Tadeusz Kwilosz
Instytut Nafty i Gazu, Oddział Krosno

The statistical methods in investment risk estimation of building UGS facilities

Introduction

In recent years the investment risk assessment has become a fixed point in any financial analysis, in particular at the stage of the feasibility study of an investment project submitted along with an application for co-funding by the monies from the EU's structural programmes funds. The government institutions' guidelines involved in the implementation of investment projects co-financed by the community funds do not specify strictly the risk measure among their many recommendations, but they only indicate the magnitudes of the financial analysis which affect the measure [1]. Hence, authors in their papers are allowed some latitude in interpreting investment risk [2, 3].

This paper shows its author's original approach to defining the investment risk measure as some probability of exceeding a pre-determined maximum unit price for gas storage service. The real gas storage unit price is determined in the form of distribution of a random variable. The main assumption to calculate this magnitude is to discount the investment outlays up to the end of a USG facility operation. The proposed model of calculating investment risk assessment is in compliance with the aforementioned guidelines and it corresponds well with the proposals of other authors [2].

The calculation model was applied to a sample UGS facility in which investments were made to increase its working gas volume. All data referring to the UGS facility and the investment outlays come from a real UGS facility. The data have been distorted by re-scaling them by a fixed factor to make the identification of the UGS facility more difficult.

The models used to determine the risk of the UGS facility building and expansion

As per the guidelines of MRR (Regional Development Ministry), regarding the requirements of the financial analysis for the investment projects in the field of infrastructure and production, being in compliance with Art. 40 of the EU's Directive No 1083/2006, "the risk assessment consists in examination of probability that the project will achieve satisfactory efficiency (as regards a threshold IRR or NPV values)" [1]. The quoted guidelines do not specify decisively which threshold IRR and NPV values are to be adopted, but they suggest that NPV = 0 and IRR = 10% are typical reference values. Most authors of financial analyses estimate investment risk as the probability of achieving NPV = 0 in a predetermined project discounting period of time. The NPV value itself as a difference between the discounted cash flows and the initial capital outlays do not carry any direct information about such basic economic values as costs, unit prices, revenues etc., which are responsible for the computed risk level. Therefore, Andrzej Paliński [2] suggested an alternative approach, though in compliance with the quoted recommendations. In the suggested model it has been assumed that NPV = 0 and, based on this equation, the values are computed of the unit price of creation of the gas storage facility working gas volume (JKPC) and the unit price of creation of the gas storage facility working gas volume available during operation (JKPCE), which satisfy the equation. These magnitudes are computed in the form of distribution of a random variable. The investment risk is defined as the probability of exceeding the predetermined threshold values. The random variables of this model are: the level of use of the UGS facility's working gas volume, a change in the capital outlays, the total fixed costs less accumulated depreciation and the unit variable costs of boreholes operation. The model described above has an advantage over the direct NPV analysis, as it links the risk with a rational (measurable) cost-related economic value. A disadvantage of the model is the fact that the cost indicator is an indicator only and it is difficult to establish its threshold value to be adopted. One can analyze this indicator for the investment projects in the EU area, but it is likely to be substantially variable from one country of the community to another.

This paper defines a similar model of investment risk assessment, based on solution of the NPV = 0 equation, but the storage service unit price was used as the model variable. The revenue-related approach was applied here and not the cost-related one as in the model described above. This choice has some advantages:

– the storage service unit price is more valuable information for UGS facility clients,
– due to its market nature it is easier to compare it with analogous values, characteristic for UGS in the EU.

Model of establishing the risk of a UGS facility construction and expansion

The following assumptions were made when compiling the described model:

a) the working gas volume increment obtained as a result of the investment is used in all calculations connected with discounting the investment, and not the total working gas volume,
b) the option of investing the company's own resources (without a bank credit) is assumed,
c) the following were selected as the model variables in the probability of distribution of a random variable: the rate of use of working gas volume, fixed costs, total rate of variable costs and the rate of discount,
d) all random variables are described by triangular distributions,
e) all random variables of the model are intrinsically independent from one another.

