

EVALUATING ECONOMIC STRATEGIES FOR
MULTI-PARTY APPLICATION OF
PERFORMANCE CONTRACTING

By

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CHAPTER I.

INTRODUCTION

Importance of Implementing Energy Efficiency Projects

Energy is used everywhere. It is hard to imagine what our society would look like without energy. However, it is also known that energy is a limited resource. How to reduce energy consumption has been a common and popular topic for a long time. The best means to optimize energy's impact is to assure that energy productivity is maximized. This requires an increase in energy efficiency. However, according to the United States Environmental Protection Agency's (EPA) Energy Star program, it is estimated that up to 30% of the dollars spent on energy every year are wasted due to system inefficiencies (Zobler and Payne, 2003). Whether by reducing negligent waste of energy, optimizing existing physical systems, or retrofitting systems with newly available technology, increasing energy efficiency is a reasonable long-term solution (Kromer, 2007). Also, given the fact that increasing the efficiency of energy systems can eliminate the need for the investment in the energy supply side, increasing the efficiency of energy systems is an efficient way to reduce the energy consumption as well as the cost of energy.

An inefficient energy system will result in both environmental and economic dilemmas. From an environmental point of view, the inefficient energy system will result in higher fuel consumption and increased emissions. Emission increases include green house gases (GHG) and regulated air pollutants such as nitrogen oxides (NO_x), sulfur dioxide (SO₂), and particulates. By adopting higher efficiency energy systems, the energy-related emissions of carbon dioxide (CO₂) could be reduced by as much as 37% under current economic conditions (U.S. NAS, 1991). Moreover, the improved environment will increase the productivity of energy users. West Bend Mutual Insurance Company reported a 7% increase in productivity (number of files processed pertaining to applications, endorsements, renewals, and quotes) following the implementation of a variety of environmental improvement measures that were energy and non-energy related (Kroner, Stark-Martin and Willemain, 1992). Research also finds that there is a positive correlation between Return on Assets (ROA) and environmental ratings. Innovest found that environmental ratings correlated closely with financial performance and that the companies with the highest environmental ratings outperformed their competitors by as much as 5%. Besides being an indicator of strong financial performance, environmental performance also correlates with the quality of sustainable earnings. Companies with top-rated environmental records, compared to those with the worst records, fared significantly better financially, manifest a 3.9% higher return on investment (ROI), a 4.4% higher earnings-to-assets ratio, and a 16.7% higher operating income growth (Pye and McKane, 2000).

From an economic point of view, increasing energy efficiency can boost the competitiveness of energy users by reducing the use of fuels and human resources.

Dollars saved on energy would be available to spend on other goods and services, which would promote the economic growth of energy users. Mills posited that energy savings were statistically associated with one-third of the total productivity gain (Mills, 2003a).

The federal government has also realized the importance of a reduction in energy consumption. The Energy Policy Act (EPA) of 2005 sets certain federal energy goals which primarily focus on energy use being reduced (compared to 2003) by 2% per year from 2006 through 2015 (U.S. DOE, 2007).

Barriers to Energy Efficiency Projects

Although people have been aware of the importance of an energy efficiency upgrade, the barriers to the improvement of energy efficiency, such as lenient energy pricing policies, lack of access to appropriate technologies and lack of funding, still exist (Howarth and Andersson, 1993). Of these barriers, lack of funding for investment into energy efficiency projects has become one of the key barriers faced by many energy users (Vine, 2005). Derrick posited that the lack of appropriate financing mechanisms available to energy users remained one of the key barriers to the wider use of high efficiency renewable energy technologies (Derrick, 1998).

Due to the funding barrier, energy users may need to adjust their energy efficiency improvement plans or possibly take no action if the funds are unavailable, which will result in greater utility charges and a possible increase in maintenance costs. The Oak Ridge National Lab (ORNL) and Department of Energy (DOE) have conducted surveys and studies that estimate the average waiting time to acquire available funding. The ORNL 2003 study examined 12 direct-funded projects and found that the average

waiting time was 63 months to implement an energy efficiency project. For its 1993 investigative report on the In-House Energy Management Program, the DOE inspector general examined 93 direct-funded projects and found that the average waiting time was 73 months to implement an energy efficiency project (U.S. GAO, 2004). The aforementioned research findings concerning funding delays make creative financing, including performance contracting, more important and attractive.

An Energy Savings Performance Contract

An Energy Savings Performance Contract (ESPC) provides a unique financial arrangement between an energy user (client) and an Energy Service Company (ESCO). The ESPC allows a client to replace its aged and inefficient energy system or upgrade its energy systems while investing relatively little capital. For example, if a client cannot afford the system, an ESCO may devise a financial arrangement to help the client purchase the system. Depending on the terms in an ESPC project, an ESCO can take over responsibility for all project phases: auditing, designing, transporting, installing, operating and maintenance of the selected energy efficient system, and control of the energy efficient system performance. Or, an ESCO can select to subcontract this work to outside contractors such as an installation company and a maintenance company. By doing this, an ESCO gets paid a portion of a client's energy savings/revenues from the project throughout the contract.

Usually, the performance of the proposed energy system decreases over time due to the lack of professional operation and maintenance. With an ESPC, an ESCO guarantees the performance of the proposed energy system within certain parameters for

the contract period, and a client can also get significant energy savings and assume little risk. If the annual actual energy savings (kWh/MMBtu) are less than the annual guaranteed energy savings (kWh/MMBtu), an ESCO must correct or resolve the situation or negotiate a change in the contract. This aspect ensures the function of the system as well as the successful realization of the savings. Compared to conventional financing methods of energy efficiency projects in which manufacturers guarantee the proper functioning of their products but do not guarantee the performance of the entire energy project, this can be seen as a major advantage of an ESPC. It transfers the performance risk from a client to an ESCO. This point has been mentioned by Laurent in 1998 (Laurent, 1998). The other advantage in an ESPC is that it can free up a client's capital, transfer non-core staff from a client, and allow a client to focus on its primary business function.

Motivation behind the Research

An ESPC project can last up to 25 years for federal facilities (U.S. DOE, 2007). There is no time restrict for private ESPC projects. An ESPC project can also involve multiple parties such as a client, an ESCO, a manufacturer, and even a utility in some projects. The long-term and multi-parties' nature of an ESPC project gives rise to a number of concerns regarding future uncertainties facing the parties involved in an ESPC project.

Economic and financial literature has addressed the investment decisions under uncertainties (Jackson, 2007; Wickart and Madlener, 2007; Sadeghi and Hosseini, 2006; Gaterell and McEvoy, 2005; Balachandra and Shekar, 2001; Caputo and Pelagagge,

2001). The fact is that in an energy efficiency project, the chance of knowing what the actual value of energy savings will be in more than a year is low. Ignoring this fact does not make it disappear. Studies have shown that the value of the actual energy savings often deviates significantly from the value of the predicted energy savings, and typically in unfavorable ways. The true benefits from the actual energy savings realized over the contract term often vary greatly from the benefits of the predicted energy savings, which are initially used to establish the contract. In a major review of the historic experience in the U.S. ESCO market, 40% of the projects had savings that deviated by more than 15% from the projections, and the predicted savings were greater than the actual savings in 30% of the cases (Goldman, Osborn, Hopper and Singer, 2002).

The deviations between the predicted energy savings and the actual energy savings discourage the application of an ESPC, and require that risk analysis be employed before the implementation of an ESPC project. The literature review in Chapter 2 introduces the risk analysis methods that have been applied in energy efficiency projects, particularly in ESPC projects. These analysis methods consider the benefits and costs from either a client's point of view or an ESCO's point of view. However, when the risk factors related to both parties vary, it is impossible that only the benefits and costs of one party change while those of the other party remain stable. Therefore, it is meaningful to analyze the influence of the risk factors on the benefits and costs for both client and ESCO, and determine if the proposed energy efficiency projects are beneficial to both parties. To date, none of the previous studies has done this work. Since an economic strategy cannot be successful unless it satisfies all participants

involved, this gives rise to the idea of developing a methodology to evaluate an ESPC strategy for multi-party applications.

Problem Statement

A lack of a general understanding of an ESPC associated with benefits and costs involved in the business venture of the possible parties such as a client and an ESCO hinders the development of an ESPC in an uncertain operating environment.

Research Objectives

The primary responsibility of business management is to increase the shareholders' value. The shareholders' value can be increased by cutting costs or raising revenues. Increasing productivity, improving product quality, reducing risk and enhancing reputation are several ways a company can cut costs or elevate revenues. Energy efficiency and pollution prevention have been shown to do all of these things. Since an ESPC can help managers eliminate the financial barriers to an energy efficiency project, and managers need to understand all of the costs and benefits associated with an investment in energy efficiency upgrades to make decisions that augment the shareholders' values, it is necessary to establish a tool to formulate and evaluate the ESPC projects for decision making and contract negotiation purposes.

The objective of this research is to (1) develop an analysis protocol (methodology) for the parties involved in an ESPC project depending on the inputs and outputs of the proposed energy system, (2) develop a procedure to empower the parties involved in an ESPC project with information regarding the inherent risks, and (3)

develop a procedure to present graphical outputs of multiple scenarios in an ESPC project to help the parties understand the influence of significant input parameters on the benefits and costs of the parties.

Research Scope

The parties in any ESPC project may face the risk of possible savings shortfalls. Hence, it is reasonable to perform risk analysis to evaluate the influence of risks factors on an ESPC project. The character of the parties, the maturity of the proposed energy system, the project risk, and the expected profit margin may be considered in project evaluations. Compared with the simple and small-scale energy efficiency projects such as a lighting system upgrade, the parties dealing with complex and large-scale energy efficiency projects such as renewable energy face more risks. These projects require that the parties communicate well and understand the proposed energy system thoroughly to understand and reduce the risks. Presently, the information that is used to evaluate the application of an ESPC in such projects is sparse; hence, more extensive considerations are needed. The scope of the research will be concentrated on the application of an ESPC in the development and commercialization of complex and large-scale energy-related projects, as well as, new technology projects. These two types of projects require the involvement of multiple parties, particularly with energy buyback scenarios.

Outline of Dissertation

This chapter presented the importance of and barriers surrounding the energy efficiency projects, the idea of an ESPC, the motivation of the research in this area, the

problem statement, the research objectives, as well as the research scope. Chapter 2 reviews the risk factors and the risk analysis methods that have been used to analyze the latent risks in conventional energy efficiency projects and ESPC projects. Chapter 3 presents the proposed research methodology. Chapter 4 deploys a case study to illustrate how the model based on the proposed methodology works. Chapter 5 presents the validation of the proposed methodology. Chapter 6 shows the conclusion from the research and the recommendations for future research.

CHAPTER II.

REVIEW OF LITERATURE

Usually large-scale projects, such as waste-to-energy conversion projects and renewable energy projects, are technologically complex and economically expensive. Full cooperation among the involved parties is needed to achieve the success of such projects. The literature review in this chapter begins with an introduction of the concept of an ESCO, then proceeds to the examples of the ESPC applications, which are followed by the risk factors in ESPC projects and the examples of risk analysis in conventional energy efficiency projects and ESPC projects. At the end of the literature review, different risk analysis approaches are discussed.

Concept of an Energy Service Company

The establishment of the Energy Service Company (ESCO) industry in the United States was driven by the rise of energy prices in the early 1980s, tax incentives, and investment in utility Demand Side Management (DSM) programs (Painuly, Park, Lee and Noh, 2003). An ESCO is generally viewed as a company which provides energy services such as energy analysis and audits, energy management, project design and implementation, maintenance and operation, and monitoring and evaluation of energy savings. ESCOs are delivering energy efficiency resources to a wide range of energy

users. Most ESCOs focus on medium to large commercial and institutional clients such as local and state governments. Schools and universities account for about 55-60% of overall ESCO activities (Vine, Nakagami, and Murakoshi, 1999).

The concept of an ESCO has been widely accepted in the United States. In 2000, the industry investment for energy efficiency related services reached \$2 billion. Typical projects saved 150-200 MJ/M²/yr and were cost effective with a median benefit/cost ratio of 1.6 and 2.1 for institutional and private sector projects respectively. The median simple payback period was seven years for institutional clients and three years for the private sector (Goldman, Hopper and Osborn, 2005). According to a study conducted by the National Association of Energy Services Companies (NAESCO), revenues for the ESCO industry increased at a 24% annualized rate over the past decade. Although this number has declined since 1996 to a 9% annualized revenue growth, it is estimated that present ESCO market activity ranges between \$1.9 billion and \$2.1 billion annually (Musser, 2003). A recently issued report from the Lawrence Berkeley National Laboratory (LBNL) and the NAESCO documents that the revenues of ESCOs grew by 20% per year from 2004 to 2006 and totaled about \$3.6 billion in 2006. A survey of the U.S. ESCO industry market growth and development from 2000 to 2006 revealed that energy efficiency accounted for almost three quarters of those revenues (for \$2.5 billion per year) (Berkeley lab tracks energy services growth, 2007).

There have been a plethora of articles written to provide guidance to an ESCO as to how to implement energy efficiency related services. Army proposed three fundamental principles: (1) give clients choice and control over the energy services they receive – and from whom; (2) foster a fully competitive market for the supply of these services; and (3)

pursue the societal objectives that the market alone does not attain through a retail user charge (Army, 1996). Weber made comments based on her experience to keep an ESPC flexible and viable in the long contract term. These comments included allowance for changed conditions and integration the ESCO into the entire team (Weber and Hucceby, 2005). All of these principles and comments will improve communication between an ESCO and its client and guide the implementation of an ESPC project.

Examples of Energy Savings Performance Contracts (ESPCs)

ESPCs have been widely applied with various energy projects for many types of clientele including government, industry and educational institutions. These energy projects include water treatment, lighting, renewable energy, heating, ventilation, air conditioning (HVAC) controls and so on. For example, a 10-year, \$8.6 million ESPC project was implemented to improve indoor comfort air quality and lighting levels in Glenbrook High School District's facilities (Top-ranked schools give performance contract top marks, 2001). The Elmendorf Air Force Base has received over 1 MMBtu of annual energy savings and more than \$123 million of energy-related cost reductions through an ESPC project (Kosub, 2004). The United States Air Force signed an ESPC with Noresco, an energy service company, to help it upgrade the energy systems at Air Force installations throughout 13 states (Noresco signs energy contracts, 1999).

Introducing ESCOs to educational institutions is a useful method to support sustainability initiatives and accelerate the implementation of comprehensive sustainability strategies (Pearce and Miller, 2006). The ESPC project not only helped Pima Community College in Tucson, Arizona save \$272,000 without any upfront or

budget increases (Performance contract saves energy costs, 1998), but also helped the Frontier Central School District in New York reduce utility consumption and improve the condition of the schools (Performance contract results in savings, 1997).

Selecting a qualified ESCO is critical for an ESPC project to be successful. There are many famous and mature ESCOs in the energy related service market such as Honeywell, Siemens and Johnson Controls, Inc. These companies have done many ESPC projects to help clients reduce energy consumption as well as energy costs. Honeywell and Malverne Union Free School District agreed upon a \$2.4 million ESPC to install a 10-kW solar power generation system (School upgrade saves money, 2006). Another ESPC project signed between Honeywell and Luke Air Force Base in Arizona was valued at \$9.6 million (Tegtmeier, 2006). Honeywell's Home and Building Control business has been awarded a \$418.1 million ESPC by the United States Army Engineering and Support Center to design and install high efficiency boiler and building control systems for 116 buildings at the Fort Dix United States Army Reserve (Honeywell inks contract with Fort Dix, 2000). With a 15-year guaranteed ESPC, Siemens Building Technologies helped the Mississippi Department of Corrections (MDOC) save over \$6 million in energy and operational costs. The annual guaranteed energy and operational savings were estimated to be \$430,000 (Skaer, 2005). Another 15-year ESPC between Siemens Building Technologies Inc. and George Mason University saved a minimum of \$1 million per year in energy costs at an interest rate of 3.81% for financing the cost of the project (Siemens to help university save on energy costs, 2005). Johnson Controls, Inc. signed a 5-year ESPC with St. Augustine's College in Raleigh,

NC to implement the college's facility retrofit (Historic campus teaches lesson in energy, 2000).

There are many ways to finance an ESPC. Clients can select self-funding or outside sourcing to pay the initial cost of the proposed energy system. Under an ESPC with Siebe Environmental Controls, Riverside County self-funded their \$8.8 million retrofit over a one-year period. The ESPC project helped Riverside County cut its annual electrical consumption by more than 9.3 million kWh, and annual natural gas consumption by 3,715 MMBtu (Performance contract helps county fund several energy-cutting retrofits, 1998). In 2003, Johnson Controls, Inc. signed a \$15 million ESPC with Tyler Water Utilities in Texas to replace the water meters in the city with models that transmitted information using radio signals. The \$15 million project was financed through a revenue bond issue, which was scheduled to be paid back over ten years through the increased utility revenue, which was guaranteed at \$1.7 million (Groover and Kunzler, 2004).

With the increase in demand of ESPC projects, a quick, reliable and simple tool for economic evaluation of ESPC projects is critical.

Risk Factors Inherent in ESPC Projects

Due to the various risks inherent in ESPC projects, the actual energy savings may deviate from the guaranteed energy savings. As a result, disputes may occur among the involved parties. Therefore, it is necessary to find the risk factors affecting an ESPC project and employ a risk analysis to evaluate their influences. The possible risk sources are as follows:

- The performance of the energy efficient system is hard to measure and verify accurately and equitably.
- Any unforeseen changes in circumstances resulting in a difference in projected savings, such as occurrences of extreme weather conditions, could cause conflicts between contracting parties. In the United States, many ESCOs have been unwilling to provide 100% savings guarantees because of their concerns about future volatilities that could adversely affect their savings predictions (Goldman, Osborn, Hopper and Singer, 2002).
- A change in occupancy conditions may increase the energy consumption of the proposed energy system. Dubin compared the engineering calculations used to calculate the energy savings from the improvements in residential heating and cooling systems relative to the actual performance. The engineering calculations overestimated the actual savings by 1-13% for cooling systems and 8-12% for heating systems (Dubin, Miedema and Chandra, 1982).
- The changes in the clients' operation modes or the operation hours of the energy system may increase the energy consumption. A number of Army Audit Agency reports issued over the last several years stated that energy savings baselines established by the ESCO were faulty, resulting in overpayments to the ESCO. This inaccuracy was caused by incorrect assumptions about the client's operation modes. For example, the ESCO overstated operating hours used in the baseline (U.S. GAO, 2004).
- Other risks include the fluctuations in energy prices, inflation rates and interest rates of loans from financial institutions due to the long term nature of ESPC

projects. Although an ESCO regularly predicts the amount of energy saved by installing energy efficient systems, it cannot guarantee the value of that saved energy in future years in the face of price volatility in a deregulated energy market (Mathew, Kromer, Sezgen and Meyers, 2005).

