Stadt Frankfurt am Main
Amt für Bau und Immobilien
Abteilung Energiemanagement

Notes on calculation of total cost (version 10.2)

The overriding principle in planning for construction, operations, and maintenance of new buildings is to minimize total cost (the sum of the cost of investments, operations, and follow-up costs) over the long term while still maintaining a certain level of quality. The difficulty consists in determining the cost drivers behind individual items. The Energy Management Department at the City of Frankfurt on Main's Construction Bureau therefore came up with a calculation method that juxtaposes all relevant costs for various varieties at the earliest possible planning point. This procedure for total cost calculation was programmed as an Excel spreadsheet and is available to all interested parties at www.stadt-frankfurt.de/energiemanagement. In decree number 23/2007, the Construction Bureau specified that the procedure is to be used for all cost estimates and calculations greater than 250,000 euros. The calculation of total cost consists of the tables as an Excel tool, help tables, and explanations.

Only the white fields on the forms are entry fields. The values entered here must be taken from planning and can also be taken from the help tables. The fields in gray, on the other hand, are output fields. If, however, data are already available from other calculations, they can also be entered in the gray result fields. If necessary, other formulas, for instance for specific data, must be adapted. To make the Excel calculation easier to understand, each individual calculation is displayed in the header. Specific values are calculated in all sheets to ensure that the values from different projects are comparable. They are the result of the division of the absolute value by the energy reference area / number of people.

1. Total costs

In this form, the total cost of different types of construction can be calculated. The costs consist of capital costs, operational costs, and environmental impact costs. Furthermore, a number of important building parameters that served as the basis for a determination of total cost are also listed to characterize the building. In other words, this sheet summarizes all of the major results of other spreadsheets (tables). First, the timeframe, capital interest, and price hike rate are entered. The timeframe can be taken from VDI 2067 or the help table for the procedure. This field is to be adjusted for the specific project based on experience. In this procedure, up to five different variants can be compared. Each variant has its own spreadsheet for each chapter (table of U-values 2.1-2.5, table of costs 3.1-3.5, table of heating demand 4.1-4.5, table of heating efficiency 5.1-5.5, table of power demand 6.1-6.5, table of water consumption 7.1-7.5). For these parameters, only the reference area (net floor area) and the average number of people during usage need to be entered. The other parameters (specific heat demand, heating efficiency, specific power demand, specific CO_2 emissions, and specific drinking water demand) are dealt with in the other sheets. The capital costs of each variety are then calculated. Here, the investment costs in spreadsheet 3.1-3.5 minus any bonuses (such as state aid) are multiplied by the annuity factor and then extrapolated for the total surface area. Current operating costs (maintenance, servicing, heating, electricity, and water) are then transferred from other spreadsheets. Furthermore,

the cost of staff, cleaning, administration, and insurance can also be entered here. Data for these items are included in the help tables for table 1. The sum of current operating costs is multiplied by the average factor to produce the average operating costs for the timeframe under consideration. These values are then extrapolated for the surface area. Finally, environmental impact costs can be taken into consideration. The City of Frankfurt's Construction Bureau estimates 50 euros per ton of CO_2 and 1 €/m³ of water. The resulting sum indicates the total cost of each variant, and this estimate is the decisive criterion for the period under review. Furthermore, the dynamic payback period of additional costs is calculated for Variant 1.

2. The cost and U-values of building components

On this help sheet, the layer composition is entered for each external building component with the parameters of thickness, price/volume, and lambda. Furthermore, a specific component price can be calculated in €/m² along with the thermal transmittance coefficient (U-value). More detailed calculations can be taken from other programs (such as more complex wall composites from PHPP, etc.), and calculations of other components can be copied and pasted. Each variant has its own sheet (2.1 to 2.5). The values from table 2.1 are taken over for all tables as a template. In other words, you only need to enter figures for other variants if they differ from 2.1.

3. Investment and maintenance costs

This sheet covers the construction costs in DIN 276. The cost of the components is the product of the number of components used (area) and the specific prices. Here, the specific prices of external building components can be directly taken from the second spreadsheet or entered individually. The total cost per component can also be entered first and the specific area cost can then be derived from that figure. For a comparison with other projects, the costs are then stated in terms of net floor area (NFA). In addition, a percentage of the annual maintenance costs is proposed and calculated based on VDI. Help tables are provided for this purpose. Each variant has its own sheet (3.1 to 3.5). The values from table 3.1/2.x are taken over for all tables as a template. In other words, you only need to enter figures for other variants if they differ from 3.1.

4. Heating energy demand

On this page, the building's heating energy demand is calculated. The calculation method was taken from the State of Hesse's guidelines on heating energy in construction (DIN 832, as in DIN 18599). This calculation method requires a lot less input than the calculation for the Energy Conservation Ordinance (EnEV) and nonetheless provides even more realistic results. It is therefore better suited than EnEV for the feasibility calculation. For passive houses and comparable standards, individual data sets can be replaced by values from the table on heating energy in the Passive House Planning Package (PHPP), such as U-values, degree-day-number, effective air exchange in terms of energy, gain factor, and solar input). By default, the building's average room temperature is entered. The average temperature is calculated for differently tempered zones. The length of the heating period and heating degree days can be adjusted, for instance based on PHPP or IWU climate data. First, transmission is calculated as the product of area, U-values, the outdoor air factor, and the number of degree days. The area and U-values of external building components are directly taken from previous sheets but can also be entered and edited manually (additional lines can

