## 1. TECHNICAL ANALYSIS – assumptions for DGC analysis

In the present case, the DGC analysis starts with the respondent answering questions on issues related with:

- • Characteristics of the general state associated with the place of acquiring the mine water,
- Shaping water temperature,
- Direction of water use (heat or electricity),
- Technological, economic and environmental aspects related to the use of mine water.

Questions are both closed and open. Some respondent responds by answering "Yes" or "No". However in case of remaining questions one should give specific numerical quantities.

Replies to asked questions are being given according to the principle "Traffic light". Which means that if the answer given is positive for the investment, it is highlighted in green. When indifferent is displayed yellow. However when he has a very great negative significance for investment, is meant with colour red.

On the picture below was presented a model way of answering.

***TECHNICAL ANALYSIS***

| | |
|---|---|
| **Is there existing mine water discharge available?** | |
| yes | good |
| **Is that pump or gravity discharge?** | |
| gravity | good |
| **Is there existing shaft or borehole on site?** | |
| yes | good |
| **How deep you have to drill to the shalowest floded level? [m]** | |
| 50 | good |
| **What is water head in flooded mine? [m]** | |
| 50 | good |
| **What is the average temperature of the mine water? [°C]** | |
| 16 | |
| **Is there demand for heating?** | |
| yes | good |
| **Is there demand for cooling?** | |
| yes | possible |
| **Is there demand for both (heating and cooling)?** | |
| yes | good |
| **Risk of clogging or corosion?** | |
| no | good |
| yes<br>no | |
| no | good |
| **What is peak heating or cooling demand? [KW]** | |
| 3 500 000 | good |

**Figure 1 General questions related to DGC analysis**
*Source: Own study*

According to the methodology, the DGC analysis should be carried out in relation to another energy source. Most often, such analyzes are carried out with respect to an existing source, such as coal, gas or electric heating. Hence, in this analysis, detailed questions have been formulated to allow for more accurate analysis and more reliable results.

With reference to the energy source used and the potential source of energy, the respondent specifies in the following part of the questionnaire:

- Energy sources so far used,
- Cost of the thermal energy associated with using current energy sources,
- CO2 emission associated with energy sources so far used,
- Basket of electricity related to the operation of an alternative energy source,
- Emissions of CO2 associated with generated electricity,
- The distance from where the mine waters are taken from their use,
- Network length.

Below an example of the excerpt filled in of the questionnaire was expressed.

| ***FINANCIAL AND ENVIRONMENTAL DATA*** |
|---|
| **What is the most favorite competitor against heat from mine water** |
| Hard coal |
| **What is the cost of this option KWh [euro/kWh]** |
| 0,058 |
| **What is $CO_2$ emision [kg/kWh]** |
| 0,25 |
| **What is the cost of electricity per kWh [euro]** |
| 0,11 |
| **What is $CO_2$ emision of electricity per kwh [CO2/kWh]** |
| 0,83 |

**Figure 2 Detailed questions - DGC analysis**
*Source: Own study*

After answering all the questions, the respondent can go to financial analysis using the "Financial analysis" button. It is located in the upper right corner of the calculation sheet. The graphical presentation of the location of the button is shown in the figure below.