Table 1 identifies 10 possible zones in which risks in an energy efficiency project may reside. These risks are in the economic, contextual, technological, operational, and Measurement and Verification (M&V) categories.

Table 1 - Matrix of risks associated with energy efficient projects

(Mills, Kromer, Weiss and Mathew, 2006)

	Intrinsic factors	Risk management	Extrinsic factors	Risk management
Economic			Fuel costs Demand charges Cost of capital Exchange rates Labor costs Equipment costs	Hedges; fixed-price contracts Hedges; fixed-price contracts Risk-based rates Hedges Fixed-price contracts; inflation bonds (dirty hedges) Fixed-price contracts; inflation bonds (dirty hedges)
Contextual	Information on facility Applicability/feasibility	Due diligence; surveys Careful design	Environment Energy service levels	Pre-project data analysis, weather hedge Contractual exclusions/adjustments
Technology	Equipment performance System performance Equipment sizing	Design, specification, measurement; ESI; stipulated savings Measurement Design	Equipment lifetime	Careful design; specification; contractual exclusions
Operational	Degradation of savings Baseline adjustments Indoor environmental quality	Monitoring and diagnostics Contractual adjustments Liability insurance	Persistence	End-user training and information; contractual exclusions; occupant incentives
Measurement and verification	Data quality	Engineering review		

The responsibility assumed by each party will dictate which party is in charge of the risk factors. An ESCO is accountable for risks associated with the performance of the proposed energy system, since normally it is the ESCO that selects and designs the system. A client generally takes the responsibility for risks related to the operational factors such as the operation schedule of the system.

There are so many risk factors that it is impossible to consider all of them in the risk analysis. Since the proposed methodology mainly deals with large-scale and complicated energy projects such as combined heat and power (CHP), photovoltaic and solar heat, based on the literature review, the risk factors that significantly influence these three types of energy systems are chosen and applied in the methodology. These risk factors are listed in the following paragraphs in accordance with the published time of the literature review.

- Hassett posited that the investment credit tax was a key factor for general energy systems in 1995 (Hassett and Metcalf, 1995);
- Wisser and Pickle pointed out that the debt interest rate, the debt maturity, and the tax incentive were significant factors considered in solar projects (Wisser and Pickle, 1998);
- Sundberg discussed that the price of electricity, the relationship between the price of sold energy and the price of purchased energy, and the investment cost of energy systems were significant factors affecting CHP projects (Sundberg and Karlsson, 2000, Sundberg, 2001, Sundberg and Sjodin, 2003);
- Colle, in 2001, mentioned that the effect of inflation rates, interest rates, fuel cost variation, and capital cost should be considered on the life cycle savings of Photovoltaic projects (Colle, de Abreu and Ruther, 2001);
- Axelsson stated that the price of electricity was a key factor for CHP projects (Axelsson, 2003);
- Taal pointed out that energy prices were important factors in retrofit projects (Taal, 2003);

- Bhattacharyya, in 2004, found that the investment cost of a CHP system and the price of electricity sold back to the utility were important factors to be considered in a CHP project (Bhattacharyya and Thang, 2004);
- Borison mentioned that the price of electricity was an important factor for general energy systems (Borison and Hamm, 2005);
- Al-Mansour and Kozuh analyzed the effect of the capital cost and the price of electricity on a CHP project (Al-Mansour and Kozuh, 2007).

The previous works point out that the risk of future conditions is a key factor when deciding if an energy efficiency project can be implemented successfully. Moreover, realizing the effects of the risk factors will help ESCOs and clients reduce the possibility of energy savings shortfalls. Therefore, rather than attempting to define a static contract and hoping that it will cope with dynamic situations, which would have little chance to succeed, a model should be built to incorporate and allow changes to accommodate the risk factors. Application of risk analysis in an energy efficiency project will help the parties involved learn how the variation of the risk factors influences the benefits and costs associated with the parties' business behaviors. The next sections describe the risk analysis methods applied in the energy efficiency projects. There are two types of risk analysis: quantitative risk analysis and qualitative risk analysis.

Quantitative Risk Analysis Methods

Implementing risk analysis is a necessary prerequisite to the benefits and costs analysis that forms the basis for the decision making of investment in energy efficiency projects. Associating projected financial returns with risks also motivates financial

decision makers to take energy efficiency projects - as an investment avenue - more seriously.

Quantitative risk analysis is applied extensively in energy efficiency projects. It can be used to analyze the baseline models in energy efficiency projects. The normal method used to determine the savings from energy efficiency projects in buildings is to identify a baseline model using known quantifiable variables and then regress the data obtained during a specific time period. However, the assumption used in the baseline model does not give the client knowledge of the error inherent in the savings determination, and the uncertainty in the assumption becomes the major determinant of the uncertainty in the resulting savings. Reddy proposed a fractional uncertainty in savings ($\Delta E_{save} / E_{save}$) to determine whether a baseline model is acceptable or not. This fraction permits the client to vary the criteria according to the factors most relevant for a particular energy efficiency project (Reddy and Claridge, 2000).

Quantitative risk analysis can also help decision makers identify the desired conditions which make an ESPC project successful. Lee and Yik observed that the restructuring of the electricity industry in the United States increased the variability in the energy cost savings realized through ESPC projects. They built a financial model to review the key factors contributing to the success of an ESPC project and found that a substantial energy-saving margin, an ample share of this margin by the ESCO, and a copious contract period were prerequisite conditions to make an ESPC project successful (Lee and Yik, 2004).

Quantitative risk analysis can be also used to analyze the influence of the discounting rate in energy efficiency projects. Thompson recommended applying a lower

discount rate to the separate cost streams, and then comparing the separately discounted present values to account for risky benefits when investing in energy efficiency projects (Thompson, 1997).

Nowadays, simulation is a common approach applied in the quantitative risk analysis. Usually the trial size in the simulation is large, which means the simulation requires substantial computer time. However, with the help of advanced computer technology, this is not a problem any more. Actually, the large number of simulations being run is one of the reasons the risk analysis is proposed.

Rickard et al analyzed the investment risks from varied energy prices and weather conditions in building energy efficiency upgrades via simulation demonstrations. Based on the results (annual energy savings from the energy efficiency upgrades) from the simulations, Rickard was able to calculate the statistical measures of the results to analyze the influence of the risks on the predicted annual energy cost savings (Rickard, Hardy, Von Neida and Mihlmester, 1998). LBNL applied the Monte Carlo simulation to integrate the risks of multiple variables into a unified economic assessment method, which is now the basis for evaluating the proposed mandatory energy efficiency standards in the United States (McMahon and Liu, 2000, Lutz, Liu, Lekov, Whitehead and McMahon, 2000). Mathew et al combined Monte Carlo simulation with engineering judgment, empirical data, and theoretical data to obtain quantitative estimates of the savings from ESPC projects (Mathew, Koehling and Kumar, 2006). Al-Mansour and Kozuh devised an improved Monte Carlo simulation called Latin Hypercube Sampling (LHS) to determine the parameters which most influenced the profitability of a CHP project running in an uncertainty environment. The level of fluctuating risks connected

with the parameters was represented by the probability distributions (Al-Mansour and Kozuh, 2007).

However, running simulations based on the joint-distribution functions of the input variables could only be exclusively applied to the projects where specific variables affecting the savings were well understood and easily modeled (Mathew, Kromer, Sezgen and Meyers, 2005).

To solve this problem, Van Groenendaal presented a method which combined the experimental design with regression modeling to analyze the variability in the Net Present Value (NPV) of energy efficiency projects (Van Groenendaal, 1998). This method did not require knowledge about the distribution of the input variables in the simulation model. Rather, it first designed simulation experiments through systematic factor variation, resulting in data on NPV variability. Then a regression model was used to fit the simulated NPV data. Krey et al applied a stochastic risk function in the energy system model to analyze the impact of fluctuations in energy prices on the supply structures (Krey, Martinsen and Wagner, 2007). The input to the model was the energy prices which were simulated based on the time series analysis of historical energy prices. The result of the model was an optimized energy supply structure.

Scenario analysis is another common approach applied in quantitative risk analysis, and it has been applied in portfolio management (Phoa, 1999) and project management (Pollack-Johnson and Liberatore, 2005). This type of analysis is based on subjectively defined scenarios prior to the implementation of projects. It corresponds to analysts' forecasts or scenarios identified by risk managers. Scenario analysis can be combined with Monte Carlo simulation to analyze the exposure of a strategy to the risks

posed by extreme events or answer “what if” scenarios involving multiple variables (Phoa, 1999 and Sheel, 1995).

Scenario analysis is applied widely in energy efficiency projects. Moran and Sherrington ran a scenario analysis to estimate the effect of non-use diameters associated with a large scale windfarm in Scotland, and found the windfarm delivered a net welfare gain to the society (Moran and Sherrington, 2007). Van Buskirk specified policy investment scenarios to calculate benefits and costs of energy efficiency and renewable energy investments in Excel (Van Buskirk, 2006). Wei et al assessed how social and economic changes affected energy requirements and energy intensity in China’s developing society. These social and economic changes included technological advancement, population, income, pattern of consumption and production and urbanization rate. The analysis results exhibited that the technological advancement had the strongest impact on the energy intensity (Wei, Liang, Fan, Okada and Tsai, 2006). Castro et al established scenarios of a grid-connected building integrated photovoltaic project to estimate the effects of a set of parameters on the project (Castro, Delgado, Argul, Colmenar, Yeves and Peire, 2005). Weisser developed different electricity supply scenarios to determine electricity generating capacities and compare various supply technologies that would be required in the future to meet specific electricity demand projections. These scenarios included business-as-usual scenario, hybrid scenario and renewable energy technology scenario (Weisser, 2004).

Qualitative Risk Analysis Methods

Qualitative risk analysis has been applied to help clients and ESCOs overcome problems with formulating and executing ESPC projects. They include developing public domain guidelines, such as the International Performance Measurement and Verification Protocol (IPMVP), to diagnose and commission the performance of the proposed energy systems (IPMVP, 2007).

Additionally, various methods have been developed to minimize the chance of undesirable situations occurring. For example, rigorous procedures and studies were performed in the pre-contract stage to ensure that the estimate of the energy savings would be realistic (Tharoor, 1999). The United States Department of Energy set the guidelines and included a sample Request for Proposal in its website as a reference (U.S. DOE, 1992). The Federal Energy Management Program (FEMP) also developed tools to aid the Measurement & Verification (M&V) decision making process for ESPC projects. These tools included M&V guidelines, the Risk/Responsibility matrix and the M&V decision support flow chart (M&V Guidelines: Measurement and Verification for Federal Energy Projects, 2000). American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Guideline 14 Annex B provided information and guidance on how to conduct risk analysis for energy projects (ASHRAE Guideline 14, 2002). The guidelines primarily provided qualitative guidance, and advocated the use of quantitative risk analysis to augment the qualitative guidance.

In addition to the guidelines and protocols provided by the federal government and professional organizations, some experts also did extensive research on how to improve the success rate of ESPC projects. Helle briefly mentioned that cooperation

should be cultivated in a project management company by modeling a joint venture in which a client and an ESCO would become partners (Helle, 1997). Mills proposed adoption of energy saving insurance to reduce both performance risks and financial risks in energy efficiency projects (Mills, 2003b). Sorrell developed a general framework which was used to assess the feasibility of energy service contracting in different circumstances. This framework was intended to help clients and ESCOs identify the conditions in which energy service contracting was most likely to be appropriate and successful (Sorrell, 2007).

Risk Analysis of Conventional Energy Efficiency Projects

Studies have been implemented to analyze the influence of the risk factors on energy efficiency projects. In the risk analysis of conventional energy efficiency projects, the influence of the risk factors is usually reflected on the variation of energy consumptions, as well as benefits and costs brought by the energy efficiency systems. Including the energy efficiency projects mentioned in the previous sections, the following paragraphs list the energy efficiency projects in which the risk analysis is applied.

- Wisser developed a cash flow model to assess a fictional wind power project with different ownerships. He found that the levelized cost of this project was highly sensitive to the ownership and financing structure of the project (Wisser, 1997).
- Colle et al demonstrated the life cycle savings of both solar water heating and photovoltaic as a function of the monthly means of global radiation. The examples presented in the paper showed that the life cycle savings were

significantly dependent on the uncertainty of the monthly means of the solar radiation (Colle, de Abreu and Ruther, 2001).

- Agashichev found that incorporating a reverse osmosis (RO) system into a co-generative system decreased the sensitivity of the co-generative system to the nominal interest rate, cost of primary fuel, and carbon tax rate (Agashichev, 2004).
- Coleman and Provol analyzed the operational and financial risk factors in wind power projects in the United States and found that the after-tax internal rate of return (IRR) of these projects was sensitive to the electric production, the energy price, the construction cost and the corresponding investment cost (Coleman and Provol, 2005).

It is important that the risk analysis of energy efficiency projects be tailored for the particular audience, specifically by linking risks to the key decision parameters of the particular audience. In the conventional energy efficiency projects, the risk analysis is usually performed from a client's point of view.

- Rickard et al analyzed the investment risks of energy prices and variations in weather conditions in building energy efficiency upgrade projects from the perspectives of a client (Rickard, Hardy, Von Neida and Mihlmester, 1998).
- Al-Mansour and Kozuh developed an economic model to evaluate the financial profit of a CHP system from the client's point of view. The financial profitability of the CHP system was evaluated as the positive difference between the total energy cost of the client before and after the installation of the CHP system (Al-Mansour and Kozuh, 2007).

- Blyth et al applied a real options methodology to analyze the investment decisions in power generation from the perspective of the client. The investments were subject to the uncertain future climate policy, which was represented as the uncertainty in the carbon price (Blyth, Bradley, Bunn, Clarke, Wilson and Yang, 2007).
- Wickart and Madlener developed an economic model for a client to compare the investment in a CHP system and a conventional heat-only generation system with respect to the risks inherent in energy prices. The model allowed the client to optimize the investment technology as well as the investment timing (Wickart and Madlener, 2007).

It is understandable that the risk analysis in the conventional energy efficiency projects is implemented from a client's point of view, since the client is the main participant in such projects and it is the client (project owner) who purchases and operates the proposed energy efficiency systems. However, in an ESPC project, the client is not the only participant involved anymore. The benefits and costs of the clients are interconnected with those of the ESCOs. The influence of risk factors on the ESCO needs to be considered, too.

Risk Analysis of ESPC Projects

Compared to the number of papers which discussed the application of risk analysis in the conventional energy efficiency projects, the number of papers which discussed the application of risk analysis in the ESPC projects is less prevalent. They are listed in the following paragraphs:

- Bannai et al discussed how to use financial derivative to hedge the fuel price fluctuation on the profit of ESCOs (Bannai, Tomita, Ishida, Miyazaki, Akisawa and Kashiwagi, 2007).
- Mathew applied Monte Carlo simulations to assess the uncertainties of the savings in an ESPC project from an ESCO's point of view. In the project, the input variables were described by the probability distributions and the outputs were the savings from the ESPC project. Based on the outputs, the probability of the savings shortfall was estimated (Mathew, Koehling and Kumar, 2006).
- Lee and Yik built a financial model to review the key factors contributing to the success of an ESPC project from an ESCO's point of view. They found that a substantial energy-saving margin, an ample share of this margin by the ESCO, and a copious contract period were prerequisite conditions to make an ESPC successful (Lee and Yik, 2004).

Summary

The risk factors in energy projects, quantitative risk analysis methods, qualitative risk analysis methods, and risk analysis in conventional energy efficiency projects and ESPC projects, are summarized in the previous sections. These works prove that risk analysis is an important and necessary tool in estimating/projecting benefits and costs of conventional energy efficiency projects and ESPC projects.

These sections did an exemplary job in assisting clients and ESCOs in understanding the sources of risks in energy efficiency projects and on how to estimate

the influence of the risks on the benefits and costs associated with energy efficiency projects. However, the previous works did not address the following information:

- The risk analysis in the previous studies was implemented from either a client's point of view or an ESCO's point of view. None of them ascertained ESPC win-win strategies for both client and ESCO. In an ESPC, the benefits and costs of all involved parties are interconnected, which means the benefits of one party may be at the expense of another party. Since the ESPC cannot be successful unless all the involved participants gain value at give parameter settings, the involved parties should be considered as a team instead of individual units. The author has realized this problem and published a paper which presented an ESPC project as a win-win strategy for multiple party applications. In this paper, the author developed a model in Excel to show the financial interactions among the parties involved in a CHP project and presented the economic analysis for each party in a deterministic environment (Zhao, Kolarik, Turner and Case, 2006).
- The inputs and outputs of the proposed energy system determine the involved participants in an ESPC project and their relationships. As the proposed energy system becomes more complex, an ESCO and a client may not be equipped to handle such a complicated environment and may benefit from a system level analysis. It is obvious that the risk analysis involving only an ESCO and a client will limit a system level view.

In Chapter 3, a methodology is proposed to fill in these gaps, help the client and the ESCO understand the relationship among the parties with respect to the inputs and

outputs of the proposed energy system, and demonstrate how to make an ESPC successful in a complex ESPC project, from a system level perspective.

CHAPTER III.

RESEARCH METHODOLOGY AND MODEL

In this chapter, the outline the proposed methodology starts with a physical system view, followed by the party view of the physical system, and continues with the model inputs/outputs. Then, the relationship among the parties in a typical ESPC, the assumptions used in the model, the abbreviations applied in the model are explained. Next, the illustration of Excel models and the model equations which mathematically describe the relationship between the parties are developed, and an example is used to explain how the model equations work in Excel models. Finally, the development of the model inputs and the analysis of the model outputs are explained at the end of this chapter.