also be added). Glazed area by orientation and related U-values are the only new pieces of information that have to be entered here. Ventilation heat loss is the product of net volume (by default, energy reference area (ERA) x 3 m, customization possible), air exchange, specific heat, and number of degree days. Here, only the air exchange must be entered from the help tables or, for instance, from the table on heating energy from PHPP, along with average ceiling height. For ventilation systems, however, you can enter your own calculation via usage and non-usage times in the field for air exchange. These values can be used to calculate heat demand based on DIN 4701. Sensible heat is the product of waste heat from electricity (from tables 6.1-6.5), the number of people, and solar input. Here, the average time spent by the number of people and the overall degree of energy transmission (g-value) of the windows is entered. All of the other parameters are standard values or taken from other spreadsheets (such as power consumption 6.1-6.5). The specific heating energy demand can be calculated from the above data. At the same time, the plausibility of the guideline's limit value is checked. Each variant has its own sheet (4.1 to 4.5). For all tables, the values from tables 2.x and 3.x are used as a template along with the values from table 4.1 (windows, etc.). In other words, you only need to enter figures for other variants if they differ from 4.1.

5. Heating efficiency, heating costs, heat emissions

On the next page, heater capacity utilization – the degree to which the heating system is used over the year – is calculated. Along with heating energy demand from the previous spreadsheet, this figure is used to calculate heating costs and heat emissions. First, hot water demand is entered (to the extent that it is heated by the heating system; electric hot water supply is taken into account in tables 6.x). The data on the storage tank, heat distribution, and hot water distribution can be taken from planning. Distribution losses can be derived from these figures if the distribution lines are not within the thermal envelope and in summer for hot water distribution. Then, a cogeneration unit can be taken into account. Heat output and full capacity hours must be taken from planning. Boiler output is taken directly from heat demand (see previous sheet). If hot water demand, etc. is greater, a deviating value can be entered. Operation losses and standby losses can be calculated from the full capacity hours for the boiler. From the previous data, final energy consumption for cogeneration and the boiler are calculated (in the example, with natural gas). For this calculation, the cogeneration unit's gas use is needed. Next, the capacity utilization of the boiler and distribution is calculated and compared to the limit value in the guidelines. Heating costs are then calculated based on the utility's terms (monthly rate and consumption rate). In the case of cogeneration, however, gas consumption for the cogen unit is already included. Finally, the heating system's emissions are calculated based on the table of emission factors at www.gemis.de. Each variant has its own sheet (5.1 to 5.5). For all tables, the values from tables 4.x (demand values) are used as a template along with the values from table 5.1 on heating data. In other words, you only need to enter figures for other variants if they differ from 5.1.

6. Power demand, power costs, power emissions

Here, power demand, cost, and resulting equivalent CO_2 emissions in the power plant are calculated. The approach behind the calculation is based on the State of Hesse's "Guidelines on electricity in construction." Power demand is always a product of output and full load hours. As on other sheets, specific power demand is calculated as a ratio of annual power demand and energy reference area. For lighting, the specific installation output (in W/m²) and the full load hours for typical cases from the guidelines are taken up in the help tables. In addition, limit values and target values are indicated here so that compliance can be checked. For ventilation and air-conditioning, average values for full load hours are also given in the help tables. In turn, there are limit and target values for the combination of ventilation and air-conditioning. Here, the targets for a passive house (0.45 W/m3/h) or DIN 13779 can be entered and used for the calculation. The limit value for auxiliary energy for heating (pumps and burners) is 0.8 kWh/m²a or, for output, one percent of boiler output. Likewise, various domestic equipment (transport, communication, etc.), appliances (computers, coffee machines, etc.), central services (kitchens, etc.), and electric hot water supply are recorded. In the next step, domestic power production from cogeneration or photovoltaics can be taken into account; here, you have to enter the share of domestic power generation consumed internally and the share sold to the grid. For the calculation of the power purchased from the grid, a simultaneity factor is used; it can be adjusted for specific projects. The utility's terms (the monthly rate and kilowatt price, possibly with different rates by time of day, and feed-in tariffs) can then be used to calculate power cost. CO_2 emissions can then simply be calculated from the preset emissions factor. Each variant has its own

sheet (6.1 to 6.5). The values from table 6.1 are taken over for all tables as a template. In other words, you only need to enter figures for other variants if they differ from 6.1.

7. Water demand and water cost

Another spreadsheet is provided to calculate water demand and water cost (see table 7). Unlike the other values, water demand and water cost are not calculated according to area, but rather according to the number of people. Demand for toilet flushing is the product of the volume needed for flushing (l/flush), the frequency of flushing (flush/P,d), the number of days of use (d/a), and the number of people (P). Typical values for flushing frequency are given in the help tables. Likewise, demand for urinals, sinks, showers, washing machines, dishwashers, and sprinkler systems is calculated. The water supply can also take rainwater usage (the roof area is automatically included) and other sources (such as wells) into account. The water cost is based on the water provider's terms (drinking water price and connection fee). Each variant has its own sheet (7.1 to 7.5). The values from table 7.1 are taken over for all tables as a template. In other words, you only need to enter figures for other variants if they differ from 7.1.

Conclusion

This total cost calculation provides a differentiated but nonetheless easy-to-use procedure for economic feasibility analyses in all areas of facility management. Calculations from other programs can easily be carried over.