 Investment with equity

When making an **investment,** a company buys for example a power plant thus converting money into fixed assets for the purpose of producing and selling electricity and heat. When the customer pays the invoice, the cycle closes as the company receives money again – hopefully more than before so that the investment was worth it.

The **investment with equity** is actually an **investment with available cash** because in the balance sheet it cannot be decided whether a certain item of the assets has been financed by equity capital or credit. Two items of the asset side are changed so that this procedure is also called an exchange of assets. On the other side, neither the equity capital is affected nor is the debt volume. But the term "investment with equity" is very commonly used in practice, so does PG-ROI.



Graphic 6-2 Balance: Investment with equity

An investment reduces the cash and results in a negative cash flow.

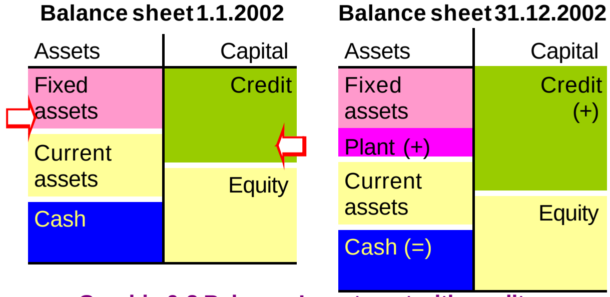
[4] **Equity capital** is defined as the amount by which the assets are higher than the credits.

6.1.2 Investment with credit

Investment with credit means that the available cash is not used, but new money is borrowed by a new credit and this new cash is then converted to a fixed asset.

Strictly speaking, these are two separate proceedings: raising a credit and investing this money, and the tow steps are separately presented by PG-ROI.

The draw of a credit line leads to an income resulting in a positive cash flow. An investment of the same amount reduces the cash and therefore results in a negative cash flow. Consequently, an investment with credit does not have any effect on the cash flow.

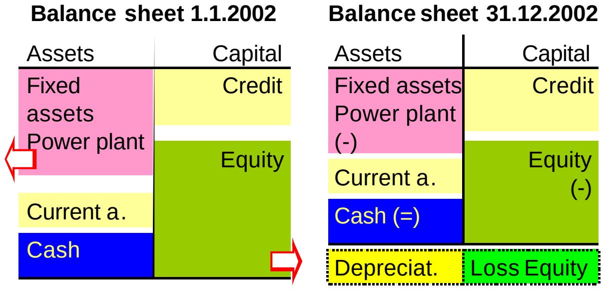


Graphic 6-3 Balance: Investment with credit

6.1.3 Depreciation and tax

Depreciation is the expression for the decrease in value of fixed assets without leading to income or payments, so that the total assets will decrease. On the capital side, the debt volume remains unchanged. Consequently, the equity capital will have to be reduced so that the balance total equals on both sides.

Since depreciation is part of the costs, it affects the profit and hence the equity capital of the company as described above. Due to the fact that **taxes** are paid on the profit of the company and therefore lead to a negative cash flow, the depreciation has an indirect negative effect on the cash flow.



Graphic 6-4 Balance: Depreciation

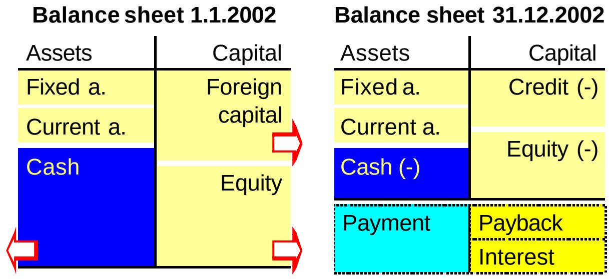
Tax depreciation is not part of the cash flow although it reduces the profit and with it the equity capital, but it does not lead to a payment. Accordingly, the fixed assets but not the cash are reduced and the cash flow remains zero.

6.1.4 Debt service – Payback and interest

In general, a drawn credit is paid back with interest in several payments over a certain payback period, called debt service (see Chapter 4.10).

The payments for paying back part of the credit lead to a reduction of the credit or the debt volume. They do not affect the equity capital whereas the payment of interest is not relevant to the credit capital but is part of the external costs, which reduce the equity capital.

The debt service consisting of payback and interest leads to a negative cash flow and, at the same time, to a decrease in the credit and equity capital.



Graphic 6-5 Balance: Debt service

The division of the debt service into payback and interest depends on the type of debt service, see Chapter 4.10. In financing, there may be a period of time during which no payments are made other than interest. PG-ROI foresees such an agreement automatically when selecting the start date of debt service: no paybacks are made from the date the credit is drawn (according to the payment schedule) until the start of debt service.

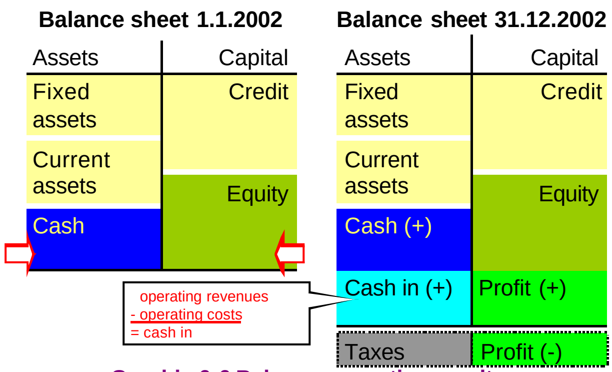
Note: The equity capital service is part of the (calculatory) costs. As no payment is effected, the equity service does not influence the cash flow.

6.1.5 Operating result

The operating result is obtained by subtracting the operating costs (fuel, personnel, maintenance) from the operating revenues (e.g. sales of electricity). Included are: all costs accruing during operation and leading to a payment at the same time; not included are: depreciation (do not lead to a payment) and credit interest (not arising from operation).

These revenues and costs are summarized over the year and at the end of the year, the profit after taxes is credited to the equity capital (a loss would reduce it). This profit corresponds to changes on the assets side, which can concern all items. Simply speaking, with regard to the operating result, it is assumed that only the cash is concerned.

When taxes are paid on profit the annual profit does not increase the equity by its full amount but reduced by the amount of these taxes.



Graphic 6-6 Balance: operating result

An operating profit leads to a positive cash flow and increases the equity capital.

6.2 Dynamic investment theory

The usual methods of dynamic investment calculation are based on the principle not to compare the cash flow figures of individual periods directly with each other but to make them comparable by means of certain factors. It is obviously not the same thing, if a payment of one million EUR is made and one year later a payment of 1.1 million EUR is received or vice versa. The factors for including the timely sequence of these two payments into the comparison of the cash flow figures are derived from the interest the money would bear when deposited in a bank.

This basic principle leads to different methods of investment calculation. In the form of key figures, all these methods together give an overview of the profitability of an investment. PG-ROI determines the four most important key figures:

- Present Value
- Net Present Value (NVP)
- Pay-off Time (POT)
- Internal Rate of Return (IRR)

The methodology of the **dynamic investment calculation** takes into account that the monetary value changes in the course of time. „Dynamic“ therefore means taking into account the timely sequence of payments (with effects from interest) in contrast to the static method of calculation, which deals only with nominal costs and revenues.

The dynamic methods are highly recommended to be applied in projects with a period of more than one year.

The basis of the dynamic investment calculation is the new evaluation of payments to be made at different points of time by referring them **to one fixed point of time**, the time of the present value.

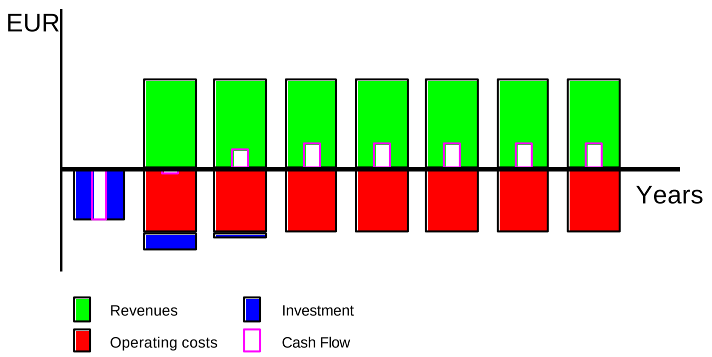
In any case, more than one of the key figures listed above should be taken into consideration to make a definite statement. It may happen however that individual methods lead to different statements, which are correct, if regarded separately, but suggest other decisions according to the point of view. It is only the consideration of several criteria, which leads to a generally accepted assessment.