Conceptual Model

The financial analysis of an energy management project provides the economic aspects and the basis for making the investment decision. An ESPC will be initiated only when all participants in the project can perceive a benefit from it. In the research, a methodology is developed to discover possible ESPC win-win strategies for both client and ESCO. The following paragraph explains how the methodology works step by step.

1. The model starts with a physical system view (Figure 1). This figure includes a physical system's life cycle, its inputs and outputs, as well as its financial environment. The life cycle starts with design and acquisition of the physical system and ends with disposition of the physical system. The inputs of the physical system include costs across its life cycle, the parameters which are used to determine the energy output such as the demand/capacity of the system and the availability/yield of the system, and the incentives/credits issued at federal and state levels or by other organizations. The outputs of the system include the energy output and other possible outputs such as waste. Two general terms will be applied in the financial environment of the model: one is the general inflation rate, and the other is the specific commodity cost/volatility.

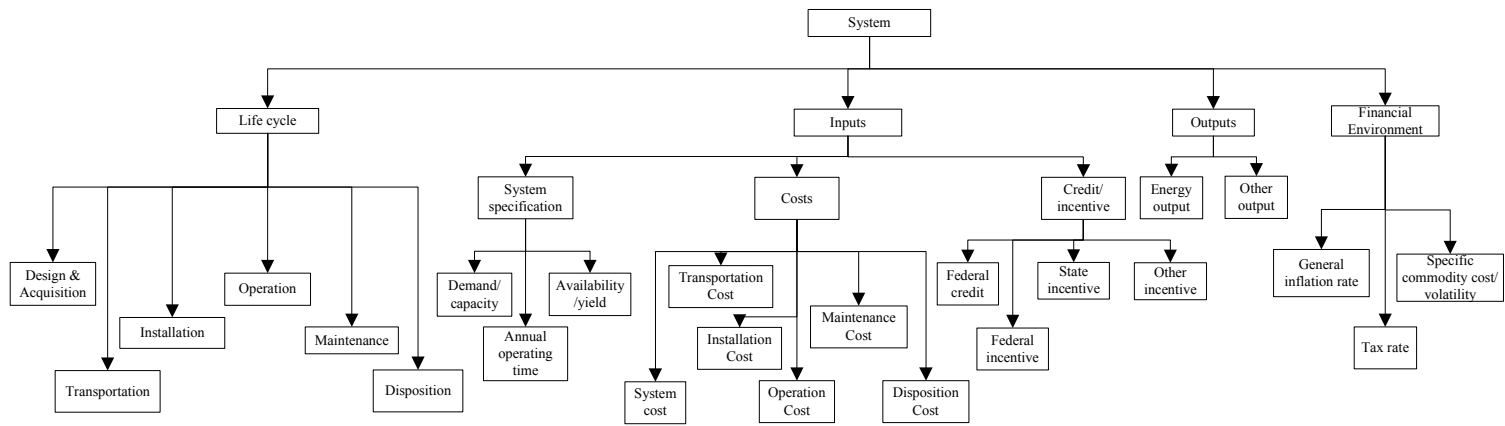


Figure 1 - The model of the physical system view

2. There may be numerous party views, whereas there is essentially only one system view. With respect to the inputs and outputs of the physical system, the possible parties that are involved in an ESPC project and the inputs of these parties are determined. This step is shown in Figure 2 and elaborated in Subchapter “Graphic Illustration of Relationship among Parties in a Typical ESPC”. As a validity check at the system level, all facets of the system must be accounted for in the party view, and the “summation” of the party view must constitute the system view.

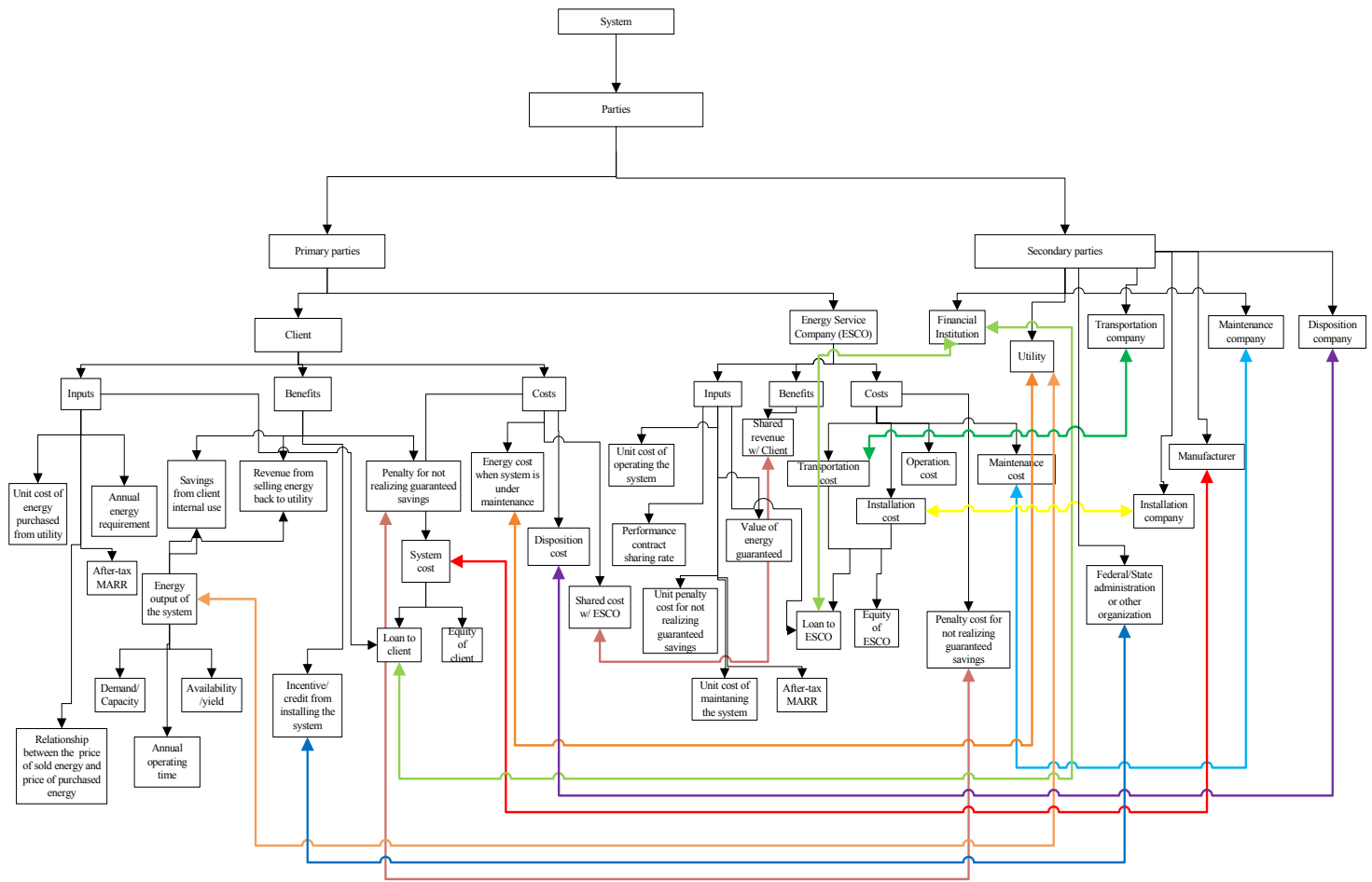


Figure 2- The party view of a physical system

3. Figure 3 shows the model inputs/outputs. In this part, the model inputs are characterized as deterministic or probabilistic based on the historical data, expert opinion, subjective judgments, or combinations thereof. Furthermore, the deterministic inputs can be separated as the inputs which can be described as single values in comparison to the inputs which can be described as discrete arrays based on expert opinion or subjective judgments. If the historical quantitative data of the probabilistic inputs are available, the probabilistic inputs can be simulated by either probability distributions or correlation coefficients using the historical data. This methodology allows the client and ESCO to assess how the various choices of the model inputs affect the benefits and costs of both client and ESCO in an ESPC.

Zoppellari points out that the net present value (NPV) should be considered initially in a cash flow analysis for the proposed investment, claiming it is sufficient to determine the economic validity of the investment (Zoppellari, 1990). Hence, the NPVs of the client and ESCO are used as the model outputs to establish the discounted cash flow implications involved in implementing the ESPC.

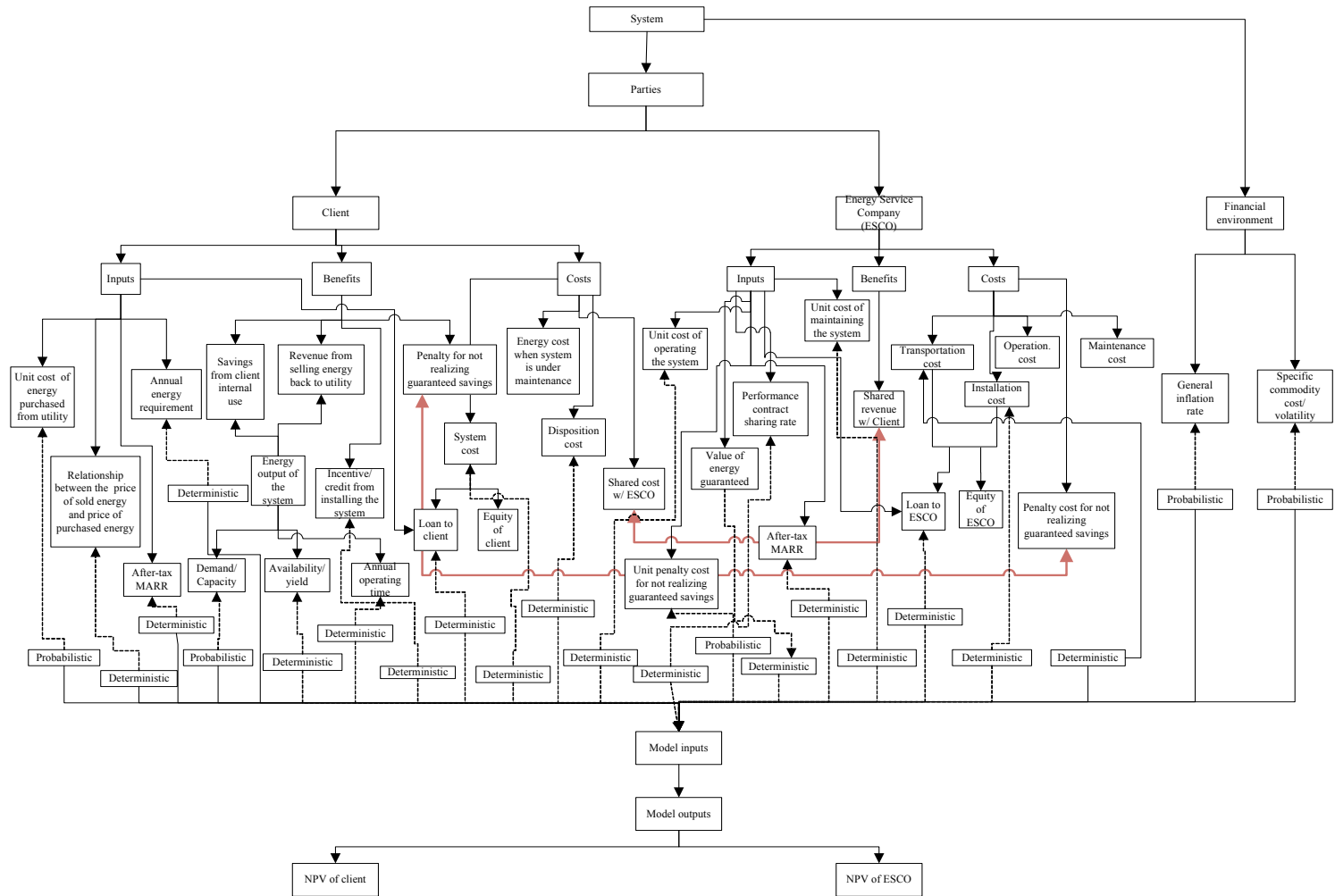


Figure 3 - Model inputs/outputs

Graphical Illustration of Relationship among Parties in a Typical ESPC Project

An important element in a successful and comprehensive evaluation of a typical ESPC is to ensure that the parties involved in the project understand each other and support a full assessment of benefits and costs in the ESPC. Figure 4 is drawn to represent the relationship among the parties and relationship between the system and each party in a typical ESPC project. Users can extend the relationship and involve more parties or inputs depending on the specific requirements of different physical systems. In the figure, the black line represents the physical flows while the red line represents the financial flows.

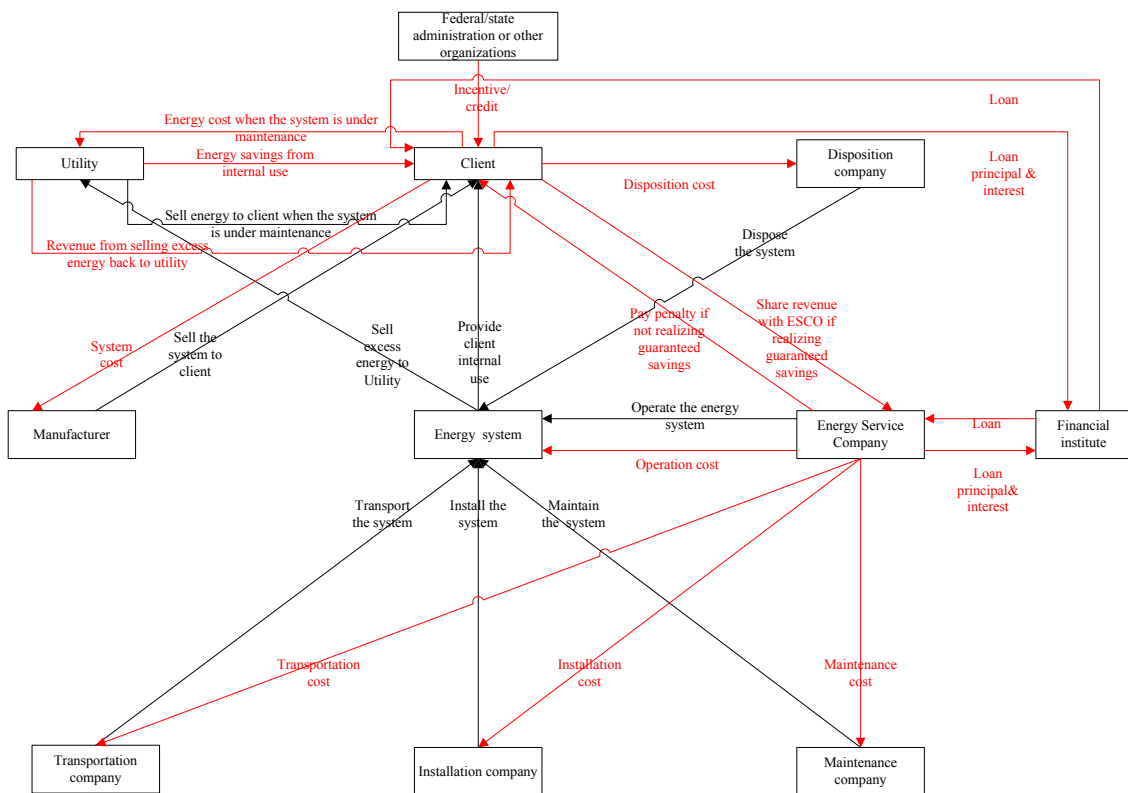


Figure 4 - Interrelationship among the participants in an ESPC Project

The Role Played by a Client

Assume in a typical ESPC project, a client purchases the system and pays the cost to the manufacturer. If the system cost is a substantial expenditure, the client may choose to borrow money from a financial institution to pay for the system cost.

The system is transported and installed at the client's site at the base year of the ESPC project. Dependent on the type of the system, the client may claim investment tax credit from the federal government, which will help increase the client's after-tax cash flow in the first year. Assuming an ESPC project lasts n years, the system generates energy from year one to year n , and receives incentives issued at the federal or state level, and/or from other organizations. After the actual energy generated from the system (kWh/MMBtu) meets the internal energy requirement of the client, if there is excess energy, it will be sold back to the utility. However, when the system is under maintenance, the system will not generate energy. The client will need to purchase the energy from a utility to meet the production requirement and pay the corresponding energy cost to the utility.

From year one to year n , the ESCO guarantees an energy value (kWh/MMBtu) generated from the system annually. If the actual value of the energy generated from the system (kWh/MMBtu) is equal to or greater than the guaranteed energy value (kWh/MMBtu), the client will share the benefits from installing the system with the ESCO. The benefit is calculated as:

$$\text{Benefit} = A + B - C$$

In which, A = The savings from the client's internal energy use

B = The revenue from selling the excess energy back to the utility

C = The cost the client pays to the utility when the system is under maintenance.

If the actual value of the energy generated from the system (kWh/MMBtu) is less than the guaranteed energy value (kWh/MMBtu), the client will not share the benefits with the ESCO; instead, the ESCO is penalized and pays a penalty cost to the client. At the end of the ESPC project, the client pays an outside company for system disposal.

The Role Played by an ESCO

Assume an ESCO signs contracts with the transportation company and the installation company to have them transport and install the system at the client's site, and pays the transportation and installation costs. If these costs are too expensive for the ESCO, the ESCO may choose to borrow money from a financial institution to pay them.

During the contract (ESPC) time, the ESCO operates the system, has an outside maintenance company maintain the system, and guarantees the energy value (kWh/MMBtu) generated from the system. If the actual energy value (kWh/MMBtu) generated from the system is equal to or greater than the guaranteed energy value (kWh/MMBtu), the ESCO will receive the shared benefits with the client. Otherwise, the ESCO will not get the shared benefits. Instead, the ESCO pays a penalty cost to the client. The penalty cost is the multiplication of the unit penalty cost and the difference between the guaranteed energy value and the actual energy value.

Assumptions Applied in the Model

Basic Assumptions

- The energy generated from the system meets the energy requirement of the client first.
- After meeting the client's requirement, if there is excess energy, the excess energy will be sold back to the utility.
- The ESCO guarantees an energy value (kWh/MMBtu) which is generated from the system.
- The system has a finite life of n years.
- General inflation rate and specific commodity cost/volatility are considered.
- The transaction costs such as the cost of finding an ESCO and the cost of settling an ESPC are not considered.