The basic equation of the model is:

$$NPV = 0$$

namely:

$$\sum_{t=1}^{n} CF_t \frac{1}{(1+k)^t} = 0$$

where:

CF_t – monies' streams in consecutive years of investing, including negative values in the first years of incurring the capital outlays,
k – rate of discount [-],
n – number of years of operation, including the investment years.

$$CF_t = B_t - NI_t - C_t$$

where:

B_t – revenues from gas storage in a year t [thousands PLN],
NI_t – capital outlays in a year t [thousands PLN],
C_t – total costs of gas storage in a year t [thousands PLN].

$$B_t = \Delta Va \times wVa \times Pm$$

where:

ΔVa – increment of the working gas volume of the UGS facility after the investment is completed [m m^3],
wVa – rate of use of the working gas volume,
Pm – storage service unit price [PLN/1 000 m^3/year].

$$NI_t = NI \times wNI_t$$

where:

NI – total capital outlays [thousands PLN],
wNI_t – rate of use of the capital outlays in a year t [-].

$$Ct = \Delta Va \times wVa \times (wkz + wkru) + Ks + Pe + Am_t$$

where:

wkz – rate of variable costs [PLN/1000 m^3/year],
$wkru$ – rate of repair and insurance costs [PLN/1 000 m^3/year],
Ks – fixed costs [thousands PLN/year],
Pe – operational charge [thousands PLN/year],
Am_t – depreciation write-off in a year t.

Both rates of variable costs may be added up to obtain the total rate of variable costs $wk = wkz + wkru$.

When solving the equation with respect to Pm one can obtain:

$$Pm = \frac{\sum_{t=1}^{n} (C_t + NI_t) \frac{1}{(1+k)^t}}{\sum_{t=1}^{n} \Delta Va * wVa \frac{1}{(1+k)^t}}$$

While treating Pm as a function of variables which are subject to random distributions we can finally obtain:

$$Pm(dVa, Ks, wk, k) = \frac{\sum_{t=1}^{n} (C_t + NI_t) \frac{1}{(1+k)^t}}{\sum_{t=1}^{n} \Delta Va * wVa \frac{1}{(1+k)^t}}$$

In order to determine the empirical probability distribution of random variable *Pm* Monte Carlo method was applied. As the measure of risk of investment in construction or expansion of a UGS facility the probability of exceeding some predetermined threshold price value Pm_{max} by the storage service price *Pm* was adopted and it was defined as a R_{PMG} function of this threshold value:

$$R_{PMG}(PM_{max}) = P[Pm > Pm_{max}]$$

Example of the method used

The developed method was tested on the data from one of underground storage facilities in Poland. Five options of analysis and settlement of accounts of the investment have been analyzed:

- basic option A,
- option B1, in which the total number of years of the investment in progress and the storage facility operation after the investment completion was decreased from 25 to 20 years (as compared to option A),
- option B2, in which the total number of years of the investment in progress and the storage facility operation after the investment completion was increased from 25 to 30 years (as compared to option A),
- option C1, in which the total value of the investment was decreased from PLN 167 804 000 to PLN 142 633 000, (as compared to option A),
- option C2, in which the total value of the investment was increased from PLN 167 804 000 to PLN 192 975 000, (as compared to option A).

Data/details of option A:

- fixed magnitudes/values:
  - increment of the UGS facility working gas volume after the investment completion = 184 000 000 m^3,
  - total capital outlays = PLN 187 804 000,
  - operational charge = PLN 168 000/year,
  - time of investment in progress = 4 years,
  - time of the UGS facility operation after the investment completion = 21 years,
  - number of sampling cycles in the Monte Carlo method = 50 000,
- distribution parameters of the random variables are shown in Table 1.

Table 1. The model's distribution parameters of the random variables

Variable	Unit	Min	Most probable	Max
Rate of use of the working gas volume, *wVa*	–	0.6	0.9	1.1
Fixed costs, *Ks*	thousands PLN	2 107	2 340	2 640
Rate of variable costs, *kz*	[PLN/1 000 m^3/year]	13.767	16.196	18.625
Rate of discount, *k*	–	0.03	0.07	0.12

In order to estimate the effect of the variability of the observed random variables on the result of the model function, the sensitivity analysis of *Pm* to each of the model variable separately was carried out. The measure of sensitivity is the proportion of the relative increment of the function value to the relative increment of the variable. It is assumed that the variable has a substantial effect on the result if the absolute value of this quotient is ≥ 1. The analysis results are shown in Table 2.

Table 2. The results of analysis of sensitivity of *Pm* to the variables of the model

Variable	Sensitivity ratio
Rate of use of the working gas volume, *wVa*	from –1.8 to 2.54
Fixed costs, *Ks*	1.0
Rate of variable costs, *kz*	1.0
Rate of discount, *k*	from 0.78 to 1.21

As it can be concluded from the analysis, the variation of each of the variables substantially affects the model's *Pm* function value.