6.2.1 Cash flow and present value

The cash flow of each period is determined according to the steps described in Chapter 5.2 and the resulting figures are then listed in a so-called row of payments. Such a row of payments for an investment with equity looks like the chart on the right:

The cash flow as a sum of income and payments are the white bars: negative at the beginning because of the investment covering a period of three years, later positive because the revenues are higher than the operating costs thus leading to a positive operating result.

The result of rows of payments are always nominal values which could be summed up but then would lose the timely aspect of their row. Hence, as a rule: never add nominal values of different years!



Graphic 6-7 Cash flow of investment with equity

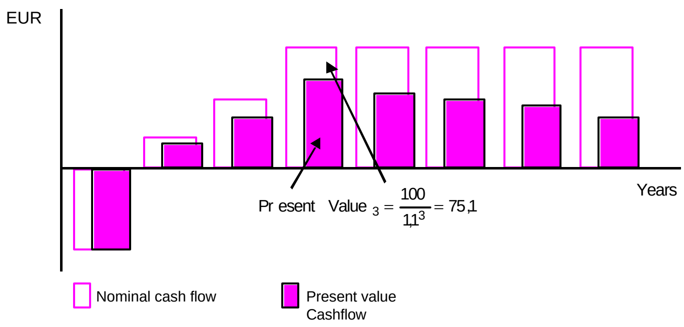
The **present value method** makes the nominal values of the cash flow comparable: the later the higher the reduction (**discount**). All payments are referred to their “present” value by reducing them at a discount rate over a number of years.

$$\text{present value}_{year} = \frac{\text{nominal value}}{(1 + \text{interest rate})^{year}}$$

Formula 6-1 Present Value

Accordingly, the present value of a payment of 100 € in three years at a discount rate of 10% is 75,1 €, because if these 75,1 € were deposited today in a bank at 10%, this payment would increase by interest and compound interest to exactly 100 €.

The above row of cash flows corresponds to the following row of present values: Although the nominal values of cash flow are equal, their present value is reduced each year by the same factor.



Graphic 6-8 Cash flow and present value

Consequently, early payments are of more importance than later payments. For assessing a project this means for example, that the distribution of initial and interim payments in the payment schedule of the first three years is more important than the question about the lifetime, 22 or 25 years.

Characteristic of the widely used present value method is the necessity to fix a **discount rate.**

There is no general rule how to fix this discount rate, every assumed value would be correct, but there are hints and conventions to follow:

The interest level for long-term credits is generally used as a criterion for the height of the discount rate so that lies between 6 and 12% in most of the cases.

6.2.2 Net Present Value

The **net present value** is calculated from the cumulated present values over the period under review. CF_p are the cash flows of the individual periods; i is the discount rate.

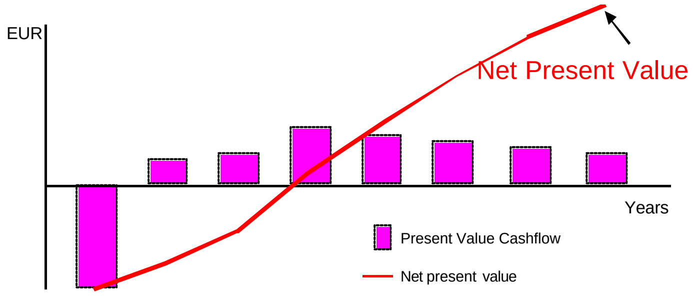
$$\text{Net Present Value} = \frac{CF_0}{(1+i)^0} + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \frac{CF_3}{(1+i)^3} + \cdots = \sum_{j=1}^{\text{period under review}} \left[\frac{\text{Cash flow}_j}{(1+i)^j} \right]$$

Formula 6-2 Net Present Value

Plotting the net present values over a period of time gives a good idea of the development of the monetary assets. Even if no equity capital is used (100% debt) a row of cash flows and thus a net present value is obtained. The chart shows a typical development of the net present value:

The term „Net Present Value" shows clearly that it is the present value at a point of time that takes into account not only future payments but also the initial investment.

Accordingly, the net present value changes along with the length of the period under review and normally a rising curve is obtained, that flattens due to the discounting.



Graphic 6-9 Chart: Net present value

The **net present value** is a **very good criterion to decide** for or against a project and to select the best alternative:

- If the net present value is > 0, the investment is better than the bank deposit.
- If the net present value is < 0, the bank deposit is better than the investment.
- The higher the net present value, the better the alternative.

At the point the curve of the net present value intersects the zero line, the discounted incoming payments are exactly of the same amount as the discounted payments made. That means, the investment yields as much money as the money would have brought when deposited in a bank at the same rate of interest. See also pay-off time in the next chapter.

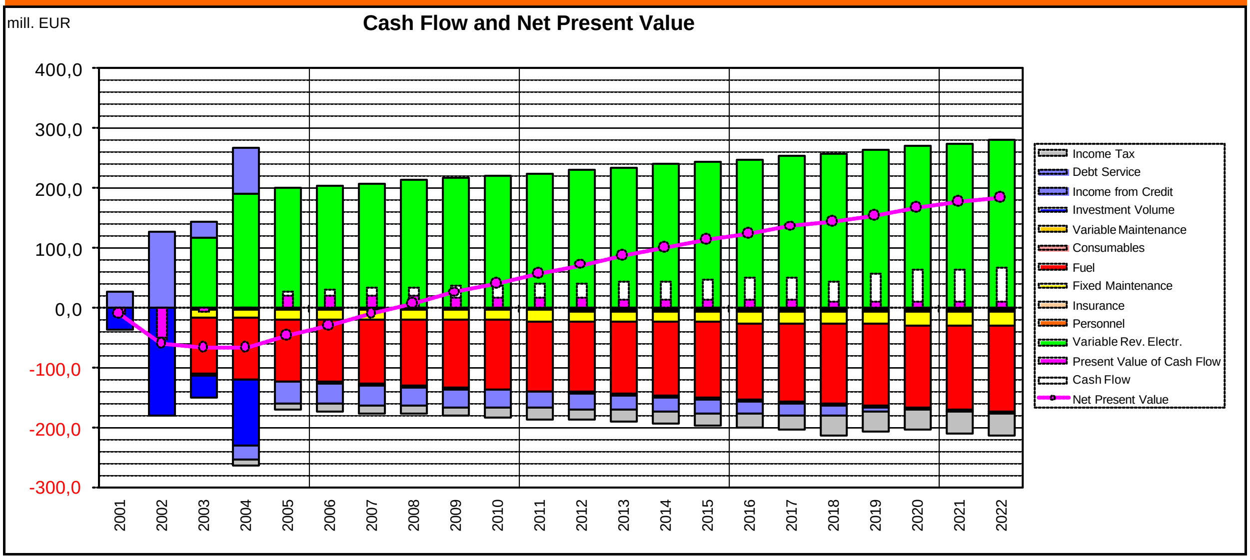
The net present value can be interpreted as the amount of money at present value that the investor earns by the project in addition to the interest he would have received from the bank.

It has to be emphasized here that the profitability calculation does not include payback or interest of the invested equity capital, which should be regarded as just the result of the cash flow calculation.

The profitability of the overall project can therefore be determined very well by one single diagram, because investment and operation of the plant lead to the cash flow from which the net present value is obtained. For this reason, such a chart is the central output of PG-ROI on sheet "Results CF":

Investment		
Debt	mill. EUR	252,000
Equity	mill. EUR	108,000
Capital Requirement	**mill. EUR**	**360,000**

Net Present Value (10,0%) at 1.1.2002	**mill. EUR**	**184,400**
Internal Rate of Return till 2011	% / a	22,5%
Internal Rate of Return till 2022	**% / a**	**28,4%**
Pay Off Time from 1.1.2003 (a)		**5,5**



Graphic 6-10 Cash flow and net present value with PG-ROI

6.2.3 Internal Rate of Return

Intrernal Rate of Return from Net Present Value

$$NPV \overset{!}{=} 0 \overset{!}{=} \frac{CF_0}{(1+i)^0} + \frac{CF_1}{(1+i)^1} + \frac{CF_2}{(1+i)^2} + \frac{CF_3}{(1+i)^3} + \cdots$$

Formula 6-3 Internal Rate of Return

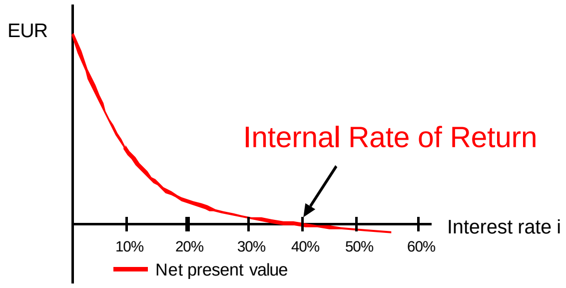
The present value method needs a given interest rate at which the nominal cash flow values are discounted. The sum of these values is the net present value.