Assumptions of Primary Parties

- The client purchases the system at the base year of the ESPC project.
- The client may finance the acquisition of the system through an external financial institution.
- The client owns the system.
- When the system is under maintenance, the client purchases energy from a utility at an energy price P_c .
- If the system needs to be disposed of at the end of the ESPC, the client will have an outside company remove the system and pay the disposition company.
- The ESCO has the outside transportation and installation companies transport and install the system, and pays the transportation and installation costs.

- The ESCO may finance the transportation and installation costs of the system through an external financial institution.
- The ESCO is in charge of operating the system.
- The ESCO has an outside maintenance company maintain the system and pays the maintenance cost to the outside maintenance company.
- If the actual value of the energy (kWh/MMBtu) generated from the system is equal to or greater than the guaranteed energy value (kWh/MMBtu), the client will share the benefits with the ESCO. There is no penalty cost from the ESCO.
- If the actual value of the energy (kWh/MMBtu) generated from the system is less than the guaranteed energy value (kWh/MMBtu), the client will not share the benefits with the ESCO. The ESCO pays the client a penalty cost.
- The client and the ESCO have individual Minimum Attractive Rate of Return (MARR) requirements.

Assumptions of Secondary Parties

- The utility sells energy to the client on demand.
- The utility purchases all excess energy from the client.
- The manufacturer sells the system to the client.
- A transportation company transports the system to the client at the base year of the ESPC project.
- An installation company installs the system at the client's site at the base year of the ESPC project.
- The system is covered by contract maintenance that may require system

downtime.

- Financial institutions may furnish capital to the client or the ESCO or a combination of both in the form of loans.

Explanation of Terms

Explanation of General Terms

- t : Assume all benefits and costs are applied at the end of each year of the ESPC term. t is the relevant year in which the benefits and costs occur.
- r_c : Minimum Attractive Rate of Return (MARR) of Client
- r_e : Minimum Attractive Rate of Return (MARR) of ESCO
- $(P|F, r, t)$: The present worth factor is used to convert the future values (F) of benefits and costs to their present values (P). r means MARR and t is the year in which the benefits and costs occur.
- U_c : Amount of Client's loan principal
- U_e : Amount of ESCO's loan principal
- I_c : Interest rate of Client's loan
- I_e : Interest rate of ESCO's loan
- n_c : Loan term of Client
- n_e : Loan term of ESCO
- TR : Tax Rate
- IR : General inflation rate
- SV : Specific commodity cost/volatility factor

- MACRS: Modified Accelerated Cost Recovery System. MACRS was implemented in the United States with the passing of the Tax Reform Act of 1986. MACRS was meant to stimulate capital purchasing by lowering the net present value post taxation to allow for faster depreciation of capital assets. The property class of the capital asset determines its depreciation life.

Explanation of System Terms

- DS: Demand/capacity of the system
- OT: Operating time in hours of the client through the entire year. It is calculated as the multiplication of the daily operating time and the operating days in a year.
- AS: Availability/yield of the system. It is presented as a percentage (between 0% and 100%) of OT. The multiplication of AS and OT is the annual operating time in hours of the system.
- DR_t : Depreciation rate in year t. Dependent on the property class and the depreciation life of the system, the depreciation rate can be applied to its cost basis. The depreciation rate used in this model is from the MACRS depreciation percentage table found in the United States Master Tax Guide book (U.S. Master Tax Guide, 2007).
- FC: FC is a rate based on the system cost and used to calculate the federal credit which is issued as the form of investment tax credit. The investment tax credit permits the client to claim a credit against income taxes at the end of the first year.

- CIR: Cumulative incentive rate. Federal incentive, state incentive and other incentive rates are claimed based on per kWh or per MMBtu saved. The cumulative incentive rate is a summation of these three types of incentive rates.

Explanation of Client Terms

- EU: Annual energy requirement of the client.
- P_c : Unit cost of the energy that the client purchases from the utility. It is represented as \$/kWh or \$/MMBtu. For electric power, this price includes both energy and demand costs.
- PR: Relationship between the price of the purchased energy and the price of the sold energy. PR is equal to the division of the price of energy sold back to the utility over P_c .

Explanation of ESCO Terms

- GS: The value of the saved energy which is guaranteed by the ESCO. It is represented as kWh/MMBtu.
- PSR: If the actual value of the energy (kWh/MMBtu) generated from the system is equal to or greater than the guaranteed energy value (kWh/MMBtu), the client will share the benefits with the ESCO. The PSR is the rate based on the shared benefits between the ESCO and the client. The ESCO receives PSR% of the benefits and the client receives (1-PSR%) of the benefits.

- P_e : Unit penalty cost for not realizing the guaranteed energy value (GS). It is represented as \$/kWh or \$/MMBtu. P_m : Unit cost of maintaining the system. It is represented as \$/kWh or \$/MMBtu.
- P_o : Unit cost of operating the system. It is represented as \$/kWh or \$/MMBtu.

Model Equations

Illustration of Excel Models

The investment has to be evaluated according to the economic benefits obtained in a pre-determined period of time. Moreover, costs and benefits are connected. Excel models for both client and ESCO are built based on Figure 2. The benefits, costs, loans, and taxes of the client and the ESCO - for the relevant years under consideration - are presented in Table 2 and 3 respectively. Based on the benefits and costs, the cash flows before and after taxes are calculated as well in the two tables.

Table 2 - Excel illustration of Client model

CLIENT																			
End of Year	System Cost	Savings From Client Internal Use	Revenue From Selling Energy Back to Utility	Energy Cost When The System is Under Maintenance	Shared Cost with ESCO	Penalty For Not Realizing The Guaranteed Value	Disposition Cost	Incentives	Total Before Tax and Loan Cash Flow B+C+D+E+F+G+H+I	MACRS Depreciation B×DR	Loan				Taxable Income J-K+M	Income Tax P×TR	Federal Credit	After Tax Cash Flow (ATCF) J+L+M-Q+R	Present Value of ATCF
											Principal Payment	Interest Payment	Total Payment	Principal					
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
0																			
1																			
2																			
3																			
4																			
5																			
6																			
7																			
8																			
9																			
10																			
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12																			
13																			
14																			
15																			
16																			
17																			
18																			
...																			
n																			

Model Equations of The client

Assume the client signs an ESPC with the ESCO in the base year zero, and this contract lasts for n years. The client borrows money from a financial institution to pay the manufacturer the acquisition cost of the system. The ESCO is in charge of having the system transported and installed at the client's site. The ESCO is also responsible for operating and maintaining the system from year 1 to year n.

The energy generated from the system will meet the energy requirement of the client first. If there is excess energy after meeting the client's requirement, all of the excess energy will be sold back to the utility. However, when the system is under maintenance, it will not generate energy. The client will purchase the energy from a utility to meet the production needs. The client's benefits and costs are presented in the columns of Table 2. The equations used to calculate the benefits and costs are listed below. Unless particularly specified, t is from year 0 to year n.

In the client Excel model Table 2,

Column A_t = End of Year t

Cell B_0 = System Cost at Year 0

Column C_t = Savings from Client Internal Use at Year t $1 \leq t \leq n$

$$= \begin{cases} (P_c)(EU)(1 + SV_1)(1 + SV_2)...(1 + SV_t), & \text{IF}[(DS)(AS)(OT)] \geq EU \\ (P_c)(DS)(AS)(OT)(1 + SV_1)(1 + SV_2)...(1 + SV_t), & \text{Otherwise} \end{cases}$$

Column D_t = Revenue from Selling Energy Back to Utility at Year t $1 \leq t \leq n$

$$= \begin{cases} (P_c)(PR)[(DS)(OT)(AS) - (EU)](1 + SV_1)(1 + SV_2)...(1 + SV_t), & \text{IF}[(DS)(AS)(OT)] \geq EU \\ 0, & \text{Otherwise} \end{cases}$$

Column E_t = Energy Cost When The System is Under Maintenance at Year t , $1 \leq t \leq n$

$$= -P_c(EU)(1-AS)(1+SV_1)(1+SV_2)\dots(1+SV_t)$$

Column F_t = Shared Cost with ESCO at Year t $1 \leq t \leq n$

$$= \begin{cases} 0, IF[(DS)(AS)(OT)] < GS \\ -(P_c)(PSR)(1+SV_1)(1+SV_2)\dots(1+SV_t)[(EU)(AS-PR) + (PR)(DS)(AT)(OS)], \\ IF[(DS)(AS)(OT)] \geq (EU) \text{ and } [(DS)(AS)(OT)] \geq (GS) \\ -(P_c)(PSR)(1+SV_1)(1+SV_2)\dots(1+SV_t)[(DS)(AS)(OT) - (EU)(1-AS)], \\ IF(EU) > [(DS)(AS)(OT)] \geq GS \end{cases}$$

Column G_t = Penalty for Not Realizing the Guaranteed Value at Year t $1 \leq t \leq n$

$$= \begin{cases} (P_c)[(GS) - (DS)(AS)(OT)](1+SV_1)(1+SV_2)\dots(1+SV_t), IF[(DS)(AS)(OT)] < GS \\ 0, Otherwise \end{cases}$$

Column H_n = Disposition Cost at Year n

Column I_t = Incentives at Year t $1 \leq t \leq n$

$$= (DS)(AS)(OT)(CIR)(1+SV_1)(1+SV_2)\dots(1+SV_t)$$

Column J_t = Total Before Tax and Loan Cash Flow at Year t

$$= B_t + C_t + D_t + E_t + F_t + G_t + H_t + I_t$$

Column K_t = MACRS Depreciation at Year t $1 \leq t \leq n$

$$= (B_0)(DR_t)$$

Cell L_0 = Amount of Loan That the Client Borrows at Year 0

Column L_t = Loan Principal Payment at Year t $1 \leq t \leq n$

$$= N_t - M_t$$

Column M_t = Loan Interest Payment at Year t $1 \leq t \leq n$

$$= - (O_{t-1})(I_c)$$

Column N_t = Total Loan Payment at Year t $1 \leq t \leq n$

$$= - \frac{(U_c)(I_c)(1 + I_c)^{n_c}}{(1 + I_c)^{n_c} - 1}$$

Cell O_0 = Amount of Loan That the Client Borrows at Year 0

Column O_t = Loan Principal at Year t $1 \leq t \leq n$

$$= O_{t-1} + L_t$$

Column P_t = Taxable Income at Year t $1 \leq t \leq n$

$$= J_t - K_t + M_t$$

Column Q_t = Income Tax at Year t $1 \leq t \leq n$

$$= (P_t)(TR)$$

Cell R_1 = Federal Credit at Year 1

$$= (B_0)(FC)$$

Column S_t = After Tax Cash Flow (ATCF) at Year t

$$= J_t + L_t + M_t - Q_t + R_t$$

Column T_t = Present Value of ATCF at Year t

$$= (S_t) (P|F, r_c, t)$$

Net present value of Client $NPV_c = \sum_{t=0}^n T_t$

Table 3 – Excel illustration of ESCO model

ENERGY SERVICE COMPANY (ESCO)															
End of Year	Transportation Cost	Installation Cost	Maintenance Cost	Operation Cost	Penalty Cost For Not Realizing The Guaranteed Value	Shared Revenue with Client	Total Before Tax and Loan Cash Flow B+C+D+E+F+G	Loan				Taxable Income H+J	Income Tax M×TR	After Tax Cash Flow (ATCF) H+I+J-N	Present Value of ATCF
								Principal Payment	Interest Payment	Total Payment	Principa l				
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
0															
1															
2															
3															
4															
5															
6															
7															
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18															
...															
n															

Model Equations of the ESCO

The ESCO has outside companies transport and install the system at the client's site. The ESCO borrows money from a financial institution to pay the installation and transportation costs. In the ESPC term (from year 1 to year n), the ESCO operates the system and has an outside maintenance company maintain the system. The benefits and costs of the ESCO are presented in the columns of Table 3. The equations used to calculate the benefits and costs are listed as the following. Unless particularly specified, t is from year 0 to year n.

In the ESCO Excel model Table 3,

Column A_t = End of Year t

Column B_0 = Transportation Cost at Year 0

Column C_0 = Installation Cost at Year 0

Column D_t = Maintenance Cost at Year t $1 \leq t \leq n$

$$= - (P_m)(DS)(AS)(OT)(1+IR_1)(1+IR_2)\dots(1+IR_t)$$

Column E_t = Operation Cost at Year t $1 \leq t \leq n$

$$= - (P_o)(DS)(AS)(OT)(1+IR_1)(1+IR_2)\dots(1+IR_t)$$

Column F_t = Penalty Cost For Not Realizing the Guaranteed Value at Year t $1 \leq t \leq n$

$$= \begin{cases} - (P_e)[(GS) - (DS)(AS)(OT)](1 + SV_1)(1 + SV_2)\dots(1 + SV_t), & \text{IF } [(DS)(AS)(OT)] < GS \\ 0, & \text{Otherwise} \end{cases}$$

Column G_t = Shared Revenue with Client at Year t $1 \leq t \leq n$

$$= \begin{cases} 0, IF[(DS)(AS)(OT)] < GS \\ (P_c)(PSR)(1+SV_1)(1+SV_2)...(1+SV_t)[(EU)(AS-PR) + (PR)(DS)(AT)(OS)], \\ IF[(DS)(AS)(OT)] \geq (EU) \text{ and } [(DS)(AS)(OT)] \geq (GS) \\ (P_c)(PSR)(1+SV_1)(1+SV_2)...(1+SV_t)[(DS)(AS)(OT) - (EU)(1-AS)], \\ IF(EU) > [(DS)(AS)(OT)] \geq GS \end{cases}$$

Column H_t = Total Before Tax and Loan Cash Flow at Year t

$$= B_t + C_t + D_t + E_t + F_t + G_t$$

Cell I_0 = Amount of Loan That the ESCO Borrows at Year 0

Column I_t = Loan Principal Payment at Year t $1 \leq t \leq n$

$$= K_t - J_t$$

Column J_t = Loan Interest Payment at Year t $1 \leq t \leq n$

$$= - (L_{t-1})(I_e)$$

Column K_t = Total Loan Payment at Year t $1 \leq t \leq n$

$$= - \frac{(U_e)(I_e)(1+I_e)^{n_e}}{(1+I_e)^{n_e} - 1}$$

Cell L_0 = Amount of Loan That the ESCO Borrows at Year 0

Column L_t = Loan Principal at Year t $1 \leq t \leq n$

$$= L_{t-1} + I_t$$

Column M_t = Taxable Income at Year t $1 \leq t \leq n$

$$= H_t + J_t$$

Column N_t = Income Tax at Year t $1 \leq t \leq n$

$$= (M_t)(TR)$$

Column O_t = After Tax Cash Flow (ATCF) at Year t

$$= H_t + I_t + J_t - N_t$$

Column P_t = Present Value of ATCF at Year t

$$= (O_t) (P|F, r_e, t)$$

Net present value of ESCO $NPV_e = \sum_{t=0}^n P_t$

Summary of the Model Equations

Objective function:

$$NPV_c \geq 0 \text{ AND } NPV_e \geq 0$$

$$\text{s.t. } 0\% \leq PR \leq 100\% \dots\dots\dots (1)$$

$$P_c = P_e \dots\dots\dots (2)$$

The objective function makes sure the NPVs of both client and ESCO are greater than or equal to zero simultaneously, so that neither of them is projected to lose money from implementing the ESPC. Constraint (1) dictates that the price of the energy that the client sells back to the utility is lower than or equal to the price of the energy the client purchases from the utility (P_e). Hence, the utility will desire to purchase the energy generated from the system instead of constructing new energy generation systems and energy distribution systems. Constraint (2) is a reasonable estimate of the unit penalty cost for not realizing the guaranteed energy value (kWh/MMBtu).

Example of Excel Models

In this Subchapter, a simplified example is used to explain how the benefits and costs in the Excel models are calculated. Assume a small-sized manufacturing plant (client) is running a 175 HP air compressor to provide compressed air for pneumatic

equipment in the production process. Based on the empirical studies, 2,500 Btu of heat can be generated per HP air compressor per hour. Presently, the client is using a gas-fired boiler to provide space heating in the winter season. Since the heat generated from the air compressor is released to the ambient environment, the client plans to install the ductwork and dampers to recover the waste heat from the air compressor for the space heating in the winter season. By doing so, the natural gas consumption, as well as the cost of the natural gas in the winter season, can be reduced. The client is operating 21 hours a day, 5 days a week.

Assume the client signs a 5-year ESPC with an ESCO to have the ESCO implement this project. The cost of the ductwork and dampers is \$3,500. Since they can be purchased from the local store, the cost of transport of raw material to the client's site is \$0. However, it costs the ESCO \$1,000 to install the ductwork and dampers. Based on the experience of the ESCO and the energy simulation software, the ESCO guarantees that 650 MMBtu of waste heat can be recovered in the winter season (five months). The natural gas cost of the client is \$14/MCF. Assume the labor rate of the ESCO is \$20/hr. It takes the ESCO 1 hour a day to verify the operation of the air compressor as expected and measure the operating data. In addition, the ESCO spends \$1,750 on material cost to do these measurement and verification work.

The client decides to borrow \$3,500 from a bank to purchase the ductwork and dampers, and returns the money in five years. The interest rate is 10%. Similarly, the ESCO chooses to borrow \$1,000 from a bank to pay the installation cost, and returns the money in five years. The interest rate is 10%.

Assume the air compressor runs during 90% of the client's operating time and is under maintenance 10% of the operating time. That is to say, when the air compressor is under maintenance, the client purchases the natural gas from the utility. The following calculates the savings of the natural gas consumption from implementing this project.

The natural gas consumption savings

= (Capacity of the air compressor)(conversion factor)(portion of recoverable heat)(daily operating time)(operating days in a week)(number of weeks in the winter season)(% of operating time)(1 MMBtu/10⁶ BTU)

= (175 HP)(2,500 Btu/HP-hr)(80%)(21 hrs/day)(5 days/wk)(20 wks/winter season)(90%)(1 MMBtu/10⁶ BTU)

= 662 MMBtu/winter season

Since the natural gas consumption savings in the winter season are greater than the guaranteed savings (650 MMBtu) from the ESCO, the client will share with the ESCO 80% of the benefits from implementing this project. In this project, there is no excess energy sold back to the utility.