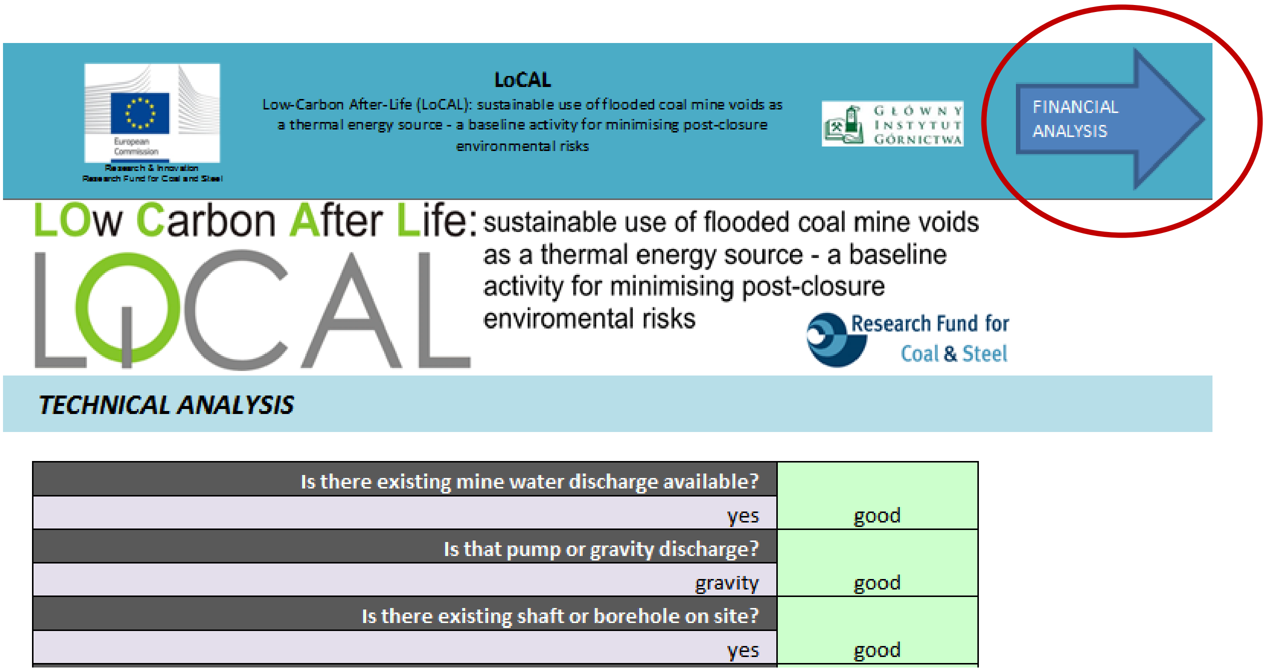

Figure 3 Location of the "Financial analysis" button in the calculation sheet

*Source: Own study*

## 2. Viability analysis for the centralized system - DGC and CBA model

The cost-effectiveness analysis of potential energy sources (for the centralized system) was based on the dynamic generation cost model (DGC). It is assumed that this is a system containing one heat pump that supplies energy to several selected sites.

The DGC indicator can be used at various stages of the preparation and selection process of investment projects. The most important ways of using this method are:

(1) comparing alternative solutions for a given problem,
(2) reducing the scope of investment,
(3) selection of investment projects.

In the case described, the first of these aspects applies. Therefore, the purpose of this study is to compare the use of two alternative sources of energy (e.g. coal and geothermal energy or gas and geothermal energy) to determine the potential profitability of one.

In the first place, the respondent writes the time period that the analysis will cover. It can be a period of 15, 20 or 25 years. The choice is related to your preferences and expectations. With a quick return on investment, a shorter analysis period (15 years) is required. On the other hand, if the investment is of an environmental and social nature, it is recommended to choose a longer analysis period (eg 20 or 25 years). The respondent selects an optimum option for himself. Example of time period selection is shown in the figure below.

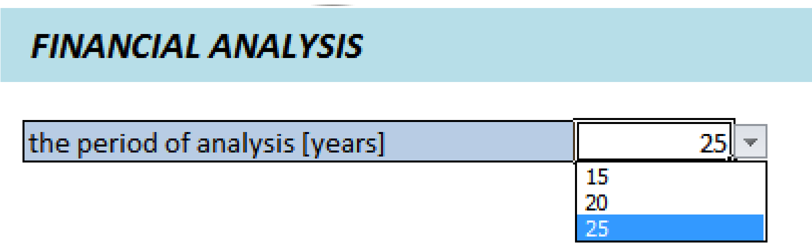


**Figure 4 Choice of the scope temporary provided with analysis**
*Source: Own study*

The rest of the analysis is done automatically. Investment and operating costs, based on which DGC is being generated are being enumerated expressed in [euro/kW]. An example of the DGC calculation is shown in the following table (XXX).