However it can also be assumed that the net present value is zero and then to search for the interest i which makes the net present value to become zero. Arithmetically, it is the zero point of the net present value equation (see formula).

Since the interest rate i is always in the denominator, the net present value decreases with an increasing interest rate and becomes zero at a certain rate and even negative, as can clearly be seen in the graphic chart.

The solution (zero) of the net present value calculation is the Internal Rate of Return (IRR).

The internal rate of return is then compared with the interest rate of other investment projects or the bank deposit. As a rule: the higher the internal rate of return the better the project.



Graphic 6-11 Internal rate of return graphically

The internal rate of return cannot be determined, if the cash flow is only negative or only positive over the whole period under review or if the IRR exceeds 100%. In these cases, zero will be indicated.

The interpretation of the internal rate of return is most simple, as long as it is approximately of the same height as the external discount rate or the bank interest that is between 10 and 25%. An alternative proves to be advantageous, if the internal rate of return is higher than the interest that an investor would receive from a bank deposit.

An interpretation is almost impossible, if the internal **rate of interest is negative**: such an alternative does not pay in any case.

An interpretation of the internal rate of return is also difficult, if the **values are very high** (above 25 %). This method assumes that a standard interest rate is used for raising and investing capital, which is not realistic. If the internal rate of return is 45% for example, the whole free cash is always invested at this interest rate, as if there were always further investments or projects with such a high rate of return. In spite of this deficiency, calculation methods with different interest rates for raising and investing capital did not become generally accepted. See the following chapter about the Modified Internal Rate of Return that avoids most of the described problems.

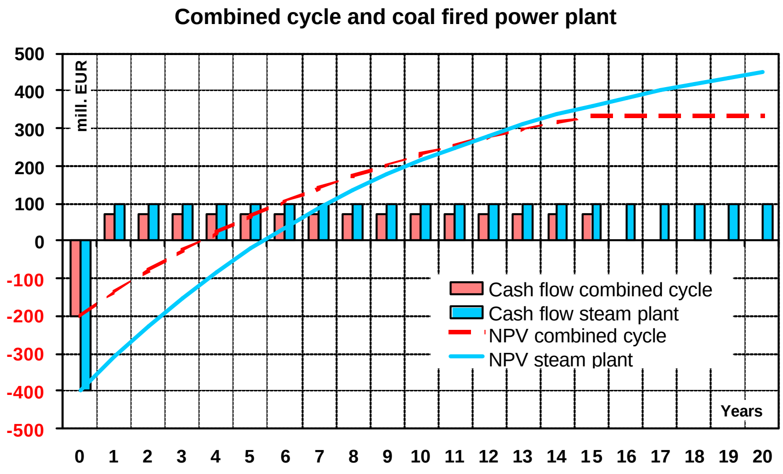
Moreover, the internal rate of return may be ambiguous, if the net present value equation has **more than one zero points**, if the row of values shows several changes of the sign. It may happen that there are two internal rates of return, e.g. 15% and 63%, and both are formally correct. In this case, it is recommended to choose the lower rate.

The third deficiency of this method is that the internal rate of return does not depend on the absolute height of the investment. Here an example for explanation:

- Combined cycle power plant for 200 mill. EUR, operating result 70 mill. EUR for 15 years, IRR 35%
- Coal-fired power plant for 400 mill. EUR, operating result 100 mill. EUR for 20 years, IRR 25%.
- No other projects available but a bank deposit at 10%.

At first sight, the combined cycle power plant seems to be the better alternative because the investor can expect a higher internal rate of return with a smaller investment. The net present value of the combined cycle power plant is only 332 mill. EUR whereas it is 451 mill. EUR for the coal-fired plant so that with his decision for "coal-fired power plant" the investor will earn 119 mill. EUR more than with the combined-cycle power plant.

This apparent contradiction is based on the great difference between the two investment projects. Obviously, the investor has 400 mill. EUR at his disposal, otherwise the alternative coal-fired power plant would not exist. For the combined-cycle power plant only half of the investment (200 m. EUR) is calculated at an interest rate of 35%, whereas the rest returns only 10% from the bank; the internal rate of return for the combined cycle power plant is only 22.5% compared to 25% of the coal-fired power plant.



Graphic 6-12 NPV of coal fired and combined cycle

The net present value method takes the absolute height of the investment volume automatically into consideration so that the net present value clearly shows the advantage of the coal-fired power plant, see diagram above.

The internal rate of return is often used as a decision criterion. However, the user should know the boundary conditions and how to interpret them. In general, the internal rate of return should not be the only decision criterion but is to be used only in combination with the net present value.

Modified Internal Rate of Return

The inherent problems with using and interpreting the Internal Rate of Return might lead to inappropriate decisions, if it is the only criteria. The following text is an adapted excerpt from "Internal Rate of Return : A Cautionary Tale, The McKinsey Quarterly, McKinsey & Co., October 20, 2004".

"If the IRR calculated to justify investment decisions had been corrected for the measure's [the IRR's] natural flaws, management's prioritization of its projects, as well as its view of their overall attractiveness, would have changed considerably.

Admittedly, some of the measure's deficiencies are technical, but the most dangerous problems with IRR are neither isolated nor immaterial, and they can have serious implications for capital budget managers. When managers decide to finance only the projects with the highest IRRs, they may be looking at the most distorted calculations — and thereby destroying shareholder value by selecting the wrong projects altogether. Companies also risk creating unrealistic expectations for themselves and for shareholders, potentially confusing investor communications and inflating managerial rewards.

We believe that managers must either avoid using IRR entirely or at least make adjustments for the measure's most dangerous assumption: that interim cash flows will be reinvested at the same high rates of return.

Practitioners often interpret internal rate of return as the annual equivalent return on a given investment; this easy analogy is the source of its intuitive appeal. But in fact, IRR is a true indication of a project's annual return on investment only when the project generates no interim cash flows — or when those interim cash flows really can be invested at the IRR.

When the calculated IRR is higher than the true reinvestment rate for interim cash flows, the measure will overestimate — sometimes very significantly — the annual equivalent return from the project. The formula assumes that the company has additional projects, with equally attractive prospects, in which to invest the interim cash flows. In this case, the calculation implicitly takes credit for these additional projects. Calculations of net present value (NPV), by contrast, generally assume only that a company can earn its cost of capital on interim cash flows, leaving any future incremental project value with those future projects.

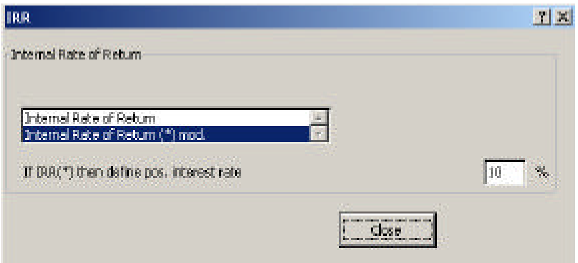
Recently, however, when we conducted an analysis with the reinvestment rate adjusted to the company's cost of capital, the true average return fell to just 16 percent. The order of the most attractive projects also changed considerably. The top-ranked project based on IRR dropped to the tenth-most-attractive project. Most striking, the company's highest-rated projects — showing IRRs of 800, 150, and 130 percent — dropped to just 15, 23, and 22 percent, respectively, once a realistic reinvestment rate was considered. Unfortunately, these investment decisions had already been made. Of course, IRRs this extreme are somewhat unusual. Yet even if a project's IRR drops from 25 percent to 15 percent, the impact is considerable.

What to Do? The most straightforward way to avoid problems with IRR is to avoid it altogether. Yet given its widespread use, it is unlikely to be replaced easily.

Executives should at the very least use a modified internal rate of return. While not perfect, MIRR at least allows users to set more realistic interim reinvestment rates and therefore to calculate a true annual equivalent yield […]."

The method of MIRR then requires the compounding of all positive cash-flows to the last period under review with the positive rate (i^{pos}) and the discounting of all negative cash-flows to the first period, at a given discount rate (i^{neg}), and draw the n-th root of their ratio (see formula), which is the MIRR.

There is no simple interpretation of the MIRR. None of typical expressions like "The true annual return rate of the investment" is correct. The MIRR does not in and of itself indicate whether the project is a winner. The decision rule for utilizing the MIRR method is similar to the decision rule employed for the IRR method. If the MIRR is greater than the hurdle rate, accept. If it is less than the hurdle rate, reject. Unfortunately, the MIRR refuses to be caught by intuition, but still comes closer to reality than the standard IRR.