Assume the ductwork and dampers fall under 7-year property class. Their depreciation rates are presented in Table 4. Although the project is terminated at the end of year 5, the ductwork and dampers can be used in the future, so there is no disposition cost. Moreover, the example is only for illustration purposes, so to simplify the calculations, assume there are no rebates, incentives, or credits to implement this project. Moreover, assume the MARR of both client and ESCO is 15%. The general inflation rate is 3.2% (the average of the Column "CPI rate of inflation percent change in CPI" in Table 13), the specific commodity cost/volatility is 2.1% (the average of the column "PPI rate

of inflation percent change in PPI" in Table 15), and the tax rate is 41%. The benefits and costs of the client and the ESCO are presented in Table 5 and 6. Following the tables, the calculations of the client's and ESCO's benefits and costs in each year are listed.

Table 4 - Depreciation rates of the ductwork and dampers

EOY	Depreciation rate
1	14.29%
2	24.49%
3	17.49%
4	12.49%
5	8.93%
6	8.92%
7	8.93%
8	4.46%

Table 5 - Excel illustration of Client model in the example

CLIENT																				
End of Year	System Cost	Savings From Client Internal Use	Revenue From Selling Energy Back to Utility	Energy Cost When The System is Under Maintenance	Shared Cost with ESCO	Penalty For Not Realizing The Guaranteed Value	Disposition Cost	Incentives	Total Before Tax and Loan Cash Flow B+C+D+E+F+G+H+I	MACRS Depreciation B×DR	Loan				Taxable Income J-K+M	Income Tax P×TR	Federal Credit R	After Tax Cash Flow (ATCF) J+L+M-Q+R	Present Value of ATCF T	
											Principal Payment L	Interest Payment M	Total Payment N	Principal O						
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	
0	\$ (3,500)								\$ (3,500)		\$ 3,500			\$ 3,500					\$ -	\$ -
1		\$ 9,455	\$ -	\$ (1,051)	\$ (6,724)	\$ -		\$ -	\$ 1,681	\$ 500	\$ (373)	\$ (350)	\$ (923)	\$ 2,927	\$ 831	\$ 341	\$ -	\$ 417	\$ 363	
2		\$ 9,654	\$ -	\$ (1,073)	\$ (6,865)	\$ -		\$ -	\$ 1,716	\$ 857	\$ (631)	\$ (293)	\$ (923)	\$ 2,296	\$ 566	\$ 232		\$ 561	\$ 424	
3		\$ 9,857	\$ -	\$ (1,095)	\$ (7,009)	\$ -		\$ -	\$ 1,752	\$ 612	\$ (694)	\$ (230)	\$ (923)	\$ 1,602	\$ 911	\$ 373		\$ 456	\$ 300	
4		\$ 10,064	\$ -	\$ (1,118)	\$ (7,156)	\$ -		\$ -	\$ 1,789	\$ 437	\$ (763)	\$ (160)	\$ (923)	\$ 839	\$ 1,192	\$ 489		\$ 377	\$ 216	
5		\$ 10,275	\$ -	\$ (1,142)	\$ (7,307)	\$ -		\$ -	\$ 1,827	\$ 313	\$ (839)	\$ (84)	\$ (923)	\$ 0	\$ 1,430	\$ 586		\$ 317	\$ 158	
																			\$ 1,460	

In Table 5,

Cell B₀ = System Cost at Year 0

$$= -\$3,500$$

Cell C₁ = Savings from Client Internal Use at Year 1

$$= (\text{natural gas consumption savings})(\text{conversion factor})(\text{natural gas cost})(1 + \text{specific commodity volatility})(\text{Cell A}_1)$$

$$= (662 \text{ MMBtu}) (1 \text{ MCF}/1 \text{ MMBtu})(\$14/\text{MCF})(1+2.1\%)^1$$

$$= \$9,455$$

Cell C₂ = Savings from Client Internal Use at Year 2

$$= (\text{natural gas consumption savings})(\text{conversion factor})(\text{natural gas cost})(1 + \text{specific commodity volatility})^2(\text{Cell A}_2)$$

$$= (662 \text{ MMBtu})(1 \text{ MCF}/1 \text{ MMBtu})(\$14/\text{MCF})(1+2.1\%)^2$$

$$= \$9,654$$

Cell C₃ = Savings from Client Internal Use at Year 3

$$= (\text{natural gas consumption savings})(\text{conversion factor})(\text{natural gas cost})(1 + \text{specific commodity volatility})^3(\text{Cell A}_3)$$

$$= (662 \text{ MMBtu})(1 \text{ MCF}/1 \text{ MMBtu})(\$14/\text{MCF})(1+2.1\%)^3$$

$$= \$9,857$$

Cell C₄ = Savings from Client Internal Use at Year 4

$$= (\text{natural gas consumption savings})(\text{conversion factor})(\text{natural gas cost})(1 + \text{specific commodity volatility})^4(\text{Cell A}_4)$$

$$= (662 \text{ MMBtu})(1 \text{ MCF}/1 \text{ MMBtu}) (\$14/\text{MCF}) (1+2.1\%)^4$$

$$= \$10,064$$

Cell C₅ = Savings from Client Internal Use at Year 5

$$\begin{aligned} &= (\text{natural gas consumption savings})(\text{conversion factor})(\text{natural gas cost})(1+ \\ &\text{specific commodity volatility})^{(\text{Cell A}_5)} \\ &= (662 \text{ MMBtu})(1 \text{ MCF}/1 \text{ MMBtu})(\$14/\text{MCF})(1+2.1\%)^5 \\ &= \$10,275 \end{aligned}$$

Column D = Revenue from Selling Energy Back to Utility

$$= \$0$$

Cell E₁ = Energy Cost When the System is Under Maintenance at Year 1

$$\begin{aligned} &= - (\text{Capacity of the air compressor})(\text{conversion factor})(\text{portion of recoverable} \\ &\text{heat})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the} \\ &\text{winter season})(1-\% \text{ of operating time})(1 \text{ MMBtu}/10^6 \text{ BTU}) (\text{natural gas cost})(1+ \\ &\text{specific commodity volatility})^{(\text{Cell A}_1)} \\ &= - (175 \text{ HP})(2,500 \text{ Btu}/\text{HP-hr})(80\%)(21 \text{ hrs}/\text{day})(5 \text{ days}/\text{wk})(20 \text{ wks})(1-90\%)(1 \\ &\text{MMBtu}/10^6 \text{ BTU}) (\$14/\text{MCF})(1+2.1\%)^{(1)} \\ &= -\$1,051 \end{aligned}$$

Cell E₂ = Energy Cost When the System is Under Maintenance at Year 2

$$\begin{aligned} &= - (\text{Capacity of the air compressor})(\text{conversion factor})(\text{portion of recoverable} \\ &\text{heat})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the} \\ &\text{winter season})(1-\% \text{ of operating time})(1 \text{ MMBtu}/10^6 \text{ BTU}) (\text{natural gas cost})(1+ \\ &\text{specific commodity volatility})^{(\text{Cell A}_2)} \\ &= - (175 \text{ HP})(2,500 \text{ Btu}/\text{HP-hr})(80\%)(21 \text{ hrs}/\text{day})(5 \text{ days}/\text{wk})(20 \text{ wks})(1-90\%)(1 \\ &\text{MMBtu}/10^6 \text{ BTU}) (\$14/\text{MCF})(1+2.1\%)^{(2)} \\ &= -\$1,073 \end{aligned}$$

Cell E₃ = Energy Cost When the System is Under Maintenance at Year 3

$$\begin{aligned} &= - (\text{Capacity of the air compressor})(\text{conversion factor})(\text{portion of recoverable heat})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season})(1-\% \text{ of operating time})(1 \text{ MMBtu}/10^6 \text{ BTU}) (\text{natural gas cost})(1+\text{specific commodity volatility})^{(\text{Cell A}_3)} \\ &= - (175 \text{ HP})(2,500 \text{ Btu}/\text{HP}\cdot\text{hr})(80\%)(21 \text{ hrs}/\text{day})(5 \text{ days}/\text{wk})(20 \text{ wks})(1-90\%)(1 \text{ MMBtu}/10^6 \text{ BTU}) (\$14/\text{MCF})(1+2.1\%)^{(3)} \\ &= -\$1,095 \end{aligned}$$

Cell E₄ = Energy Cost When the System is Under Maintenance at Year 4

$$\begin{aligned} &= - (\text{Capacity of the air compressor})(\text{conversion factor})(\text{portion of recoverable heat})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season})(1-\% \text{ of operating time})(1 \text{ MMBtu}/10^6 \text{ BTU}) (\text{natural gas cost})(1+\text{specific commodity volatility})^{(\text{Cell A}_4)} \\ &= - (175 \text{ HP})(2,500 \text{ Btu}/\text{HP}\cdot\text{hr})(80\%)(21 \text{ hrs}/\text{day})(5 \text{ days}/\text{wk})(20 \text{ wks})(1-90\%)(1 \text{ MMBtu}/10^6 \text{ BTU}) (\$14/\text{MCF})(1+2.1\%)^{(4)} \\ &= -\$1,118 \end{aligned}$$

Cell E₅ = Energy Cost When the System is Under Maintenance at Year 5

$$\begin{aligned} &= - (\text{Capacity of the air compressor})(\text{conversion factor})(\text{portion of recoverable heat})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season})(1-\% \text{ of operating time})(1 \text{ MMBtu}/10^6 \text{ BTU}) (\text{natural gas cost})(1+\text{specific commodity volatility})^{(\text{Cell A}_5)} \\ &= - (175 \text{ HP})(2,500 \text{ Btu}/\text{HP}\cdot\text{hr})(80\%)(21 \text{ hrs}/\text{day})(5 \text{ days}/\text{wk})(20 \text{ wks})(1-90\%)(1 \text{ MMBtu}/10^6 \text{ BTU}) (\$14/\text{MCF})(1+2.1\%)^{(5)} \end{aligned}$$

$$= -\$1,142$$

Cell F₁ = Shared Cost with ESCO at Year 1

$$= - (\text{performance contract sharing rate})[(\text{Cell C}_1)+(\text{Cell D}_1)+(\text{Cell E}_1)]$$

$$= - (80\%)(\$9,455+\$0-\$1,051)$$

$$= - \$6,724$$

Cell F₂ = Shared Cost with ESCO at Year 2

$$= - (\text{performance contract sharing rate})[(\text{Cell C}_2)+(\text{Cell D}_2)+(\text{Cell E}_2)]$$

$$= - (80\%)(\$9,654+\$0-\$1,073)$$

$$= - \$6,865$$

Cell F₃ = Shared Cost with ESCO at Year 3

$$= - (\text{performance contract sharing rate})[(\text{Cell C}_3)+(\text{Cell D}_3)+(\text{Cell E}_3)]$$

$$= - (80\%)(\$9,857+\$0-\$1,095)$$

$$= - \$7,009$$

Cell F₄ = Shared Cost with ESCO at Year 4

$$= - (\text{performance contract sharing rate})[(\text{Cell C}_4)+(\text{Cell D}_4)+(\text{Cell E}_4)]$$

$$= - (80\%)(\$10,064+\$0-\$1,118)$$

$$= - \$7,156$$

Cell F₅ = Shared Cost with ESCO at Year 5

$$= - (\text{performance contract sharing rate})[(\text{Cell C}_5)+(\text{Cell D}_5)+(\text{Cell E}_5)]$$

$$= - (80\%)(\$10,275+\$0-\$1,142)$$

$$= - \$7,307$$

Column G = Penalty for Not Realizing the Guaranteed Value

$$= \$0$$

Column H = Disposition Cost

$$= \$0$$

Column I = Incentives

$$= \$0$$

Cell J₀ = Total before Tax and Loan Cash Flow at Year 0

$$\begin{aligned} &= (\text{Cell B}_0)+(\text{Cell C}_0)+(\text{Cell D}_0)+(\text{Cell E}_0)+(\text{Cell F}_0)+(\text{Cell G}_0)+(\text{Cell H}_0) + (\text{Cell} \\ &\text{I}_0) \\ &= (-\$3,500)+(\$0)+(\$0)+(\$0)+(\$0)+(\$0)+(\$0)+(\$0) \\ &= - \$3,500 \end{aligned}$$

Cell J₁ = Total before Tax and Loan Cash Flow at Year 1

$$\begin{aligned} &= (\text{Cell B}_1)+(\text{Cell C}_1)+(\text{Cell D}_1)+(\text{Cell E}_1)+(\text{Cell F}_1)+(\text{Cell G}_1)+(\text{Cell H}_1) + (\text{Cell} \\ &\text{I}_1) \\ &= (\$0)+(\$9,455)+(\$0)+(-\$1,051)+(- \$6,724)+(\$0)+(\$0)+(\$0) \\ &= \$1,681 \end{aligned}$$

Cell J₂ = Total before Tax and Loan Cash Flow at Year 2

$$\begin{aligned} &= (\text{Cell B}_2)+(\text{Cell C}_2)+(\text{Cell D}_2)+(\text{Cell E}_2)+(\text{Cell F}_2)+(\text{Cell G}_2)+(\text{Cell H}_2) + (\text{Cell} \\ &\text{I}_2) \\ &= (\$0)+(\$ 9,654)+(\$0)+(-\$ 1,073)+(- \$6,865)+(\$0)+(\$0)+(\$0) \\ &= \$1,716 \end{aligned}$$

Cell J₃ = Total before Tax and Loan Cash Flow at Year 3

$$\begin{aligned} &= (\text{Cell B}_3)+(\text{Cell C}_3)+(\text{Cell D}_3)+(\text{Cell E}_3)+(\text{Cell F}_3)+(\text{Cell G}_3)+(\text{Cell H}_3) + (\text{Cell} \\ &\text{I}_3) \\ &= (\$0)+(\$9,857)+(\$0)+(-\$1,095)+(- \$7,009)+(\$0)+(\$0)+(\$0) \end{aligned}$$

$$= \$1,752$$

Cell J₄ = Total before Tax and Loan Cash Flow at Year 4

$$\begin{aligned} &= (\text{Cell B}_4) + (\text{Cell C}_4) + (\text{Cell D}_4) + (\text{Cell E}_4) + (\text{Cell F}_4) + (\text{Cell G}_4) + (\text{Cell H}_4) + (\text{Cell I}_4) \\ &= (\$0) + (\$10,064) + (\$0) + (-\$1,118) + (-\$7,156) + (\$0) + (\$0) + (\$0) \\ &= \$1,789 \end{aligned}$$

Cell J₅ = Total before Tax and Loan Cash Flow at Year 5

$$\begin{aligned} &= (\text{Cell B}_5) + (\text{Cell C}_5) + (\text{Cell D}_5) + (\text{Cell E}_5) + (\text{Cell F}_5) + (\text{Cell G}_5) + (\text{Cell H}_5) + (\text{Cell I}_5) \\ &= (\$0) + (\$10,275) + (\$0) + (-\$1,142) + (-\$7,306) + (\$0) + (\$0) + (\$0) \\ &= \$1,827 \end{aligned}$$

Cell K₁ = MACRS Depreciation at Year 1

$$\begin{aligned} &= (\text{System cost})(\text{depreciation rate at year 1}) \\ &= (\$3,500)(14.29\%) \\ &= \$500 \end{aligned}$$

Cell K₂ = MACRS Depreciation at Year 2

$$\begin{aligned} &= (\text{System cost})(\text{depreciation rate at year 2}) \\ &= (\$3,500)(24.49\%) \\ &= \$857 \end{aligned}$$

Cell K₃ = MACRS Depreciation at Year 3

$$\begin{aligned} &= (\text{System cost})(\text{depreciation rate at year 3}) \\ &= (\$3,500)(17.49\%) \\ &= \$612 \end{aligned}$$

$$\begin{aligned}\text{Cell K}_4 &= \text{MACRS Depreciation at Year 4} \\ &= (\text{System cost})(\text{depreciation rate at year 4}) \\ &= (\$3,500)(12.49\%) \\ &= \$437\end{aligned}$$

$$\begin{aligned}\text{Cell K}_5 &= \text{MACRS Depreciation at Year 5} \\ &= (\text{System cost})(\text{depreciation rate at year 5}) \\ &= (\$3,500)(8.93\%) \\ &= \$313\end{aligned}$$

$$\begin{aligned}\text{Cell L}_0 &= \text{Loan Principal Payment at Year 0} \\ &= \$3,500\end{aligned}$$

$$\begin{aligned}\text{Cell L}_1 &= \text{Loan Principal Payment at Year 1} \\ &= (\text{Cell N}_1) - (\text{Cell M}_1) \\ &= (-\$923) - (-\$350) \\ &= -\$573\end{aligned}$$

$$\begin{aligned}\text{Cell L}_2 &= \text{Loan Principal Payment at Year 2} \\ &= (\text{Cell N}_2) - (\text{Cell M}_2) \\ &= (-\$923) - (-\$293) \\ &= -\$631\end{aligned}$$

$$\begin{aligned}\text{Cell L}_3 &= \text{Loan Principal Payment at Year 3} \\ &= (\text{Cell N}_3) - (\text{Cell M}_3) \\ &= (-\$923) - (-\$230) \\ &= -\$694\end{aligned}$$

$$\text{Cell L}_4 = \text{Loan Principal Payment at Year 4}$$

$$= (\text{Cell N}_4) - (\text{Cell M}_4)$$

$$= (-\$923) - (-\$160)$$

$$= -\$763$$

Cell L₅ = Loan Principal Payment at Year 5

$$= (\text{Cell N}_5) - (\text{Cell M}_5)$$

$$= (-\$923) - (-\$84)$$

$$= -\$839$$

Cell M₁ = Loan Interest Payment at Year 1

$$= - (\text{Cell O}_0)(\text{loan interest rate})$$

$$= - (\$3,500)(10\%)$$

$$= - \$350$$

Cell M₂ = Loan Interest Payment at Year 2

$$= - (\text{Cell O}_1)(\text{loan interest rate})$$

$$= - (\$2,927)(10\%)$$

$$= - \$293$$

Cell M₃ = Loan Interest Payment at Year 3

$$= - (\text{Cell O}_2)(\text{loan interest rate})$$

$$= - (\$2,296)(10\%)$$

$$= - \$230$$

Cell M₄ = Loan Interest Payment at Year 4

$$= - (\text{Cell O}_3)(\text{loan interest rate})$$

$$= - (\$1,602)(10\%)$$

$$= - \$160$$

Cell M₅ = Loan Interest Payment at Year 5

$$= - (\text{Cell O}_4)(\text{loan interest rate})$$

$$= - (\$839)(10\%)$$

$$= - \$84$$

Cell N₁ = Total Loan Payment at Year 1

$$= - (\text{Cell O}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$3,500)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$923$$