Results obtained

In order to make an assessment of the results obtained, a limit value of the storage service price should be adopted, for which the investment risk is to be calculated. With this end in view a survey of analogous values for UGS facilities operated in the EU was performed. On the basis of this analysis the amount of PLN 274.21/1 000 m^3/year was adopted as the limit price. Based on the criterion of competitiveness of the domestic power industry relative to the EU countries, the price calculated as a critical parameter of the risk calculation model was adopted (Pm_{max} = PLN 274.21). As it has been already mentioned, the calculations were performed for five options of the investment in progress. The following conclusions result from the calculations:

1. In the case of basic option A, the value of calculated risk function is equal to 7%, which means that the probability of exceeding the predetermined limit price of the service, PLN 274.21, equals 0.07. The most probable value is the service price equal to PLN 212.
2. In the case of option B1, in which the capital outlays turned out to be lower than those assumed by 15%, the value of calculated risk function is equal to 1%, which means that the probability of exceeding the predetermined limit price of the service, PLN 274.21, equals 0.01. The most probable value is the service price equal to PLN 186.
3. In the case of option B2, in which the capital outlays turned out to be higher than those assumed by 15%, the value of calculated risk function is equal to 21%, which means that the probability of exceeding the predetermined limit price of the service, PLN 274.21, equals 0.21. The most probable value is the service price equal to PLN 186.
4. In the case of option C1, in which the time period for the settlement of accounts related to the investment was shortened from 25 to 20 years, the value of calculated risk function is equal to 17%, which means that the probability of exceeding the predetermined limit price of the service, PLN 274.21, equals 0.17. The most probable value is the service price equal to PLN 234.
5. In the case of option C2, in which the time period for the settlement of accounts related to the investment was lengthened from 25 to 30 years, the value of calculated risk function is equal to 4%, which means that the probability of exceeding the predetermined limit price of the service, PLN 274.21, 0.04. The most probable value is the service price equal to PLN 199.

The percentiles of the random distribution of *Pm* (for 1-F(*Pm*)) are shown in Table 3.

Table 3. The percentiles of *Pm* distribution

$P[x \geq Pm]$	Option A *Pm* [PLN]	Option B1 *Pm* [PLN]	Option B2 *Pm* [PLN]	Option C1 *Pm* [PLN]	Option C2 *Pm* [PLN]
0%	380	333	430	408	368
10%	264	231	297	289	250
20%	245	214	275	269	232
30%	232	203	260	255	219
40%	221	194	249	244	208
50%	212	186	238	234	199
60%	203	178	228	225	191
70%	195	171	218	217	182
80%	185	163	208	207	173
90%	173	153	194	195	161
100%	135	118	149	153	121

Conclusions

- This paper constitutes one of the proposals of defining and practical computation of the investment risk measure for building or expanding a UGS facility.
- The assessment of the obtained values depends on the level of acceptability of investment risk (risk aversion). It is assumed that, as far as large investments in the power sector are concerned, the acceptable risk should be lower than 30% [2]. From this point of view the computed risk values for all presented options are within the 30% limit.
- An additional effect, apart from the investment risk calculation, is establishing the most probable storage service price for which the investment will be cost-effective (profitable) (NPV = 0).
- The proposed method is easy to use and it gives a possibility of quick verification of various scenarios of an investment performed.

Artykuł nadesłano do Redakcji 12.07.2010 r. Przyjęto do druku 29.09.2010 r.

Recenzent: prof. dr hab. inż. Józef Raczkowski

Bibliography

[1] European Commission, Directorate General for Regional Policy, *Guide to Cost-Benefit Analysis of Investment Projects – Final Report*. Materials of MRR (Ministry of Regional Development), Warsaw 2008.

[2] Paliński A.: *Ocena ryzyka finansowego budowy podziemnego magazynu gazu z wykorzystaniem symulacji Monte Carlo*. (Financial Risk Assessment of UGS Facility Building Using the Monte Carlo Simulation), Międzynarodowa Konferencja Naukowo-Techniczna GEOPETROL 2008 (International Scientific and Technological Conference, GEOPETROL 2008), Zakopane 15–18.09.2008.

[3] Łucki Z.: *Ocena inwestycji i podejmowanie decyzji w górnictwie naftowym i gazownictwie*. (Investment Estimation and Decision-Making Process in Oil and Gas Industry), Polska Fundacja Promocji Kadr (Polish Foundation for Management Promotion), Kraków 1995.

Dr Tadeusz KWILOSZ – adiunkt w Zakładzie Podziemnego Magazynowania Gazu Instytutu Nafty i Gazu, Oddział w Krośnie. Zajmuje się optymalizacją i modelowaniem zagadnień związanych z eksploatacją złóż oraz podziemnych magazynów gazu.