Graphic 6-13 Interest rate for MIRR

While the MIRR method does eliminate the potential for calculating multiple IRR when projects have negative cash-flows late in their useful lives, it does not eliminate the problems that arise from mutually exclusive projects or capital rationing, as expressed in the above example of the coal fired power plant.

$$MIRR = \left[-\frac{\sum_{n=0}^{N} CF_n^{pos} \cdot \left(1+i^{pos}\right)^{(N-n)}}{\sum_{n=0}^{N} CF_n^{neg} \cdot \left(1+i^{neg}\right)^{(-n)}} \right]^{\frac{1}{n}} - 1$$

Formula 6-4 Internal Rate of Return

6.2.4 Pay-Off Time

The pay-off time (POT) is the time needed until the negative cash flow at the beginning is breaks even with the positive cash flow. According to the ideas of the dynamic investment theory, the present values of the cash flow are used for a dynamic pay-off time.

There is no common definition or methodology for determining the pay-off time, so that each comparison of pay-off times should be preceded by a comparison of its calculation method. None of the methods is right in principle and the others are wrong. They only start from different assumptions, which are just more or less reasonable for different cases.

PG-ROI offers three different methods for calculating the pay-off time. One of which is especially suitable for new plants and modernization projects whereas the other two methods reflect long project periods and payment schedules over several years.

- 1 pay-off time from net present value accumulated
- 2 pay-off time from weighted cash flow or present value.

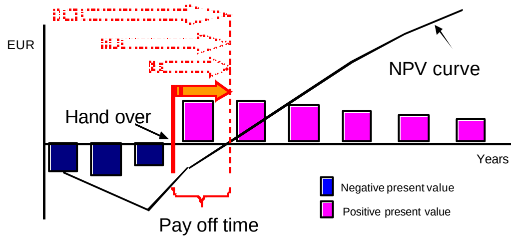
The parties involved in the respective case should select the best interpretation.

In general, the pay-off time will lie between two periods irrespective of the applied method so that in practice, a linear interpolation is used to increase the exactness of the result. This simplification is actually impermissible since payments are only made at the end of a period. However, since PG-ROI calculates on a monthly basis, the error is insignificant.

The dynamic pay-off time is generally longer than the static pay-off time (determined by the nominal cash flow) because the later incoming payments are less weighted by the discounting.

Pay-Off Time from net present value

The net present value method offers a plausible way for defining the pay-off time. At the point where the net present value curve crosses the x-axis, the investor has broken even the negative cash flow with the revenues from the project. Consequently, the investment project in this moment is as good as a bank deposit. This is the end of the pay-off period as can also be clearly seen from the graphic chart.



Graphic 6-14 Pay-off time from net present value

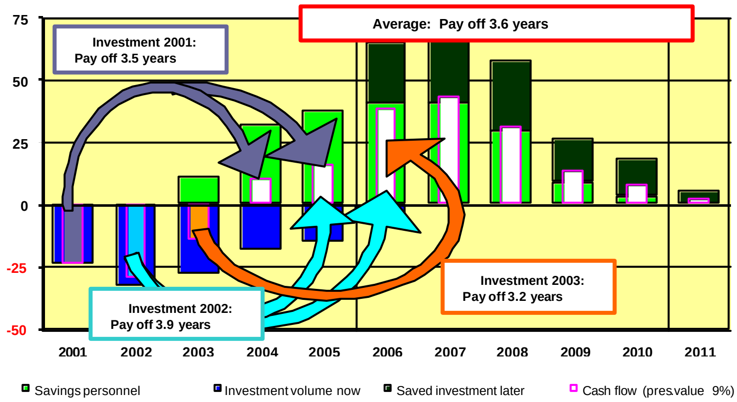
The **end of the pay-off period** is clearly determinable[5] but not the **starting point**. If there is one single payment the starting point is definite, but not if there are several payments before handover. In the case of long-term projects with a payment schedule over several years the question arises whether the pay-off time starts with the first payment, the medium payment or highest payment or at a definite date. In some projects (particularly modernization projects) it may happen that the cash flow becomes negative already before the first payment so that it cannot be used as a criterion at all.

For practical reasons, the pay-off time should be referred to a definite start date, especially the date of handover or the beginning of commercial operation, which is also used by PG-ROI. If required, it is easy to change to one of the other methods.

Pay-Off Time for long projects

Long-term projects are often carried out step-by-step so that it is not possible to determine one definite date for the start of commercial use (like the date of handover). A large part of the investment is made only after the first savings or additional revenues are achieved so that these savings can partially pay the investment project.

A step-by-step determination of the pay-off time reflects the reality of long-term projects better than does the previously described method. It may also be called „average break even period of the cash flow“ or „rolling pay-off time“ **and is derived from the weighted average of periods until a partial investment will be paid back.**



Graphic 6-15 Rolling pay-off time

- In the example above, 50% of the investment made in the year of 2001 is covered by the savings of the year 2004 (3 years), the rest is paid back by the investment in 2005 (4 years) so that the pay-off time is 3.5 years.
- In 2005 there is only a little surplus to cover the 2002 investment (approximately one tenth with 3 years POT), whereas the greatest part will be covered only in 2006 (4 years) so that for 2002 the pay off time is 3.9 years.
- Analogously, the pay-off time of the investment in 2004 is shorter, i.e. 3.2 years.
- Weighted with the respective amount of the investment, the average pay-off time is 3.6 years.

This value is considerable lower than the pay-off time calculated according to the net present value method (more than 5 years).

The nominal cash flow or its present value is used for the weighted pay-off time as the row of payments, so that it is possible to take account of the effects from interest (see example).

[5] If there are several zero crossings the last one counts.

7 Examples

7.1 Additional investment and goal seek

For a combined cycle power plant there are two options for the cooling system:

Option A: Open cooling water cycle to a nearby riverwith the following benefits and disadvantages:

- + Increase of efficiency from 55.9 to 56.5%
- + Increase of power output from 720 to 722 MW
- - Environmental tax (for heating up the river water) of 250,000 Euro, increasing 5% per year
- - Additional investment of **approx.** 4 m. Euro

Option B: Closed cycle with cooling tower

General assumptions:

- 8000 operating hours per year and lifetime 22 years
- Financing 100% debt share
- Fuel costs 2,6 Euro/GJ
- Variable revenues electricity 28 Euro/MWh
- 35% tax
- Interest and discount rate 10%

The following questions should be answered:

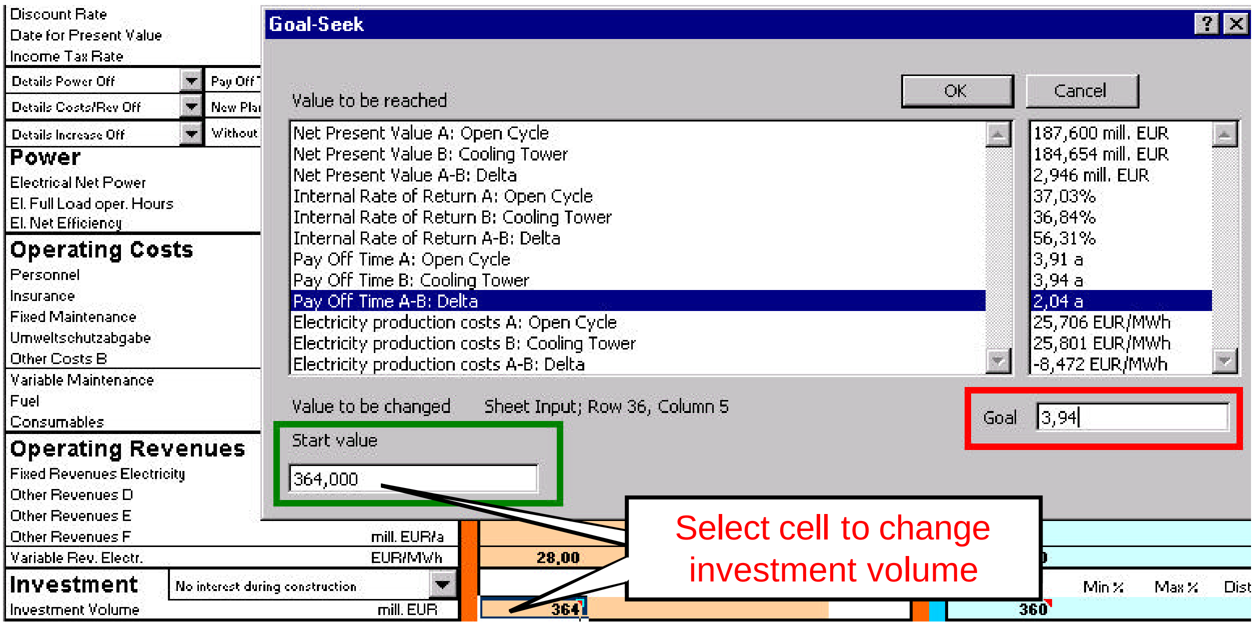
- How much more expensive the open cycle may be while resulting as beneficial as the rest of the investment?
- What is the maximum height of the environmental tax, so that the additional investment of 4 mill. Euro is still beneficial?