Cell N₂ = Total Loan Payment at Year 2

$$= - (\text{Cell O}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$3,500)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$923$$

Cell N₃ = Total Loan Payment at Year 3

$$= - (\text{Cell O}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$3,500)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$923$$

Cell N₄ = Total Loan Payment at Year 4

$$= - (\text{Cell O}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$3,500)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$923$$

Cell N₅ = Total Loan Payment at Year 5

$$\begin{aligned} &= - (\text{Cell O}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan} \\ &\text{interest rate})^{(\text{loan term})}-1] \\ &= - (\$3,500)(10\%)(1+10\%)^5/[(1+10\%)^5-1] \\ &= -\$923 \end{aligned}$$

Cell O₀ = Loan Principal at Year 0

$$= \$3,500$$

Cell O₁ = Loan Principal at Year 1

$$\begin{aligned} &= (\text{Cell O}_0) + (\text{Cell L}_1) \\ &= \$3,500 - \$573 \\ &= \$2,927 \end{aligned}$$

Cell O₂ = Loan Principal at Year 2

$$\begin{aligned} &= (\text{Cell O}_1) + (\text{Cell L}_2) \\ &= \$2,927 - \$631 \\ &= \$2,296 \end{aligned}$$

Cell O₃ = Loan Principal at Year 3

$$\begin{aligned} &= (\text{Cell O}_2) + (\text{Cell L}_3) \\ &= \$2,296 - \$694 \\ &= \$1,602 \end{aligned}$$

Cell O₄ = Loan Principal at Year 4

$$\begin{aligned} &= (\text{Cell O}_3) + (\text{Cell L}_4) \\ &= \$1,602 - \$763 \end{aligned}$$

$$= \$839$$

Cell O₅ = Loan Principal at Year 5

$$= (\text{Cell O}_4) + (\text{Cell L}_5)$$

$$= \$839 - \$839$$

$$= \$0$$

Cell P₁ = Taxable Income at Year 1

$$= (\text{Cell J}_1) - (\text{Cell K}_1) + (\text{Cell M}_1)$$

$$= (\$1,681) - (\$500) + (-\$350)$$

$$= \$831$$

Cell P₂ = Taxable Income at Year 2

$$= (\text{Cell J}_2) - (\text{Cell K}_2) + (\text{Cell M}_2)$$

$$= (\$1,716) - (\$857) + (-\$293)$$

$$= \$566$$

Cell P₃ = Taxable Income at Year 3

$$= (\text{Cell J}_3) - (\text{Cell K}_3) + (\text{Cell M}_3)$$

$$= (\$1,752) - (\$612) + (-\$230)$$

$$= \$910$$

Cell P₄ = Taxable Income at Year 4

$$= (\text{Cell J}_4) - (\text{Cell K}_4) + (\text{Cell M}_4)$$

$$= (\$1,789) - (\$437) + (-\$160)$$

$$= \$1,192$$

Cell P₅ = Taxable Income at Year 5

$$= (\text{Cell J}_5) - (\text{Cell K}_5) + (\text{Cell M}_5)$$

$$\begin{aligned} &= (\$1,827) - (\$313) + (-\$84) \\ &= \$1,430 \end{aligned}$$

Cell Q₁ = Income Tax at Year 1

$$\begin{aligned} &= (\text{Cell P}_1)(\text{tax rate}) \\ &= (\$831)(41\%) \\ &= \$341 \end{aligned}$$

Cell Q₂ = Income Tax at Year 2

$$\begin{aligned} &= (\text{Cell P}_2)(\text{tax rate}) \\ &= (\$566)(41\%) \\ &= \$232 \end{aligned}$$

Cell Q₃ = Income Tax at Year 3

$$\begin{aligned} &= (\text{Cell P}_3)(\text{tax rate}) \\ &= (\$911)(41\%) \\ &= \$373 \end{aligned}$$

Cell Q₄ = Income Tax at Year 4

$$\begin{aligned} &= (\text{Cell P}_4)(\text{tax rate}) \\ &= (\$1,192)(41\%) \\ &= \$489 \end{aligned}$$

Cell Q₅ = Income Tax at Year 5

$$\begin{aligned} &= (\text{Cell P}_5)(\text{tax rate}) \\ &= (\$1,430)(41\%) \\ &= \$586 \end{aligned}$$

Column R = Federal credit

$$= \$0$$

Cell S₀ = After Tax Cash Flow (ATCF) at Year 0

$$= (\text{Cell J}_0) + (\text{Cell L}_0) + (\text{Cell M}_0) - (\text{Cell Q}_0) + (\text{Cell R}_0)$$

$$= (-\$3,500) + (\$3,500) + (\$0) - (\$0) + (\$0)$$

$$= \$0$$

Cell S₁ = After Tax Cash Flow (ATCF) at Year 1

$$= (\text{Cell J}_1) + (\text{Cell L}_1) + (\text{Cell M}_1) - (\text{Cell Q}_1) + (\text{Cell R}_1)$$

$$= (\$1,681) + (-\$573) + (-\$350) - (\$341) + (\$0)$$

$$= \$417$$

Cell S₂ = After Tax Cash Flow (ATCF) at Year 2

$$= (\text{Cell J}_2) + (\text{Cell L}_2) + (\text{Cell M}_2) - (\text{Cell Q}_2) + (\text{Cell R}_2)$$

$$= (\$1,716) + (-\$631) + (-\$293) - (\$232) + (\$0)$$

$$= \$561$$

Cell S₃ = After Tax Cash Flow (ATCF) at Year 3

$$= (\text{Cell J}_3) + (\text{Cell L}_3) + (\text{Cell M}_3) - (\text{Cell Q}_3) + (\text{Cell R}_3)$$

$$= (\$1,752) + (-\$694) + (-\$230) - (\$373) + (\$0)$$

$$= \$456$$

Cell S₄ = After Tax Cash Flow (ATCF) at Year 4

$$= (\text{Cell J}_4) + (\text{Cell L}_4) + (\text{Cell M}_4) - (\text{Cell Q}_4) + (\text{Cell R}_4)$$

$$= (\$1,789) + (-\$763) + (-\$160) - (\$489) + (\$0)$$

$$= \$377$$

Cell S₅ = After Tax Cash Flow (ATCF) at Year 5

$$\begin{aligned} &= (\text{Cell J}_5) + (\text{Cell L}_5) + (\text{Cell M}_5) - (\text{Cell Q}_5) + (\text{Cell R}_5) \\ &= (\$1,827) + (-\$839) + (-\$84) - (\$586) + (\$0) \\ &= \$317 \end{aligned}$$

Cell T₀ = Present Value of ATCF at Year 0

$$\begin{aligned} &= (\text{Cell S}_0) / (1 + \text{MARR of Client})^{(\text{Cell A}_0)} \\ &= (\$0) / (1 + 15\%)^{(0)} \\ &= \$0 \end{aligned}$$

Cell T₁ = Present Value of ATCF at Year 1

$$\begin{aligned} &= (\text{Cell S}_1) / (1 + \text{MARR of Client})^{(\text{Cell A}_1)} \\ &= (\$417) / (1 + 15\%)^{(1)} \\ &= \$363 \end{aligned}$$

Cell T₂ = Present Value of ATCF at Year 2

$$\begin{aligned} &= (\text{Cell S}_2) / (1 + \text{MARR of Client})^{(\text{Cell A}_2)} \\ &= (\$561) / (1 + 15\%)^{(2)} \\ &= \$424 \end{aligned}$$

Cell T₃ = Present Value of ATCF at Year 3

$$\begin{aligned} &= (\text{Cell S}_3) / (1 + \text{MARR of Client})^{(\text{Cell A}_3)} \\ &= (\$456) / (1 + 15\%)^{(3)} \\ &= \$300 \end{aligned}$$

Cell T₄ = Present Value of ATCF at Year 4

$$\begin{aligned} &= (\text{Cell S}_4) / (1 + \text{MARR of Client})^{(\text{Cell A}_4)} \\ &= (\$377) / (1 + 15\%)^{(4)} \end{aligned}$$

$$= \$216$$

Cell T₅ = Present Value of ATCF at Year 5

$$= (\text{Cell S}_5)/(1+\text{MARR of Client})^{(\text{Cell A}_5)}$$

$$= (\$317)/(1+15\%)^{(5)}$$

$$= \$158$$

NPV of Client = (Cell T₀)+(Cell T₁)+(Cell T₂)+(Cell T₃)+(Cell T₄)+(Cell T₅)

$$= (\$0)+(\$363)+(\$424)+(\$300)+(\$216)+(\$158)$$

$$= \$1,460$$

Table 6 - Excel illustration of ESCO model in the example

ENERGY SERVICE COMPANY (ESCO)															
End of Year	Transportation Cost	Installation Cost	Maintenance Cost	Operation Cost	Penalty Cost For Not Realizing The Guaranteed Value	Shared Revenue with Client	Total Before Tax and Loan Cash Flow B+C+D+E+F+G	Loan				Taxable Income H+J	Income Tax M×TR	After Tax Cash Flow (ATCF) H+I+J-N	Present Value of ATCF
								Principal Payment I	Interest Payment J	Total Payment K	Principal L				
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
0	\$ -	\$ (1,000)					\$ (1,000)	\$ 1,000			\$ 1,000			\$ -	\$ -
1			\$ -	\$ (3,870)	\$ -	\$ 6,724	\$ 2,854	\$ (164)	\$ (100)	\$ (264)	\$ 836	\$ 2,754	\$ 1,129	\$ 1,461	\$ 1,270
2			\$ -	\$ (3,994)	\$ -	\$ 6,865	\$ 2,871	\$ (180)	\$ (84)	\$ (264)	\$ 656	\$ 2,788	\$ 1,143	\$ 1,465	\$ 1,107
3			\$ -	\$ (4,122)	\$ -	\$ 7,009	\$ 2,888	\$ (198)	\$ (66)	\$ (264)	\$ 458	\$ 2,822	\$ 1,157	\$ 1,467	\$ 964
4			\$ -	\$ (4,254)	\$ -	\$ 7,156	\$ 2,903	\$ (218)	\$ (46)	\$ (264)	\$ 240	\$ 2,857	\$ 1,171	\$ 1,468	\$ 839
5			\$ -	\$ (4,390)	\$ -	\$ 7,307	\$ 2,917	\$ (240)	\$ (24)	\$ (264)	\$ 0	\$ 2,893	\$ 1,186	\$ 1,467	\$ 729
														NPV	\$ 4,911

In Table 6,

Cell B₀ = Transportation Cost at Year 0

$$= \$0$$

Cell C₀ = Installation Cost at Year 0

$$= \$1,000$$

Column D = Maintenance Cost

$$= \$0$$

Cell E₁ = Operation Cost at Year 1

$$= - [(\text{material cost}) + (\text{labor rate})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season}) (1 + \text{general inflation rate})]^{(\text{Cell A}_1)}$$

$$= - [(\$1,750) + (\$20/\text{hr})(1 \text{ hr/day})(5 \text{ days/wk})(20 \text{ wks})(1 + 3.2\%)]^{(1)}$$

$$= - \$3,870$$

Cell E₂ = Operation Cost at Year 2

$$= - [(\text{material cost}) + (\text{labor rate})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season}) (1 + \text{general inflation rate})]^{(\text{Cell A}_2)}$$

$$= - [(\$1,750) + (\$20/\text{hr})(1 \text{ hr/day})(5 \text{ days/wk})(20 \text{ wks})(1 + 3.2\%)]^{(2)}$$

$$= - \$3,994$$

Cell E₃ = Operation Cost at Year 3

$$= - [(\text{material cost}) + (\text{labor rate})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season}) (1 + \text{general inflation rate})]^{(\text{Cell A}_3)}$$

$$= - [(\$1,750)+(\$20/hr)(1 \text{ hr/day})(5 \text{ days/wk})(20 \text{ wks})(1+3.2\%)]^{(3)}$$

$$= -\$4,122$$

Cell E₄ = Operation Cost at Year 4

$$= - [(\text{material cost}) + (\text{labor rate})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season}) (1 + \text{general inflation rate})]^{(\text{Cell A}_4)}$$

$$= - [(\$1,750)+(\$20/hr)(1 \text{ hr/day})(5 \text{ days/wk})(20 \text{ wks})(1+3.2\%)]^{(4)}$$

$$= -\$4,254$$

Cell E₅ = Operation Cost at Year 5

$$= - [(\text{material cost}) + (\text{labor rate})(\text{daily operating time})(\text{operating days in a week})(\text{number of weeks in the winter season}) (1 + \text{general inflation rate})]^{(\text{Cell A}_5)}$$

$$= - [(\$1,750)+(\$20/hr)(1 \text{ hr/day})(5 \text{ days/wk})(20 \text{ wks})(1+3.2\%)]^{(5)}$$

$$= -\$4,390$$

Column F = Penalty for Not Realizing the Guaranteed Value

$$= \$0$$

Cell G₁ = Shared Revenue with Client at Year 1

$$= - (\text{Cell F}_1 \text{ of Table 5})$$

$$= \$6,724$$

Cell G₂ = Shared Revenue with Client at Year 2

$$= - (\text{Cell F}_2 \text{ of Table 5})$$

$$= \$6,865$$

Cell G₃ = Shared Revenue with Client at Year 3

= - (Cell F₃ of Table 5)

= \$7,009

Cell G₄ = Shared Revenue with Client at Year 4

= - (Cell F₄ of Table 5)

= \$7,156

Cell G₅ = Shared Revenue with Client at Year 5

= - (Cell F₅ of Table 5)

= \$7,307

Cell H₀ = Total before Tax and Loan Cash Flow at Year 0

= (Cell B₀)+(Cell C₀)+(Cell D₀)+(Cell E₀)+(Cell F₀)+(Cell G₀)

= (\$0)+(-\$1,000)+(\$0)+(\$0)+(\$0)+(\$0)

= - \$1,000

Cell H₁ = Total before Tax and Loan Cash Flow at Year 1

= (Cell B₁)+(Cell C₁)+(Cell D₁)+(Cell E₁)+(Cell F₁)+(Cell G₁)

= (\$0) + (\$0) + (\$0)+(-\$3,870)+(\$0)+(\$6,724)

= \$2,854

Cell H₂ = Total before Tax and Loan Cash Flow at Year 2

= (Cell B₂)+(Cell C₂)+(Cell D₂)+(Cell E₂)+(Cell F₂)+(Cell G₂)

= (\$0) + (\$0) + (\$0)+(-\$3,994)+(\$0) +(\$6,865)

= \$2,871

Cell H₃ = Total before Tax and Loan Cash Flow at Year 3

= (Cell B₃)+(Cell C₃)+(Cell D₃)+(Cell E₃)+(Cell F₃)+(Cell G₃)

$$= (\$0) + (\$0) + (\$0) + (-\$4,122) + (\$0) + (\$7,009)$$

$$= \$2,888$$

Cell H₄ = Total before Tax and Loan Cash Flow at Year 4

$$= (\text{Cell B}_4) + (\text{Cell C}_4) + (\text{Cell D}_4) + (\text{Cell E}_4) + (\text{Cell F}_4) + (\text{Cell G}_4)$$

$$= (\$0) + (\$0) + (\$0) + (-\$4,254) + (\$0) + (\$7,156)$$

$$= \$2,903$$

Cell H₅ = Total before Tax and Loan Cash Flow at Year 5

$$= (\text{Cell B}_5) + (\text{Cell C}_5) + (\text{Cell D}_5) + (\text{Cell E}_5) + (\text{Cell F}_5) + (\text{Cell G}_5)$$

$$= (\$0) + (\$0) + (\$0) + (-\$4,390) + (\$0) + (\$7,307)$$

$$= \$2,917$$

Cell I₀ = Loan Principal Payment at Year 0

$$= \$1,000$$

Cell I₁ = Loan Principal Payment at Year 1

$$= (\text{Cell K}_1) - (\text{Cell J}_1)$$

$$= (-\$264) - (-\$100)$$

$$= -\$164$$

Cell I₂ = Loan Principal Payment at Year 2

$$= (\text{Cell K}_2) - (\text{Cell J}_2)$$

$$= (-\$264) - (-\$84)$$

$$= -\$180$$

Cell I₃ = Loan Principal Payment at Year 3

$$= (\text{Cell K}_3) - (\text{Cell J}_3)$$

$$= (-\$264) - (-\$66)$$

$$= -\$198$$

Cell I₄ = Loan Principal Payment at Year 4

$$= (\text{Cell K}_4) - (\text{Cell J}_4)$$

$$= (-\$264) - (-\$46)$$

$$= -\$218$$

Cell I₅ = Loan Principal Payment at Year 5

$$= (\text{Cell K}_5) - (\text{Cell J}_5)$$

$$= (-\$264) - (-\$24)$$

$$= -\$240$$

Cell J₁ = Loan Interest Payment at Year 1

$$= - (\text{Cell L}_0)(\text{loan interest rate})$$

$$= - (\$1,000)(10\%)$$

$$= - \$100$$

Cell J₂ = Loan Interest Payment at Year 2

$$= - (\text{Cell L}_1)(\text{loan interest rate})$$

$$= - (\$836)(10\%)$$

$$= - \$84$$

Cell J₃ = Loan Interest Payment at Year 3

$$= - (\text{Cell L}_2)(\text{loan interest rate})$$

$$= - (\$656)(10\%)$$

$$= - \$66$$

Cell J₄ = Loan Interest Payment at Year 4

$$= - (\text{Cell L}_3)(\text{loan interest rate})$$

$$= - (\$458)(10\%)$$

$$= - \$46$$

Cell J₅ = Loan Interest Payment at Year 5

$$= - (\text{Cell L}_4)(\text{loan interest rate})$$

$$= - (\$240)(10\%)$$

$$= - \$24$$

Cell K₁ = Total Loan Payment at Year 1

$$= - (\text{Cell L}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$1,000)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$264$$