| Year | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Investment costs | 1 107 038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 254 578 | 0 | 0 | 0 | 0 |
| works [euro] | 725 701 | | | | | | | | | | | | | | | |
| equipments [euro] | 254 578 | | | | | | | | | | | 254 578 | | | | 0 |
| start-up costs [euro] | 126 760 | | | | | | | | | | | | | | | |
| Operation cost | 0 | 33 272 | 34 104 | 34 957 | 35 831 | 36 727 | 37 645 | 38 586 | 39 550 | 40 539 | 41 553 | 42 592 | 43 656 | 44 748 | 45 866 | 47 013 |
| materials [euro/year] | | 627 | 643 | 659 | 676 | 692 | 710 | 727 | 746 | 764 | 783 | 803 | 823 | 844 | 865 | 886 |
| energy [euro/year] | | 18 260 | 18 716 | 19 184 | 19 664 | 20 155 | 20 659 | 21 176 | 21 705 | 22 248 | 22 804 | 23 374 | 23 958 | 24 557 | 25 171 | 25 800 |
| services [euro/year] | | 2 509 | 2 572 | 2 636 | 2 702 | 2 770 | 2 839 | 2 910 | 2 983 | 3 057 | 3 134 | 3 212 | 3 292 | 3 374 | 3 459 | 3 545 |
| maintenance cost [euro/year] | | 2 509 | 2 572 | 2 636 | 2 702 | 2 770 | 2 839 | 2 910 | 2 983 | 3 057 | 3 134 | 3 212 | 3 292 | 3 374 | 3 459 | 3 545 |
| personnel cost [euro/year] | | 6 273 | 6 430 | 6 590 | 6 755 | 6 924 | 7 097 | 7 274 | 7 456 | 7 643 | 7 834 | 8 030 | 8 230 | 8 436 | 8 647 | 8 863 |
| overheads [euro/year] | | 3 095 | 3 172 | 3 251 | 3 332 | 3 416 | 3 501 | 3 589 | 3 678 | 3 770 | 3 865 | 3 961 | 4 060 | 4 162 | 4 266 | 4 373 |
| fees for the discharge of water (if applicable), en | 0 | 216 | 221 | 227 | 232 | 238 | 244 | 250 | 256 | 263 | 269 | 276 | 283 | 290 | 297 | 305 |
| other [euro/year] | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| producition of energy [kW] | | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 | 3 500 000 |
| discounted cost | 1 107 038 | 31 376 | 30 353 | 29 364 | 28 378 | 27 435 | 26 540 | 25 660 | 24 798 | 23 999 | 23 186 | 156 608 | 21 697 | 20 987 | 20 273 | 19 604 |
| discounted amount of energy | 0 | 3 300 500 | 3 115 000 | 2 940 000 | 2 772 000 | 2 614 500 | 2 467 500 | 2 327 500 | 2 194 500 | 2 072 000 | 1 953 000 | 1 844 500 | 1 739 500 | 1 641 500 | 1 547 000 | 1 459 500 |
| sum of the discounted cost [euro] | 1 617 2[illegible],66 | | | | | | | | | | | | | | | |
| sum of the discounted amount of energy [kW] | 33 988 500,[illegible] | | | | | | | | | | | | | | | |
| DGC (dynamic generation cost) [euro/kW] | 0,048 | | | | | | | | | | | | | | | |
| Financial cost - Hard coal | [illegible] | 208 075 | 213 277 | 218 609 | 224 074 | 229 676 | 235 418 | 241 303 | 247 336 | 253 519 | 259 857 | 266 354 | 273 012 | 279 838 | 286 834 | 294 005 |
| Financial cost - Source of mine waters | 1 107 038 | 33 272 | 34 104 | 34 957 | 35 831 | 36 727 | 37 645 | 38 586 | 39 550 | 40 539 | 41 553 | 297 169 | 43 656 | 44 748 | 45 866 | 47 013 |
| Summary cash flows - Hard coal | 0 | 208 075 | 421 352 | 639 961 | 864 035 | 1 093 711 | 1 329 128 | 1 570 432 | 1 817 767 | 2 071 286 | 2 331 144 | 2 597 497 | 2 870 510 | 3 150 347 | 3 437 181 | 3 731 186 |
| Summary cash flows - Source of mine waters | 1 107 038 | 1 140 311 | 1 174 415 | 1 209 372 | 1 245 202 | 1 281 929 | 1 319 574 | 1 358 160 | 1 397 710 | 1 438 249 | 1 479 802 | 1 776 971 | 1 820 627 | 1 865 375 | 1 911 242 | 1 958 255 |

**Table 1 Indicator for DGC for the 15-year investment period**
*Source: Own study*

If you choose a calculation period of more than 15 years, the table is automatically modified (expanded) by the number of years you choose.