The answers cannot be derived directly from the calculations of option A and B, as the RoI figures are almost identical with 3.9 years pay-off time. But in the Delta calculation it becomes obvious that the 4 million Euro are a good investment.

		Open Cycle	Cooling Tower	Delta
Net Present Value (10,0%) at 1.1.2002	**mill. EUR**	**187,600**	**184,654**	**2,946**
Internal Rate of Return till 2012	% / a	31,9%	31,7%	54,6%
Internal Rate of Return till 2023	**% / a**	**37,0%**	**36,8%**	**56,3%**
Pay Off Time from 1.1.2004 (a)		**3,9**	**3,9**	**2,0**

Graphic 7-1 RoI figures for additional investment

With the PG-ROI goal seek function it is easy to find the investment volume that leads to a pay-off time of the 3.9 years for the Delta option: Select the cell "Investment volume" in sheet "Input" and then click on the goal seek button:



Graphic 7-2 Goal seek for additional investment

The result is 5.168 mill Euro. With that result, the first question has the following answer:

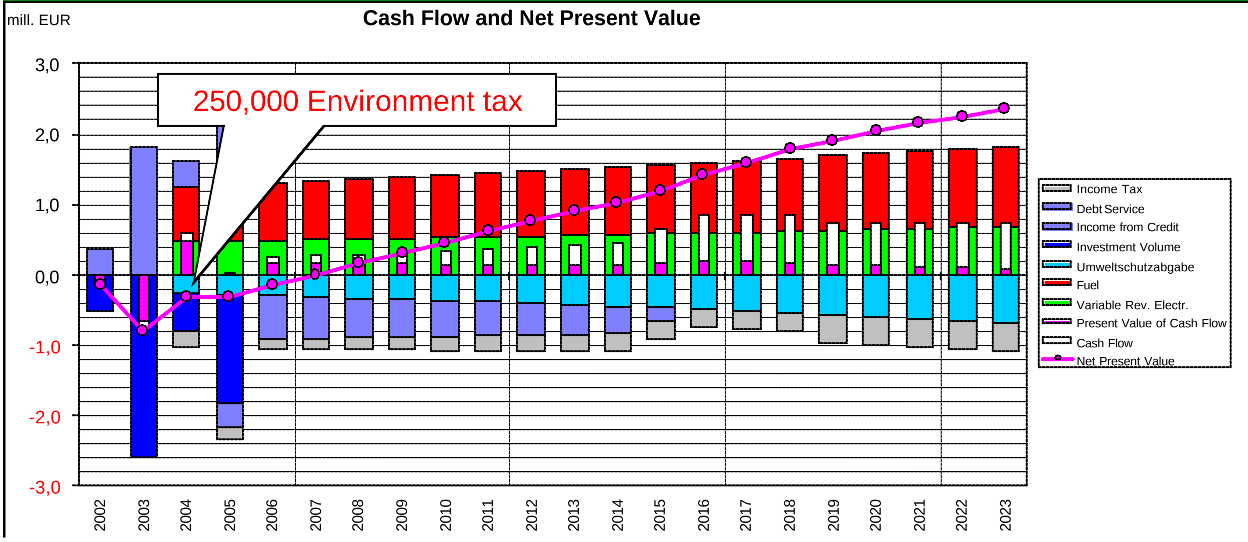
Delta-Investment: Cooling Tower or Open Cycle

Delta

5.168 mill Invest

Investment		
Debt	mill. EUR	3,618
Equity	mill. EUR	1,550
Capital Requirement	**mill. EUR**	**5,168**

Net Present Value (10,0%) at 1.1.2002	**mill. EUR**	**2,349**
Internal Rate of Return till 2012	% / a	30,9%
Internal Rate of Return till 2023	**% / a**	**35,9%**
Pay Off Time from 1.1.2004 (a)		**3,9**



Graphic 7-3 Delta investment open cooling cycle

If the additional price for the open cooling water cycle is not more than 5.168 mill. Euro, it has a pay-off time of 3.9 years. The total project's profitability deteriorates a little with the additional investment, but despite of the increase in investment volume from 364 to 365.168 mill. Euro, the pay-off time of the whole projects stays at 3.9 years.

The second question about the maximum environmental tax will be answered also by the goal seek function: input 364 mill. Euro as investment, selection of cell "Environmental tax" and click on the goal seek button. The goal is again 3.9 years pay-off time for the Delta option. The result is 441,000 Euro.

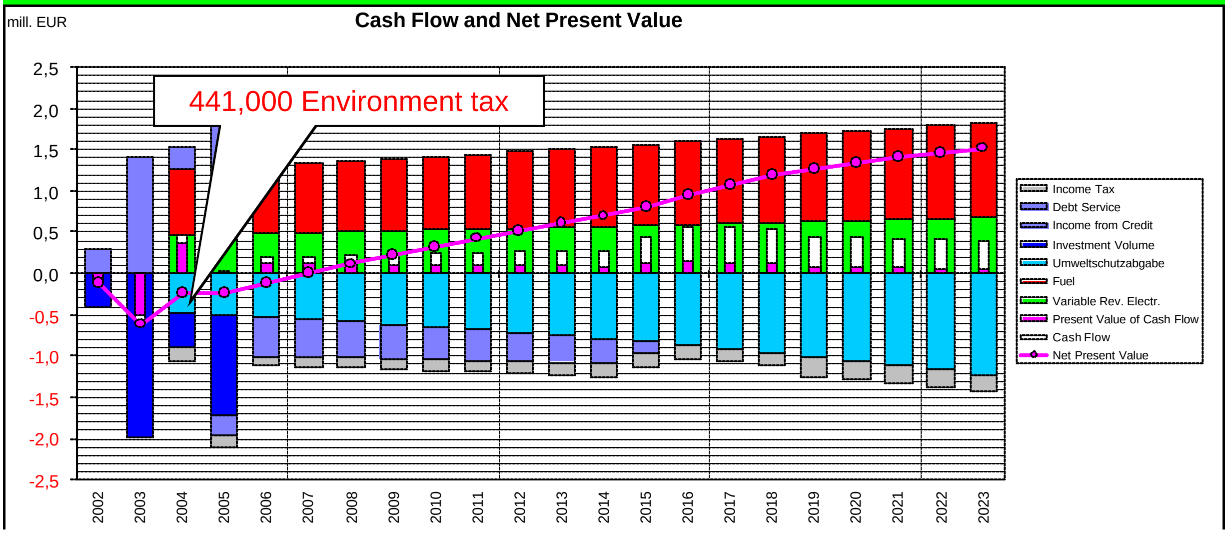
Delta-Investment: Cooling Tower or Open Cycle

Delta

4.000 mill Invest

Investment		
Debt	mill. EUR	2,800
Equity	mill. EUR	1,200
Capital Requirement	**mill. EUR**	**4,000**

Net Present Value (10,0%) at 1.1.2002	**mill. EUR**	**1,518**
Internal Rate of Return till 2012	% / a	29,8%
Internal Rate of Return till 2023	**% / a**	**34,6%**
Pay Off Time from 1.1.2004 (a)		**3,9**



Graphic 7-4 Delta investment environmental tax

If the environmental tax does not exceed 441,000 Euro, the additional investment of 4 mill. Euro pays off within 3.9 years.

7.2 Modernization

In this example the modernization of an older 500 MW coal fired power plant is modeled, in which the exchange of the control system and instrumentation of the boilers the availability will increase significantly. The following pros and cons will be caused by the modernization:

- Increase of lifetime from 12 to 12.5 years
- Increase of efficiency from 41 to 42%
- Increase of availability with operating hours rising from 7000 to 7600
- Participation in the pool of power plant for grid frequency control, which gives extra revenues of 1.5 mill. Euro per year.

Other boundary conditions are:

- Standstill 3 months, of which one months is planned for regular turbine revision.
- Fuel costs 2 Euro/GJ, electricity price 25 Euro/MWh
- **Approx**. 10 m. Euro investment, financing 100% equity with 6 month payment schedule

The following questions should be answered:

- Is the project beneficial at all (criteria: internal rate of return higher than 25% and pay-off time lower than 5 years)?
- How much may of the investment volume increase, if the standstill is two weeks shorter?
- At which electricity price the pay-off time is higher than 5 years?