Cell K₂ = Total Loan Payment at Year 2

$$= - (\text{Cell L}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$1,000)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$264$$

Cell K₃ = Total Loan Payment at Year 3

$$= - (\text{Cell L}_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$1,000)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$264$$

Cell K₄ = Total Loan Payment at Year 4

$$= - (\text{Cell } L_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$1,000)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= -\$264$$

Cell K₅ = Total Loan Payment at Year 5

$$= - (\text{Cell } L_0)(\text{loan interest rate})(1+\text{loan interest rate})^{(\text{loan term})}/[(1+\text{loan interest rate})^{(\text{loan term})}-1]$$

$$= - (\$1,000)(10\%)(1+10\%)^5/[(1+10\%)^5-1]$$

$$= - \$264$$

Cell L₀ = Loan Principal at Year 0

$$= \$1,000$$

Cell L₁ = Loan Principal at Year 1

$$= (\text{Cell } L_0) + (\text{Cell } I_1)$$

$$= \$1,000 - \$164$$

$$= \$836$$

Cell L₂ = Loan Principal at Year 2

$$= (\text{Cell } L_1) + (\text{Cell } I_2)$$

$$= \$836 - \$180$$

$$= \$656$$

Cell L₃ = Loan Principal at Year 3

$$= (\text{Cell } L_2) + (\text{Cell } I_3)$$

$$= \$656 - \$198$$

$$= \$458$$

Cell L₄ = Loan Principal at Year 4

$$= (\text{Cell L}_3) + (\text{Cell I}_4)$$

$$= \$458 - \$218$$

$$= \$240$$

Cell L₅ = Loan Principal at Year 5

$$= (\text{Cell L}_4) + (\text{Cell I}_5)$$

$$= \$240 - \$240$$

$$= \$0$$

Cell M₁ = Taxable Income at Year 1

$$= (\text{Cell H}_1) + (\text{Cell J}_1)$$

$$= (\$2,854) + (-\$100)$$

$$= \$2,754$$

Cell M₂ = Taxable Income at Year 2

$$= (\text{Cell H}_2) + (\text{Cell J}_2)$$

$$= (\$2,871) + (-\$84)$$

$$= \$2,788$$

Cell M₃ = Taxable Income at Year 3

$$= (\text{Cell H}_3) + (\text{Cell J}_3)$$

$$= (\$2,888) + (-\$66)$$

$$= \$2,822$$

Cell M₄ = Taxable Income at Year 4

$$= (\text{Cell H}_4) + (\text{Cell J}_4)$$

$$= (\$2,903) + (-\$46)$$

$$= \$2,857$$

Cell M₅ = Taxable Income at Year 5

$$= (\text{Cell H}_5) + (\text{Cell J}_5)$$

$$= (\$2,917) + (-\$24)$$

$$= \$2,893$$

Cell N₁ = Income Tax at Year 1

$$= (\text{Cell M}_1)(\text{tax rate})$$

$$= (\$2,754)(41\%)$$

$$= \$1,129$$

Cell N₂ = Income Tax at Year 2

$$= (\text{Cell M}_2)(\text{tax rate})$$

$$= (\$2,788)(41\%)$$

$$= \$1,143$$

Cell N₃ = Income Tax at Year 3

$$= (\text{Cell M}_3)(\text{tax rate})$$

$$= (\$2,822)(41\%)$$

$$= \$1,157$$

Cell N₄ = Income Tax at Year 4

$$= (\text{Cell M}_4)(\text{tax rate})$$

$$= (\$2,857)(41\%)$$

$$= \$1,171$$

Cell N₅ = Income Tax at Year 5

$$= (\text{Cell M}_5)(\text{tax rate})$$

$$= (\$2,893)(41\%)$$

$$= \$1,186$$

Cell O₀ = After Tax Cash Flow (ATCF) at Year 0

$$= (\text{Cell H}_0) + (\text{Cell I}_0) + (\text{Cell J}_0) - (\text{Cell N}_0)$$

$$= (-\$1,000) + (\$1,000) + (\$0) - (\$0)$$

$$= \$0$$

Cell O₁ = After Tax Cash Flow (ATCF) at Year 1

$$= (\text{Cell H}_1) + (\text{Cell I}_1) + (\text{Cell J}_1) - (\text{Cell N}_1)$$

$$= (\$2,854) + (-\$164) + (-\$100) - (\$1,129)$$

$$= \$1,461$$

Cell O₂ = After Tax Cash Flow (ATCF) at Year 2

$$= (\text{Cell H}_2) + (\text{Cell I}_2) + (\text{Cell J}_2) - (\text{Cell N}_2)$$

$$= (\$2,871) + (-\$180) + (-\$84) - (\$1,143)$$

$$= \$1,465$$

Cell O₃ = After Tax Cash Flow (ATCF) at Year 3

$$= (\text{Cell H}_3) + (\text{Cell I}_3) + (\text{Cell J}_3) - (\text{Cell N}_3)$$

$$= (\$2,888) + (-\$198) + (-\$66) - (\$1,157)$$

$$= \$1,467$$

Cell O₄ = After Tax Cash Flow (ATCF) at Year 4

$$= (\text{Cell H}_4) + (\text{Cell I}_4) + (\text{Cell J}_4) - (\text{Cell N}_4)$$

$$= (\$2,903) + (-\$218) + (-\$46) - (\$1,171)$$

$$= \$1,468$$

Cell O₅ = After Tax Cash Flow (ATCF) at Year 5

$$= (\text{Cell H}_5) + (\text{Cell I}_5) + (\text{Cell J}_5) - (\text{Cell N}_5)$$

$$= (\$2,917) + (-\$240) + (-\$24) - (\$1,186)$$

$$= \$1,467$$

Cell P₀ = Present Value of ATCF at Year 0

$$= (\text{Cell O}_0) / (1 + \text{MARR of ESCO})^{(\text{Cell A}_0)}$$

$$= (\$0) / (1 + 15\%)^{(0)}$$

$$= \$0$$

Cell P₁ = Present Value of ATCF at Year 1

$$= (\text{Cell O}_1) / (1 + \text{MARR of ESCO})^{(\text{Cell A}_1)}$$

$$= (\$1,461) / (1 + 15\%)^{(1)}$$

$$= \$1,270$$

Cell P₂ = Present Value of ATCF at Year 2

$$= (\text{Cell O}_2) / (1 + \text{MARR of ESCO})^{(\text{Cell A}_2)}$$

$$= (\$1,465) / (1 + 15\%)^{(2)}$$

$$= \$1,107$$

Cell P₃ = Present Value of ATCF at Year 3

$$= (\text{Cell O}_3) / (1 + \text{MARR of ESCO})^{(\text{Cell A}_3)}$$

$$= (\$1,467) / (1 + 15\%)^{(3)}$$

$$= \$964$$

Cell P₄ = Present Value of ATCF at Year 4

$$= (\text{Cell O}_4) / (1 + \text{MARR of ESCO})^{(\text{Cell A}_4)}$$

$$= (\$1,468) / (1+15\%)^4$$

$$= \$839$$

Cell P₅ = Present Value of ATCF at Year 5

$$= (\text{Cell O}_5) / (1+\text{MARR of ESCO})^{\text{(Cell A}_5)}$$

$$= (\$1,467) / (1+15\%)^5$$

$$= \$729$$

$$\text{NPV of ESCO} = (\text{Cell P}_0) + (\text{Cell P}_1) + (\text{Cell P}_2) + (\text{Cell P}_3) + (\text{Cell P}_4) + (\text{Cell P}_5)$$

$$= (\$0) + (\$1,270) + (\$1,107) + (\$964) + (\$839) + (\$729)$$

$$= \$4,911$$

Since the NPVs of both client and ESCO are positive, this ESPC project is a win-win strategy for them.

Development of Model Inputs

This part lists the model inputs and explains how to simulate the continuous variables based on historical data.

Characteristic of Model Inputs

The inputs of the system and the parties in a typical ESPC are presented in Figures 1 and 2. Their characteristics are described in Figure 3. Based on the literature reviews, expert statements and subjective judgments, the deterministic inputs are further separated into deterministic values and discrete arrays. The deterministic inputs and probabilistic inputs are listed in Table 7.

Table 7 - Probabilistic and deterministic inputs of the model in a typical ESPC

Client				
After-tax MARR (%)	Deterministic value			
Unit cost of energy purchased from the utility (\$/kWh or \$/MMBtu)	Probabilistic			
Relationship between the price of sold energy and the price of purchased energy (%)	Discrete array			
Annual energy requirement of the client (kWh or MMBtu)	Deterministic value			
Disposition cost (\$)	Deterministic value			
Amount of loan (\$)	Deterministic value			
Loan interest rate (%)	Deterministic value			
Loan terms (yr)	Discrete array			
System cost (\$)	Deterministic value			
Financial Environment				
General inflation rate (%)	Probabilistic			
Specific commodity cost/volatility (%)	Probabilistic			
Tax rate (%)	Deterministic value			
Energy Service Company				
After-tax MARR (%)	Deterministic value			
Unit cost of operating the system (\$/kWh or \$/MMBtu)	Deterministic value			
Unit penalty cost for not realizing the guaranteed value (\$/kWh or \$/MMBtu)	Probabilistic			
Performance contract sharing rate (%)	Discrete array			
Unit cost of maintaining the system (\$/kWh or \$/MMBtu)	Deterministic value			
Value of energy guaranteed (kWh or MMBtu)	Deterministic value			
Transportation cost of the system (\$)	Deterministic value			
Installation cost of the system (\$)	Deterministic value			
Amount of loan (\$)	Deterministic value			
Loan interest rate (%)	Deterministic value			
Loan terms (yr)	Discrete array			
		System		
		Descriptive	Location	Deterministic
			Depreciation method	MACRS
			Depreciation period (yrs)	Deterministic value
			Project term (yrs)	Deterministic value
			Base year	Deterministic value
		System specification	Demand/capacity (kW or MMBtu/hr)	Probabilistic
			Availability/yield (%)	Discrete array
			Annual operating time (hrs/yr)	Deterministic value
		Costs	System cost (\$)	Deterministic value
			Transportation cost (\$)	Deterministic value
			Installation cost (\$)	Deterministic value
			Operationg cost (\$)	Deterministic value
			Maintenance cost (\$)	Deterministic value
			Disposition cost (\$)	Deterministic value
			Federal tax credit (\$)	Deterministic value
		Incentive /credit	Federal incentive (\$/kWh or \$/MMBtu)	Deterministic value
			State incentive (\$/kWh or \$/MMBtu)	Deterministic value
			Other incentive (\$/kWh or \$/MMBtu)	Deterministic value

In energy models, uncertainties are typically addressed by analyzing multiple deterministic scenarios (Krey, Martinsen & Wagner, 2007). Compared to the deterministic scenarios, the scenarios which incorporate the uncertainties of the probabilistic inputs in the model can help the users understand the impact of the uncertainties on energy-economic scenarios. These probabilistic inputs are simulated by the probability distributions or the correlation coefficients of the historical data.

Simulation of Probabilistic Inputs

The probabilistic inputs include the demand/capacity of the system, the unit cost of energy purchased from the utility, the general inflation rate and the specific commodity cost/volatility. The simulations of these probabilistic inputs are explained in more detail in the following paragraphs.

1. Simulation of Demand/Capacity of the System

Since the system is new to the client, there is no historical data for the demand/capacity of the system. However, one can predict the minimum and maximum demand level for the system. Also, an appropriate estimation of the modal demand level for the system can be gathered from the manufacturer of the system. For example, the manufacturer designs the capacity of a CHP system at 25,000 kW. After the system is installed at the client's site and starts operating, the minimum and maximum demand outputs that the system produces are 23,000 kW and 26,000 kW respectively. Since the sample data for the demand/capacity of the system is limited, it is simulated by a triangular distribution with the minimum, maximum and modal value of 23,000 kW, 26,000 kW and 25,000 kW respectively.

2. Simulation of the Unit Cost of Energy Purchased from the Utility

Since the unit penalty cost for not realizing the guaranteed energy value is set to be equal to the unit cost of energy purchased from the utility, this chapter only discusses how to simulate the unit cost of energy purchased from the utility. The simulation of the unit cost of energy purchased from the utility is derived from its historical data which show a certain behavior over the course of utilization. Now the problem is: which distribution should be used to describe its uncertainty?

Based on the historical data, the best fit distribution for the data can be determined using computer programs. In the CHP project that will be discussed in Chapter 4, the industrial electricity price of the state in which the system is installed, from 1990 to 2007, is used as the historical data of the unit cost of energy purchased from the utility. The data are from the Energy Information Administration database; and the Individual Distribution Identification function, in Minitab software, is used to determine the distribution that best fits the data. The historical data are treated equally, which means that part of the data set is not under- or overweighed because the future trends cannot be exactly derived from past history. This procedure will determine the best fit distribution of the unit cost of energy purchased from the utility and the parameters of the distribution.

Since the models of the client and the ESCO are built into Excel, based on the best fit distribution and its parameters, the random number generation function in Excel is used to simulate the unit cost for the appropriate years in the ESPC term (year 1 to year n). Subsequently, the simulated unit cost of energy purchased from the utility is used as an input to the model.

3. Simulation of General Inflation Rate and Specific Commodity Cost/Volatility

The Autocorrelation function in Minitab software is used to derive the correlations of the historic general inflation rate (from 1984 to 2006) and the correlations of the historic specific commodity cost/volatility (from 1983 to 2006). The general inflation rate and specific commodity cost/volatility for the relevant years in the ESPC term (year 1 to year n) are generated this way to make sure the correlation coefficient of the generated data is not significantly different from the correlation coefficient of the historical data. The simulation of the specific commodity cost/volatility is similar to this process. The following steps illustrate how to simulate the general inflation rates.

In Step 1, generate a serial M with n numbers (since the ESPC lasts n years) in Excel. These n numbers are generated using the random number generation formula of the standard normal distribution $\sqrt{(-2) \times \ln(rand())} \times \cos((2\pi) \times rand())$ (Law and Kelton, 2000). The variance of the serial M is one. *rand()* is a random number generation function in Excel.

In Step 2, generate a new serial X with n numbers. The first number X_1 in this serial is generated based on the random number generation formula of the standard normal distribution $\sqrt{(-2) \times \ln(rand())} \times \cos((2\pi) \times rand())$.

In Step 3, for the numbers X_2 to X_n , set $X_i = A \times X_{i-1} + B \times M_i$, where X_i is the i^{th} number in the serial X and M_i is the i^{th} number in the serial M, and A and B are two constants.

In Step 4, set r as the multiplication of A and the variance of X_{i-1} , where r is the correlation coefficient of the historical general inflation rates in two continuous years.

In Step 5, because X_1 and serial M follow the normal distribution, the n numbers in the serial X are also normally distributed.

In Step 6, because serial X and serial M are independent, A and B are constants, and serial M follows the standard normal distribution, the variance of X_i can be written as

$$\begin{aligned}\text{VAR}(X_i) &= \text{VAR}(A \times X_{i-1} + B \times M) \\ &= \text{VAR}(A \times X_{i-1}) + \text{VAR}(B \times M) \\ &= A^2 \times \text{VAR}(X_{i-1}) + B^2 \times \text{VAR}(M) \\ &= A^2 \times \text{VAR}(X_{i-1}) + B^2\end{aligned}$$

If the variance of all X_i in serial X set as one, then B can be calculated.

$$\text{VAR}(X_i) = A^2 \times \text{VAR}(X_{i-1}) + B^2 = A^2 + B^2 = 1, \text{ and } B = \sqrt{1 - A^2}.$$

In Step 7, since the variance of all X_i in serial X is one and r is the multiplication of A and the variance of X_{i-1} , A is equal to r. For example, if the correlation coefficient r is 0.5, A will be equal to 0.5 and B will be 0.866. Therefore,

$$X_2 = 0.5 \times X_1 + 0.866 \times M_2, X_3 = 0.5 \times X_2 + 0.866 \times M_3 \dots \text{ and } X_n = 0.5 \times X_{n-1} + 0.866 \times M_n.$$

In Step 8, the mean μ_r and standard deviation σ_r of the historical general inflation rates are derived from the historical values.

In Step 9, the desired general inflation rates IR that will be used in the Excel model to calculate the annually inflated benefits and costs are calculated as

$$IR_t = \mu_r + \sigma_r \times X_t, \text{ in which } t \text{ stands for the year.}$$

Model Outputs and Outputs Analysis

The model starts collecting the data that will be used as the deterministic inputs and the probabilistic inputs. The deterministic inputs are further separated as discrete arrays and deterministic values; and the simulations are used to represent the level of uncertainty connected with the probabilistic inputs. The model applies the multiple scenario analysis. In each scenario, all probabilistic inputs are simulated, and two values are randomly picked from the two deterministic inputs which are referred to as the discrete arrays. Then the simulated values and the two deterministic values are combined and entered in the model. The user can choose to use different discrete arrays, repeat the analysis with different sets of data and make a new scenario. The number of scenarios is determined by the number of the discrete arrays and the number of values in each discrete array. For example, if there are m deterministic inputs which can be referred to as the discrete arrays, and there are n values in each discrete array, then the total number of the scenarios will be $n \times n \times C_2^m$.

With each simulation, a calculation is made in the scenario to yield the NPVs of the client and ESCO. The NPV outputs show their uncertainty level which is propagated through the model. These outputs determine the range of the NPV values and render distributions which show the relative likelihood of the occurrence of each possible outcome. The user can also compare the NPV outputs among the scenarios. All calculations are done by computer programs. The calculation time is dependent on the computer speed, the number of the simulation runs, and may range from a few seconds to a few minutes.

Determination of Simulation Runs

Since the probabilistic inputs are simulated by either best fit probability distribution or the correlation coefficient from the historical data, the value of the simulation runs needs to be determined. This value can either be a random number or be determined from the criteria set by the users. In the model, the stop criteria “half width of a two-side confidence interval /mean in %” of the simulations is set at 10% for both client and ESCO, and the trial and error method is used to find the number of the simulation runs which can meet the stop criteria. The following paragraphs explain how to find the desired number of the simulation runs step by step.