Comparing many alternative solutions to the problem, the most advantageous solution is that the DGC is the smallest.

This analysis also allows you to specify the time period during which the cumulative costs associated with the operation of mine-based investment will be lower than the cumulative costs of using another source of energy. In the analyzed case (a summary of the use of mine and hard coal for energy purposes) is presented in the diagram below (Table 1). He points out that the cumulative costs associated with the use of mine waters after 6 years of investment will be lower than for conventional energy sources (e.g. coal).

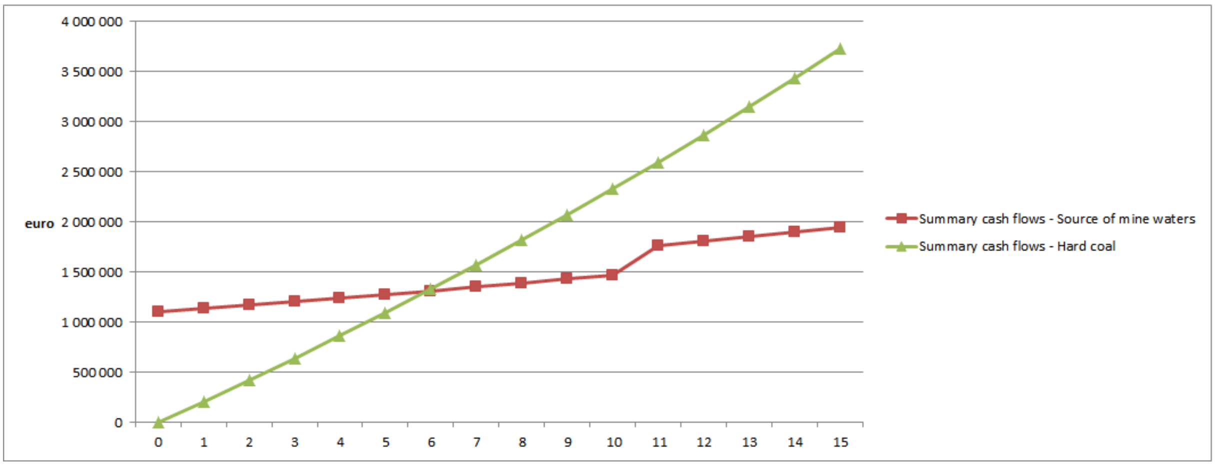


**Figure 5 Accumulated operating costs of the investment of the two compared investments (use of mine and hard coal)**
*Source: Own study*

For this analysis, it is also possible to analyze the discounted cash flows and benefits over the period considered. An example of calculations is presented in the table below.

**Table 2 Discounted cash flow**

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Financial cost - Hard coal | 0 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 | 208 075 |
| Financial cost - Source of mine waters | 1 107 038 | 33 272 | 34 104 | 34 957 | 35 831 | 36 727 | 37 645 | 38 586 | 39 550 | 40 539 | 41 553 | 297 169 | 43 656 | 44 748 | 45 866 | 47 013 |
| Cash flows | -1 107 038 | 174 803 | 173 971 | 173 118 | 172 244 | 171 348 | 170 430 | 169 489 | 168 525 | 167 536 | 166 522 | -89 094 | 164 419 | 163 327 | 162 209 | 161 062 |
| discounted cash flows | -1 107 038 | 164 839 | 154 834 | 145 419 | 136 417 | 127 997 | 120 153 | 112 710 | 105 665 | 99 181 | 92 919 | -46 953 | 81 716 | 76 600 | 71 696 | 67 163 |

*Source: Own study*

In the further part of the analysis, environmental issues related to the realization and functioning of the intended investment were presented. For the selected time period, CO2 emissions for the investments compared are shown and the costs and benefits associated with them. This analysis refers to the cost index associated with CO2 emissions. This means that CO2 emissions are converted into environmental costs. This makes it possible to indicate the difference between the analyzed investments, which will contribute to the identification of environmentally-friendly (CO2-based) energy production technologies.
The graphical presentation was introduced to the issue mentioned above in the following table (Table 3).