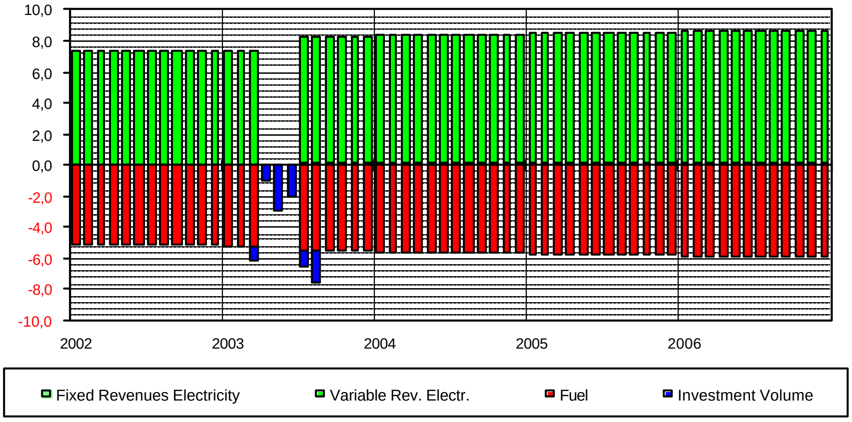
The calculation is done with the Delta option; with option A being "with modernization" and option B being "no modernization", the operating hours are entered with monthly resolution. The first diagram shows the first years' cash flow of the option A: The three months of standstill stand out as a cut of revenues and costs, remaining only the partial payments of the modernization.

The option "no modernization" shows a revenues cut during one month of the turbine revision, during the other months the costs and revenues remain constant.

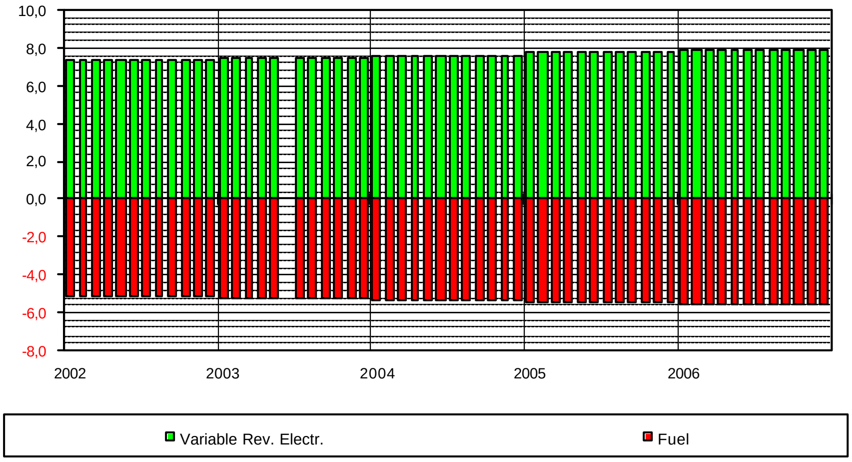
The difference of both cash flows is the net benefit of the modernization; it is obtained by subtracting the second cash flow from the first one. The diagram shows clearly that the standstill causes loss of revenues that reach the same magnitude as the investment, but only during the first two months of modernization. The third month leads to standstill in both cases and therefore must not be credited to the modernization, but cancels out.

After hand over of the modernized plant the modernization leads to higher revenues due to the additional operating hours and the additional fixed revenues from frequency control. These benefits stand opposite the slightly higher fuel costs.

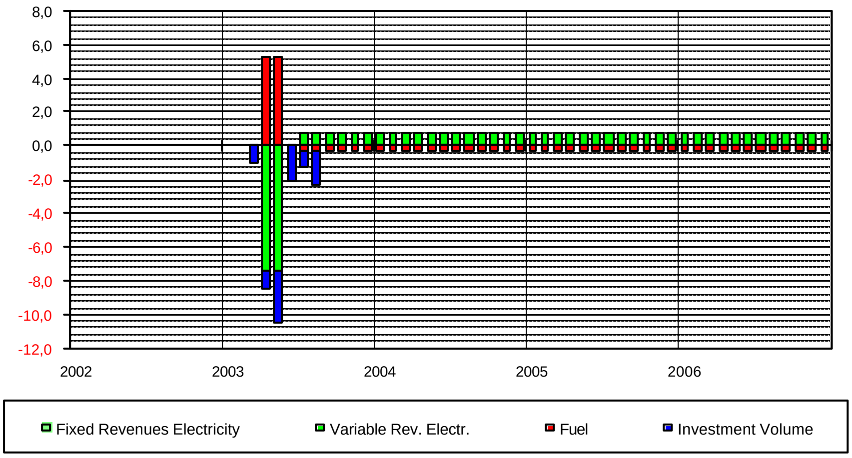
The loss of revenue is not part of the investment volume but directly affects the cash flow. Therefore it is no use calculating some "return on invested capital" but only the profitability of the resulting cash flow.



Graphic 7-5 Option with modernization



Graphic 7-6 Option without modernization



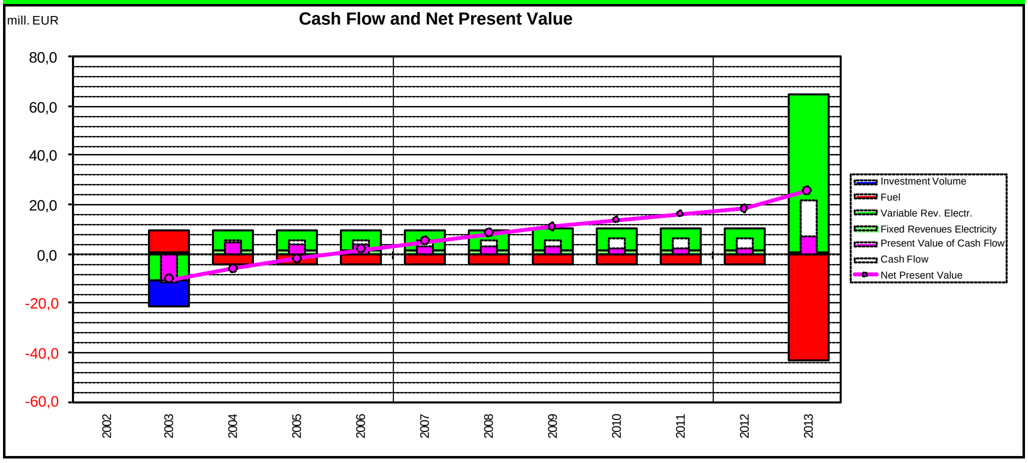
Graphic 7-7 Delta modernization

The benefit from lifetime extension becomes visible in the last year of operation; therefore it is not detectable in the charts with monthly resolution that only cover the first five years. Even though the nominal amount of additional revenues in 2013 is high, the discounting over 12 years makes them less significant and decisive for the whole project.

Modernization Coal fired Power Plant

Net Benefit of Modernization

Investment			**Net Present Value (10,0%) at 1.1.2002**	mill. EUR	25,555
Debt	mill. EUR		Internal Rate of Return till 2012	% / a	43,6%
Equity	mill. EUR	10,000	**Internal Rate of Return till 2013**	% / a	45,6%
Capital Requirement	mill. EUR	10,000	**Pay Off Time from 1.7.2003 (a)**		3,0



Graphic 7-8 Modernization with lifetime extension

The question about profitability can be answered in the affirmative with a quick glimpse on the RoI figures and the charts:

The internal rate of return is 45.6%, the pay-off time is 3 years and the net present value is 25.5 mill. Euro – all three figures are very positive .

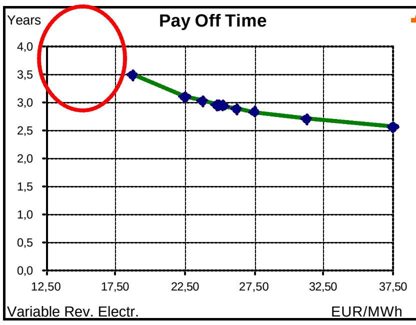
For answering the second question "How much may of the investment volume increase, if the standstill is two weeks shorter?" in sheet "Power_M" the first month of standstill will have half of the previous month's operating hours instead of Zero, i. e. 7000/12/2 = 292 hours. This reflects the assumption that the modernization starts half a months later and ends in the same moment (it is possible to put half of the new plant's operating hours into the last month of the modernization – the information gives room for both interpretations).

The new calculation leads to a net present value of 26.529 instead of 25.555 mill. Euro. The goal seek function adjusts the investment volume of 10 mill. Euro so that the net present value of the delta again becomes 25.555 mill. Euro. The result of the goal seek is 11.121 mill. Euro investment volume.

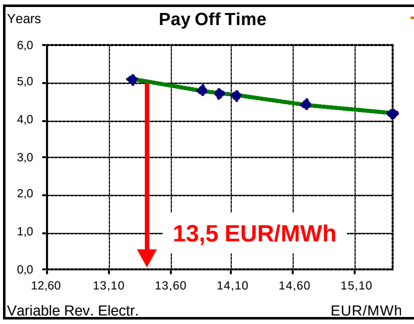
		3 Months Standstill 10 mill. Investment	2,5 Months Standstill 10 mill. Investment	2,5 Months Standstill 11,121 mill. Investment
Net Present Value (10,0%) at 1.1.2002	mill. EUR	25,555	26,529	25,555
Internal Rate of Return till 2013	% / a	45,6%	50,1%	45,7%
Pay Off Time from 1.7.2003 (a)		3,0	2,7	3,0

Graphic 7-9 Goal seek of investment volume

The third question "At which electricity price the pay -off time is higher than 5 years?" could be solved with the goal seek function, but the graphical display of the single sensitivity analysis is more comprehensible: If the electricity price is lower than 12.50 Euro/MWh, then no pay-off time is reached, and above 18 Euro/MWh all calculated pay-off periods are shorter than 4 years. It is useful to detail the search in the lower range, starting from a new calculation with 14 Euro/MWh and then a new sensitivity analysis:



X (A)	X (B)	Y
EUR/MWh	EUR/MWh	Years
12,50	12,50	
18,75	18,75	3,50
22,50	22,50	3,12
23,75	23,75	3,03
24,75	24,75	2,97
25,00	25,00	2,96
25,25	25,25	2,95
26,25	26,25	2,90
27,50	27,50	2,84
31,25	31,25	2,72
37,50	37,50	2,58



X (A)	X (B)	Y
EUR/MWh	EUR/MWh	Years
12,60	12,60	
13,30	13,30	5,10
13,86	13,86	4,78
14,00	14,00	4,71
14,14	14,14	4,65
14,70	14,70	4,42
15,40	15,40	4,18

Graphic 7-10 Two step sensitivity analysis

The new calculation with 14 Euro/MWh results in 4.7 years pay-off time, the sensitivity analysis around this value lead to the result of 13.5 Euro/MWh for a 5-year pay-off time.

Remark: In this example there is no pay-off time longer than 5 years, because with very low electricity prices the benefit from lifetime extension turns into disadvantage, the whole modernization becomes obsolete and the plant should be shut off.

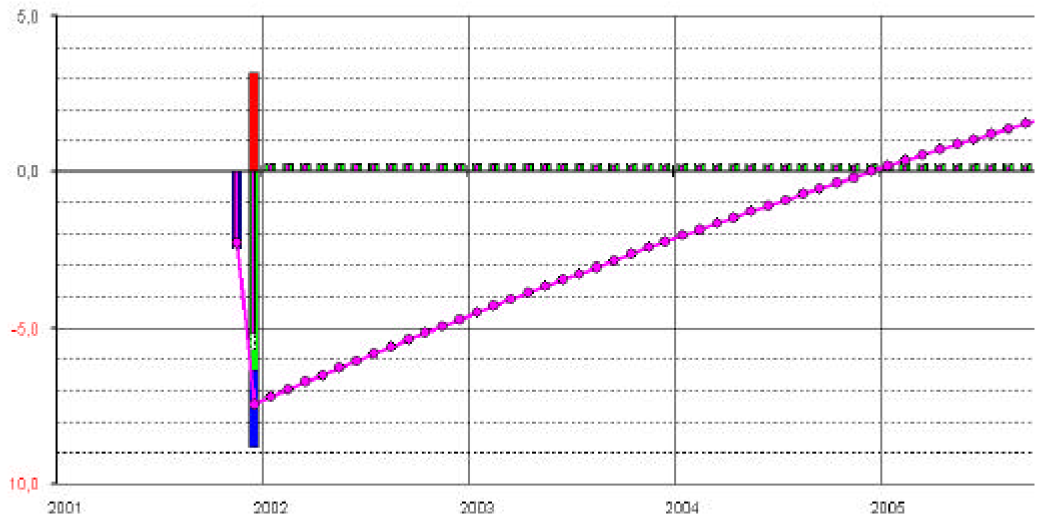
7.3 Internal rate of return with monthly resolution

This Chapter shows the Delta calculation of a turbine blade modernization with the following parameters:

- Increase of power output from 290 to 300 MW
- Increase of efficiency from 41 to 43%
- Standstill 1 month
- Investment volume: 5 mill. Euro, 100 % equity
- Payment schedule: 50% two months and 50% one month before hand over

The results of PG-ROI with **monthly resolution**:

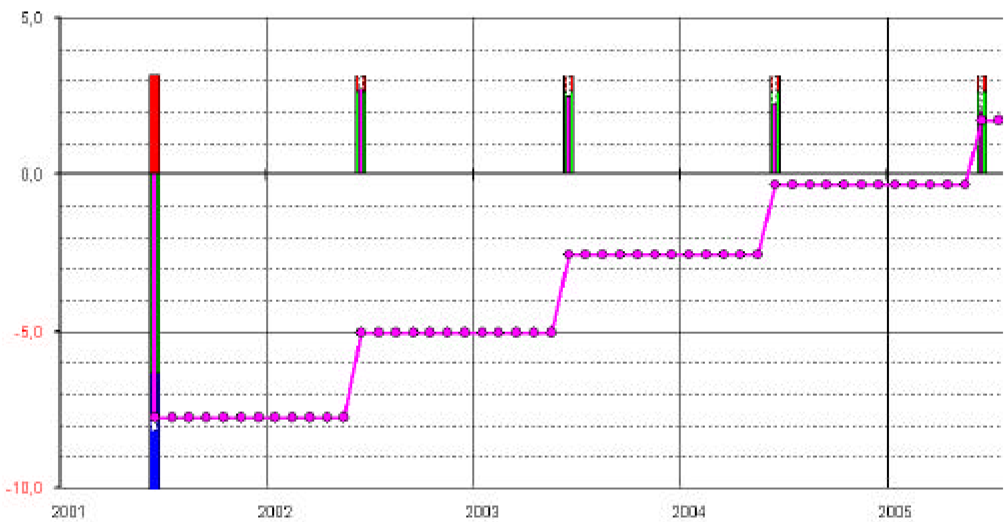
Net Present Value (10,0%) at 1.1.2001	**mill. EUR**	**11,974**
Internal Rate of Return till 2011	% / a	44,3%
Internal Rate of Return till 2012	**% / a**	**44,7%**
Pay Off Time from 1.1.2002 (a)		**2,9**



Graphic 7-11 Cash flow with monthly resolution

The results of a **yearly resolution** (i. e. all payments are mid-year):

Net Present Value (10,0%) at 1.1.2001	**mill. EUR**	**11,664**
Internal Rate of Return till 2011	% / a	36,8%
Internal Rate of Return till 2012	**% / a**	**37,3%**
Pay Off Time from 1.1.2002 (a)		**3,3**



Graphic 7-12 Cash flow with yearly resolution

The chart of monthly resolution clearly reflects the partial payments, while in the chart with yearly resolution all payments of one year are accumulated, which leads to biased and not exact results.

The IRR depends very much on short-term payment schedules and it differs significantly between a monthly calculation and a yearly resolution. The general rule applies: The shorter the project, the more detailed the calculation should be.

8 Installation and license agreement for PG-ROI

8.1 Installation

Precondition for the use of PG-ROI is an operational installation of one of the operating systems Windows 97[6], Windows 2000 or Windows NT and the installation of MS Excel 97, MS Excel 2000 or MS Excel 2003/XP which are not included in the scope of PG-ROI.

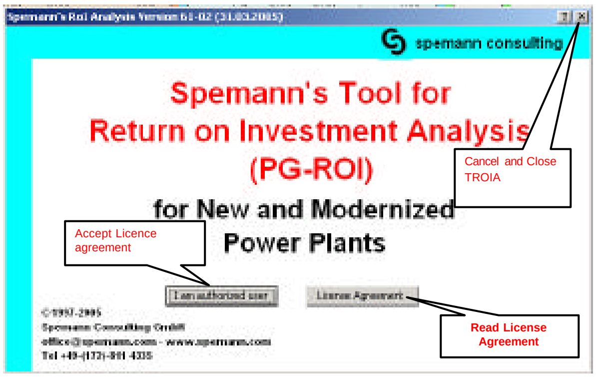
The PG-ROI program is delivered as an Excel file on a **CD-ROM**. You can copy the file into any folder on the licensed computer or leave it on the CD-ROM. Open the program via the Windows-Explorer and activate the macros. Otherwise, you cannot make any calculations but only read the existing data. Please note that calculations can only be carried out on a licensed computer.