**Table 3 Costs and benefits associated with applying chosen methods**

***ECONOMICAL ANALYSIS***

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CO2 emision per year - Hard coal [kg] | 0 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 | 875 000 |
| CO2 emision per year - Source of mine waters [k | 0 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 | 259 858 |
| Economical cost [euro/Mg CO2 emision] | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 |
| Economical cost - Hard coal | 0 | 28 875 | 29 750 | 30 625 | 31 500 | 32 375 | 33 250 | 34 125 | 35 000 | 35 875 | 36 750 | 37 625 | 38 500 | 39 375 | 40 250 | 41 125 |
| Economical cost - Source of mine waters | 0 | 8 575 | 8 835 | 9 095 | 9 355 | 9 615 | 9 875 | 10 134 | 10 394 | 10 654 | 10 914 | 11 174 | 11 434 | 11 694 | 11 953 | 12 213 |
| Economical benefits - Investment | 0 | 20 300 | 20 915 | 21 530 | 22 145 | 22 760 | 23 375 | 23 991 | 24 606 | 25 221 | 25 836 | 26 451 | 27 066 | 27 681 | 28 297 | 28 912 |
| discounted benefits | 0 | 19 143 | 18 614 | 18 085 | 17 539 | 17 002 | 16 480 | 15 954 | 15 428 | 14 931 | 14 416 | 13 940 | 13 452 | 12 983 | 12 507 | 12 056 |
| sum of the discounted benefits [euro] | | 232 528,57 | | | | | | | | | | | | | | |
| benefits | 0 | 183 981 | 173 448 | 163 504 | 153 956 | 144 999 | 136 633 | 128 664 | 121 093 | 114 112 | 107 336 | 13 940 | 95 168 | 89 583 | 84 203 | 79 219 |
| financial | 0 | 164 839 | 154 834 | 145 419 | 136 417 | 127 997 | 120 153 | 112 710 | 105 665 | 99 181 | 92 919 | 0 | 81 716 | 76 600 | 71 696 | 67 163 |
| economic | 0 | 19 143 | 18 614 | 18 085 | 17 539 | 17 002 | 16 480 | 15 954 | 15 428 | 14 931 | 14 416 | 13 940 | 13 452 | 12 983 | 12 507 | 12 056 |
| cost | 1 107 038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 953 | 0 | 0 | 0 | 0 |
| financial | 1 107 038 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 46 953 | 0 | 0 | 0 | 0 |
| economic | | | | | | | | | | | | | | | | |

*Source: Own study*

As a result of this analysis, the respondent receives information on the costs associated with the production of 1 kWh from various energy carriers, the amount of CO2 emitted, and the benefits (or losses) associated with the implementation of this project. It allows you to indicate which of the following ways of gaining energy it:

- is cheaper (e.g. coal or use of mine waters) – A,

- allows you to emit as little CO2 as possible - B,
- allows you to achieve the greatest possible economic and environmental benefits - C.

The results of this analysis are summarized below (Figure 6).

***SUMMARY ANALYSIS***

| Price for 1 kWh of energy | | |
|---|---|---|
| Hard coal | 0,058 | A |
| Source of mine waters | 0,048 | |

| $CO_2$ emision per year [kg Co2] | | |
|---|---|---|
| Hard coal | 875 000 | B |
| Source of mine waters | 259 858 | |

| Results of Economic Analysis | | |
|---|---|---|
| NPV | 403 321 | C |
| ENPV | 635 849 | |
| B / C | 1,551 | |

**Figure 6 Summary of DGC and CBA analysis**
*Source: Own study*

Where:

- NPV - This is the return on investment expressed in money that an investor can achieve. Its positive value suggests "earnings" and a negative "loss" for the investor,
- ENPV - this is the return on investment expressed in money that can reach the investor and the environment and society. Its positive value suggests "earnings" and negative "loss",
- B / C - this is the ratio of total benefits to costs (both financial and environmental). A value greater than 1 suggests the advantage over cost.