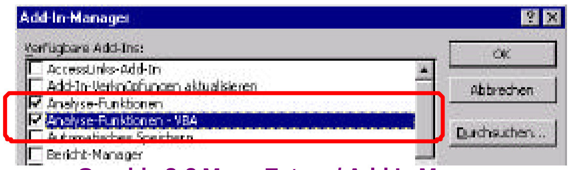
The use of PG-ROI does not affect any other Excel functions so that formatting and copying of data can be done as usual.

On opening the program you are requested to enter the **Password**, which you got with the acquisition of the license. Enter the correctly written password and confirm with OK.

Subsequently, you see the **Welcome Window** to PG-ROI. When clicking the right menu button, you find the PG-ROI licensing conditions. On confirmation with the left button you accept at once the PG-ROI licensing conditions.

A few MS Excel functions are not installed automatically but are to install via the Extras/Add-In-Manager menu. PG-ROI calls in these Add-Ins automatically. However, the Excel installation CDs may be necessary. Therefore, make sure that the Add-Ins opposite are installed.





Graphic 8-2 Menu Extras / Add-In-Manager

8.2 License agreement and guarantee

This agreement provides for the issuance of single licenses. By installing or using the PG-ROI application tool, the user declares his consent to the terms of the license agreement. All rights reserved.

Spemann Consulting GmbH has all the rights to the texts, graphics and figures contained in this manual. Duplication or use is subject to written authorization by Spemann Consulting GmbH.

The name „Spemann", PG-ROI and the company logo are registered trademarks and must not be used without express written agreement by Spemann Consulting GmbH.

All marks and trademarks mentioned in this manual and which may be protected by third parties are subject without any restrictions to the terms of the valid marks law and the rights of possession of the respective registered owner.

Usufructuary right

Spemann Consulting GmbH grants the user a non-transferable single license for the use of PG-ROI and the documentation belonging to it. A license is always committed to the user and the PC on which PG-ROI is installed. The license cannot be transferred to another PC.

The user is authorized to

- Use PG-ROI on one single computer
- Use PG-ROI within a computer network on precondition that each person having access to PG-ROI and each PC using PG-ROI within a network are licensed.

The user is not authorized to

- Permit other persons to use PG-ROI other than the person having his own license;
- To rent, sell or transfer the rights to PG-ROI to third parties;
- To alter or remove marks and registrations with regard to the right of ownership.
- To alter protected programming code (e. g. the „source code" in Visual Basic for Applications) or to avoid or break the protection
- The user has no right whatsoever by this license to the product name, the right of ownership or copyright.
- With the acquisition of this license all these rights are reserved for Spemann Consulting GmbH.

The user agrees to use PG-ROI and the documentation exclusively according to the terms of the agreement and not to transfer them to third parties or to allow third parties to gain access in any other way. Unauthorized reproduction or unauthorized transfer or sale of PG-ROI ensues legal proceedings. The user guarantees to preserve PG-ROI in a way to prevent third parties in a best possible way from duplicating PG-ROI without being authorized to do so.

PG-ROI Demo Version

Spemann Consulting distributes the program PG-ROI free of charge as DEMO Version. This Version is limited in its functionality compared to the licensed full version, and partially the results are not shown or shown within a range of uncertainty. Some results randomly vary within a certain range. Spemann Consulting is not liable in any way for any direct or indirect damages, that a user of PG-ROI DEMO Version without license might suffer. For reliable results of the calculations with PG-ROI and their further use, exclusively the program PG-ROI is to be used in its licensed version.

PG-ROI LIGHT Version

Spemann Consulting distributes the program PG-ROI free of charge as LIGHT Version. This Version is limited in its functionality compared to the licensed full version. However, the results are exact and coincide with the results obtained by the licensed full version. Spemann Consulting is not liable in any way for any direct or indirect damages, that a user of PG-ROI DEMO Version without license might suffer from its use. For reliable results of the calculations with PG-ROI and their further use, exclusively the program PG-ROI is to be used in its licensed version.

[6] Windows 97®, Windows 2000®, Windows NT®, MS Excel 97® and MS Excel 2000® are registered trademarks of Microsoft Corp.

Duration

This license is granted for an indefinite time. However, it is committed to the licensed user and to the PC on which PG-ROI is installed. To ensure this vinculation PG-ROI checks the license number of the program MS Excel, the ID of the processor and the ID of the hard disc. A change of one or several of these components invalidates the license.

Violation of the usufructuary terms

The license lapses automatically, if the user acts against the terms specified in this agreement. Spemann Consulting GmbH have the right in this case to cancel the agreement without notice or to license PG-ROI subsequently so that the use contrary to the terms of the agreement is additionally covered by the terms of the license agreement valid at that time.

In any case, Spemann Consulting GmbH reserves the right to raise claims for indemnity against the customer resulting from the violation of the terms of the agreement.

At the end of the license period the user has to see to it that the supplied version of PG-ROI as well as the medium on which PG-ROI was supplied and all stored copies of PG-ROI and the documentation are destroyed.

Guarantee

The following guarantees will be effective 6 months from the day the user has received PG-ROI.

Spemann Consulting GmbH guarantees that PG-ROI corresponds to the functionality set forth in the documentation and works as described in the documentation when duly operated. Spemann Consulting GmbH, however, does not guarantee that PG-ROI works without interruptions or defects.

Spemann Consulting GmbH guarantees additionally, that the medium PG-ROI is supplied on is free from defects. The guarantee refers only to those media supplied directly from Spemann Consulting GmbH.

With regard to this guarantee, Spemann Consulting GmbH undertakes only to:

- Exchange defective media or
- Explain to the user how to achieve the performance described in the documentation,
- Reimburse the license fees, if above cures cannot be carried out.

Claims under guarantee can only be raised, if the user informs Spemann Consulting GmbH in time about the problems with PG-ROI and establishes proof of the date PG-ROI was delivered. Spemann Consulting GmbH will take appropriate measures to eliminate occurring defects within 30 days following the customer's advice on defects.

The guarantee is restricted exclusively to the use of PG-ROI with the operating systems and the software environment PG-ROI was designed for. Any kind of modification, non-authorized or inappropriate use of PG-ROI or of the medium on which PG-ROI was supplied leads to an immediate exclusion of guarantee; the license for using PG-ROI and the documentation will lapse as well.

These are the only guarantees on the part of Spemann Consulting GmbH.

Exclusion of guarantee and liability

Spemann Consulting GmbH does not take responsibility for the correctness, current accuracy, quality or completeness of all statements and information.

Claims for liability against Spemann Consulting GmbH and/or employees of Spemann Consulting GmbH which are related to direct or indirect damages of material or idealistic kinds and are caused by the use or non-use of PG-ROI or the setting forth information, or by the use of faulty and incomplete information, are generally excluded. Any liability on the part of Spemann Consulting GmbH exceeding the points set out above are excluded as far as is legally permitted. In particular, Spemann Consulting GmbH cannot be made liable for damages/consequent damages, accruing costs, non-achieved income and non-realized profit in connection with the use of PG-ROI or the information contained in this manual.

The use of PG-ROI is at the user's risk. It is not guaranteed that PG-ROI comes up to special applications and requirements. As for the rest, the provisions of the law are applicable.

Should PG-ROI turn out to be defective, it is for the user to defray all repair and service costs, and not Spemann Consulting GmbH. This reservation excludes damages to the PC resulting from a virus, worm and the like.

This exclusion of guarantee is an essential part of the license agreement.

Law / Place of jurisdiction

Place of jurisdiction for all disputes arising from the contractual relationship is Berlin for both contracting parties. The disputes are settled exclusively under the law of the Federal Republic of Germany.

Confidentiality / Data protection

The contracting parties engage themselves to keep secret the knowledge acquired by the object of the contract – in particular technical or economic data as well as other knowledge – and to use it exclusively for the purpose of the object of the contract. This does not apply to information, which is accessible to the public or is made accessible to the public without unauthorized effort or default on the part of the contracting parties or which is to be made accessible by judicial order or by law.

As far as data relating to persons have to be processed within the scope of the object of the contract, Spemann Consulting GmbH undertakes to observe the legal terms of data protection. Spemann Consulting GmbH points out to the customer according to Federal law on data protection (Bundesdatenschutzgesetz BDSG), that the customer's data is stored.

Salvatoric clause

Cancellation of individual parts of this agreement by law or special agreement does not affect the effectiveness of the remaining provisions. Invalid parts are to be replaced by others the content of which comes next to the desired economic result. The same applies to a gap in the agreement when becoming evident.

Index of graphics and formulas

Gleichungen

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Calculate and visualize the
return on investment
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