In Step 1, run 500-time simulations in each scenario. For each simulation there is a pair of NPV values for the client and the ESCO. Therefore, for each scenario 500 pairs of NPV are generated.

In Step 2, calculate the mean and the standard deviation for the 500 client's NPV values and the 500 ESCO's NPV values respectively. The half width of a two-side confidence interval (CI) can be accomplished in Excel with the following expression:

$$CI = CONFIDENCE (\alpha, \sigma, N)$$

Where: α = 1- confidence level (for 95% confidence level, $\alpha= 0.05$)

σ = Standard deviation of outcomes of N trials

N = the number of the simulation runs for which outcomes are recorded

(500)

Given α , in each scenario, the half width of a two-side CI of the client's NPV values and the ESCO's NPV values are calculated from the simulation, as well as

the corresponding “half width of a two-side CI /mean in %” of the client and the ESCO.

In Step 3, find the maximum absolute value of the “half width of a two-side CI/mean in %” and compare this value with the set stop criteria (10%). If this value is greater than 10%, increase the number of the simulation runs for all scenarios to decrease the “half width of a two-side CI/mean in %”.

In Step 4, repeat Step 2 and Step 3 until the maximum absolute value of the “half width of a two-side CI/mean in %” of the client and the ESCO is equal to or lower than the set stop criteria (10%). Then the desired number of the simulation runs is determined.

Model Output Analysis

Once the number of the simulation runs is determined, the model outputs – NPVs of the client and the ESCO from the simulation runs– will be analyzed. Based on the outputs, the rate "percentage of the positive NPVs for both client and ESCO" can be calculated. Then this rate is compared among the scenarios with the same deterministic inputs. Also, these outputs determine the range of the NPV values and render distributions which show the relative likelihood of the occurrence of each possible outcome. Studying the histograms based on the NPV outputs of the client and ESCO can help the users learn the frequency of NPV outputs.

Summary

In this chapter, the conceptual model which will be applied in an ESPC project is introduced. Then the assumptions, the equations used, and the development of the inputs used in the model are explained.

In the next chapter, the model will be applied in a CHP project in a deterministic environment and a probabilistic environment respectively. Taking the application of the model in the deterministic environment as a reference, the advantages of incorporating the uncertainty of the inputs in the economic analysis of an ESPC project can be determined, as compared to the application in the deterministic environment.

CHAPTER IV.

MODEL DEMONSTRATION

This chapter demonstrates the application of the model in a Combined Heat and Power (CHP) project. The first section describes the background of the project. The next section applies the model in the CHP project to show how the model works in both deterministic environment and probabilistic environment. Following the application of the model, the outputs of the model in the probabilistic environment are analyzed. A similar process can be applied to most energy management projects.

A Combined Heat and Power (CHP) Project

Background of the CHP Project

Assume an Industrial Assessment Center (IAC) conducts an energy audit at a plant (the client) which produces a carbon-based product for the aluminum industry. The production process begins with raw coke unloaded using a car tipper and stored in large piles. Raw coke received, via trucks, is dumped into the truck dumping area and is carried to yard storage by conveyors. It is then drawn from the yard storage and conveyed to the storage hoppers via a conveyor system. Raw coke from different sources is blended

in required proportions and transported to the kilns. Temperature of each kiln is maintained at approximately 2,350 °F. The natural gas fired burners are used at the product end. The hot calcined coke exits the kiln from the burner at the end of the kiln and is cooled by passing through a cooler. Then it is conveyed to a silo and transported to the crushing plant using conveyors. The crushed calcined coke is then bagged and transported to the customers (OIAC, 2003).

There are three main energy users in the client's plant: calcining kilns, a cooler and a setting chamber. The next segments describe their functions in more details (Kapil, 2004).

1. Calcining kilns

Three kilns are used to calcine the raw coke. After entering the kiln, the moisture is driven off the coke in the "Heat-Up Zone". Devolatilization occurs at 950 to 1,800°F in the "Calcining Zone". Further dehydrogenation, some desulphurization, and coke structure shrinkage (densification) take place in the "Calcined Coke Zone" at 2,200 to 2,350°F. The coke moves through the kiln in 40 to 60 minutes and drops off the discharge from the end of the kiln into a refractory-lined chute and into a rotary cooler.

2. Cooler

The cooler is a bare steel cylinder similar to the kiln but smaller in diameter and rotated at a higher Revolution per Minute (RPM) than the calcining kiln, with water sprays in the front end. By spraying the water onto the hot coke, the very high latent heat of vaporized water can be utilized for cooling. The water sprays are adjusted to maintain the coke at the cooler exit at 250 to 350°F in order to keep the calcined product dry.

3. Settling chamber

The water vapor from the moisture of the raw coke, hot combustion gases, unburned entrained coke fines, and unburned tars and gases (from the volatile matter of the raw coke) flow out the feed end of the kiln into the settling chamber where excess fuel and fines are burned.

During the audit, the audit team finds that the heat from the stack gas of the setting chamber is released to the ambient. The temperature of the heat is high enough that the heat can be recovered and reused. Hence, the audit team recommends that the client do research to see if an industrial CHP system can be installed at the client's site to make use of the wasted heat.

Based on the measurements taken during the audit and the information provided by the plant personnel, the audit team finds that a bottoming cycle 25,000 kW steam turbine CHP system is technically feasible. The system includes a water tube boiler, a steam turbine, an electric generator, and a cooling tower. The entire system costs \$27,500,000 (estimate). It takes an additional cost of \$2,500,000 (estimate) to transport and install the whole system.

Considering the energy profile of the client and the information from the manufacturer of the system, the energy generated from the system is greater than what the production of the client requires. Since the energy generation is not the core business of the client, and the client may be unable to raise the required capital or unwilling to accept the risks from installing the system, investing in the project and operating the system are difficult for the client. This can be solved by inviting a third party (such as an ESCO) to participate in the project. The ESCO mitigates the risk of the project by providing the professional operation activity and guaranteeing the performance of the

system. This will enable the client to borrow money from a financial institution to purchase the system. The client then gives up a predetermined fraction of the benefits it receives from the project in exchange for the ESCO responsibility. Before implementing the ESPC, the client and ESCO need to determine if the ESPC is economically feasible for both of them. Hence, a tool is required to help the client and ESCO in the decision making process. The model developed in Chapter 3 will be applied in this project.

Application of the Model in a Deterministic Environment

This part briefly describes the application of the model in a deterministic environment, which serves as a baseline and reference point for the application of the model in the probabilistic environment. The purpose of the reference is to demonstrate the advantages of the model by incorporating the uncertainties of the model inputs.

Inputs of the Model in a Deterministic Environment

The model inputs include the system inputs and party inputs that are presented in Figure 1 and Figure 2. The meaning of the inputs is explained in the following section and their values are listed in Table 8.

The descriptive inputs of the system include -

- Location: Oklahoma (assumed).
- Depreciation method: The CHP system falls under a 15-year class life or recovery period using the modified accelerated cost recovery system (MACRS) schedule according to federal tax strategies. The calculation is based on the equipment cost, which is \$27,500,000.

- Depreciation period (yrs): As mentioned in "depreciation method", the CHP system is depreciated over 15 years.
- Project term (yrs): The project term, in years, will be used to calculate the investment's cash flows and NPVs. The default value is assumed to be 20 years.
- Base year: The case study assumes that the year when the CHP system is installed at the client's site and starts to operate is year 0. The year 0 is the base year during which the after tax cash flows in the project term are converted to the present values.

The specification inputs of the system -

- Demand/capacity (kW): The capacity of the CHP system is 25,000 kW.
- Availability/yield (%): The system runs 86% of the client's operating time, which means the system is under maintenance 14% of the client's operating time.
- Operating time (hrs/yr): The production process of the client is running 24 hours a day, 7 days a week. Therefore, the annual operating time of the client is 8,760 hours.

The cost inputs of the system

- System cost (\$): The cost of the system is \$27,500,000.
- Transportation cost (\$): It takes the ESCO \$1,000,000 to transport the system from the manufacturer to the client.
- Installation cost (\$): It costs the ESCO \$1,500,000 to install the system at the client's site.
- Operation cost (\$): This is the multiplication of the unit cost of operating the system and the energy output of the system.

- Maintenance cost (\$): This is the multiplication of the unit cost of maintaining the system and the energy output of the system.
- Disposition cost (\$): Assume the system can be used for the future at the end of the ESPC project. Therefore, the disposition cost is zero.

The incentive/credit inputs of the system -

- Federal credit (%): Assume the system can only claim federal credit and no incentives. This credit is issued in the form of investment tax credit at the end of first year in the ESPC term to help the client reduce its tax charge.
- Federal incentive (\$/kWh): Assume the system is not qualified to claim the federal incentive in this case. Therefore, the federal incentive is \$0/kWh.
- State incentive (\$/kWh): Assume the system is not qualified to claim the state incentive in this case. Therefore, the state incentive is \$0/kWh.
- Other incentive (\$/kWh): Assume the system is not qualified to claim the incentive from the utility or other organizations in this case. Therefore, the other incentives are \$0/kWh.

The financial environment of the system -

- Tax rate (%): Taxes are calculated at the federal and state level. The tax rate for the client and ESCO is assumed to be 41.0%.
- General inflation rate (%): The general inflation rate is used to calculate a sustained increase in the price of activities which are not connected with electricity generation. These activities include the operation and maintenance of the system. The general inflation rate is assumed to be 3.2%, which is calculated as the average of the general inflation rates from 1984 to 2006 (BLS, 2007a).

- Specific commodity cost/volatility (%): The specific commodity cost/volatility is used to calculate a sustained variation in the price of activities connected with electricity generation. The specific commodity cost/volatility is assumed to be 2.1%, which is calculated as the average of the specific commodity cost/volatility rates from 1983 to 2006 (BLS, 2007b).

The inputs of the client -

1. Annual energy requirement (kWh/yr): The annual energy requirement of the client before the installation of the system is 8,435,200 kWh. This information can be obtained from the historical utility bills.
2. Unit cost of energy purchased from the utility (\$/kWh): The unit cost of energy that the client purchases from the utility before the installation of the system and when the system is under maintenance is \$0.042/kWh. This value includes both energy cost and demand charge, and is an average of the annual industrial electricity cost in Oklahoma (OK) from 1990 to 2007 (EIA, 2007). The industrial electricity price in this time period is listed in Table 12.
3. Relationship between the price of sold energy and the price of purchased energy (%): Bhattacharyya points out that this rate is usually between 60% to 70% (Bhattacharyya and Thang, 2004). In this project, the relationship is assumed to be 65%, which means the price of energy sold back to the utility is \$0.026/kWh, the multiplication of 65% and \$0.042/kWh.
4. After-tax MARR (%): MARR is the return that could be earned by investing elsewhere and it is used to calculate the present value of a stream of cash flows over time. The after-tax MARR of the client is 15%.

5. Amount of loan principal (\$): Dependent on the financial needs, the client may need to borrow money initially for cash flow purposes, with the principal to be paid back over time to a financial institution. The amount of the loan may be selected by the client. In this case, the amount of loan principal is \$27,500,000.
6. Loan interest rate (%): The client needs to pay interest on the loan to the financial institution. The loan interest rate between the client and the financial institution is determined by market rates, the perceived risk of the ESPC project, the stability of the client's implementation of the project, and other factors. The loan interest rate of the client in this case is 10%.
7. Loan term (yrs): The loan term is the time period over which the loan principal is scheduled to be paid down through periodic payments. This case assumes a default loan term of seven years for the client.

The inputs of the ESCO -

1. Performance contract sharing rate (%): The client will share with the ESCO the benefits from installing the system, if the value of the energy (kWh) generated from the system is greater than or equal to the guaranteed energy value. The region of the rate decides the revenue of the ESCO and the cost of the client. Therefore, it should be discussed thoroughly. In this case, the rate is 90%.
2. Unit cost of operating the system (\$/kWh): The ESCO pays the cost for the labor and material it spends on operating the CHP system. In this case, the unit cost of operating the system, including the labor and the material cost, is \$0.02/kWh.
3. Unit penalty cost for not realizing the guaranteed value (\$/kWh): If the actual value of energy (kWh) perceived from the CHP system is less than the energy

value (kWh) guaranteed by the ESCO, the ESCO has to pay a penalty cost to the client. Assume the unit penalty cost for not realizing the guaranteed value is the same as the unit cost of the energy purchased from the utility, which is \$0.042/kWh. This assumption is a reasonable approximation since it is hard to get the unit penalty cost from an actual ESPC contract. Moreover, setting these two unit costs as being equal will make the ESCO compensate for the loss of the client for not realizing the guaranteed energy value, which is determined by the ESCO in the design period of the ESPC project.

4. Unit cost of maintaining the system (\$/kWh): The ESCO pays the maintenance company for maintaining the CHP system. The unit cost of maintaining the system is \$0.002/kWh in this case.
5. Value of energy guaranteed (kWh): Based on the engineering simulation software and the information collected from the client, the ESCO calculates that the system can generate 187,245,000 kWh a year.
6. After-tax MARR (%): MARR is the return that could be earned by investing elsewhere and it is used to calculate the present value of a stream of cash flows over time. The after-tax MARR of the ESCO is 15%.
7. Amount of loan principal (\$): Dependent on the financial needs, the ESCO may need to borrow money initially for cash flow purposes, with the principal to be paid back over time to a financial institution. The amount of the loan may be selected by the ESCO. In this case, the amount of loan principal is \$2,500,000.
8. Loan interest rate (%): The ESCO needs to pay interest on the loan to the financial institution. The loan interest rate between the ESCO and the financial institution is

determined by market rates, the perceived risk of the ESPC project, the stability of the ESCO's implementation of the project, and other factors. The loan interest rate of the ESCO in this case is 10%.

9. Loan term (yrs): The loan term is the time period over which the loan principal is scheduled to be paid down through periodic payments. In this case, the default loan term of the ESCO is seven years.

Table 8 - Model inputs in a deterministic environment

Client			
After-tax MARR (%)	15%		
Unit cost of energy purchased from the utility (\$/kWh)	0.042		
Relationship between the price of sold energy and the price of purchased	65%		
Annual energy requirement of the client (kWh)	8,435,200		
Disposition cost (\$)	0		
Amount of loan (\$)	27,500,000		
Loan interest rate (%)	10%		
Loan terms (yr)	7		
System cost (\$)	27,500,000		
Financial Environment			
General inflation rate (%)	3.2%		
Specific commodity cost/volatility (%)	2.1%		
Tax rate (%)	41%		
Energy Service Company			
After-tax MARR (%)	15%		
Unit cost of operating the system (\$/kWh)	0.02		
Unit penalty cost for not realizing the guaranteed value (\$/kWh)	0.042		
Performance contract sharing rate (%)	90%		
Unit cost of maintaining the system (\$/kWh)	0.002		
Value of energy guaranteed (kWh)	187,245,000		
Transportation cost of the system (\$)	1,000,000		
Installation cost of the system (\$)	1,500,000		
Amount of loan (\$)	2,500,000		
Loan interest rate (%)	10%		
Loan terms (yr)	7		

		System	
Descriptive	Location	Arkansas	
	Depreciation method	MACRS	
	Depreciation period (yrs)	15	
	Project term (yrs)	20	
System specification	Base year	0	
	Demand/capacity (kW)	25,000	
	Availability/yield (%)	86%	
Costs	Annual operating time (hrs/yr)	8,760	
	System cost (\$)	27,500,000	
	Transportation cost (\$)	1,000,000	
	Installation cost (\$)	1,500,000	
	Operating cost (\$)	3,766,800	
	Maintenance cost (\$)	376,680	
	Disposition cost (\$)	0	
Incentive/credit	Federal tax credit (%)	30%	
	Federal incentive (\$/kWh)	0	
	State incentive (\$/kWh)	0	
	Other incentive (\$/kWh)	0	

Depreciation Rates

Table 9 presents the MACRS depreciation rates for the 15-year property. For example, after the first year, an owner depreciates 5% of the equipment's cost basis. The equipment's "book value" equals the remaining unrecovered depreciation. Thus, after the first year the book value would be 100% - 5%, which is equivalent to 95% of the original value.

Table 9 - Depreciation rates of the CHP system

End of Year	MACRS Rate
0	
1	5.00%
2	9.50%
3	8.55%
4	7.70%
5	6.93%
6	6.23%
7	5.90%
8	5.90%
9	5.91%
10	5.90%
11	5.91%
12	5.90%
13	5.91%
14	5.90%
15	5.91%
16	2.95%
17	0.00%
18	0.00%
19	0.00%
20	0.00%

Outputs of the Model in a Deterministic Environment

Based on the equations listed in Subchapter “Illustration of Excel Models” and the values of the inputs shown in Subchapter “Inputs of the Model in a Deterministic Environment”, the model calculates the NPV outputs of the client and the ESCO in a deterministic environment. They are presented in Table 10 and Table 11.

The NPV outputs of both client and ESCO are negative, which means this ESPC project cannot satisfy both client’ and ESCO’ MARRs when the inputs of the model are setting at these values (Table 8). As a result, it is very risky for the client and the ESCO to implement this ESPC project.

Table 10 – Client’s NPV output from the model in a deterministic environment

CLIENT																			
End of Year	System Cost	Savings From Client Internal Use	Revenue From Selling Energy Back to Utility	Energy Cost When The System is Under Maintenance	Shared Cost with ESCO	Penalty For Not Realizing The Guaranteed Value	Disposition Cost	Incentives	Total Before Tax and Loan Cash Flow	MACRS Depreciation	Loan				Taxable Income	Income Tax	Federal Credit	After Tax Cash Flow (ATCF)	Present Value of ATCF
											B+C+D+E+F+G+H+I	BxDR	Principal Payment	Interest Payment					
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
0	\$ (27,500,000)										\$ 27,500,000				\$ -	\$ -		\$ -	\$ -
1		\$ 359,452	\$ 4,983,128	\$ (50,323)	\$ (4,763,031)	\$ -	\$ -	\$ -	\$ 529,226	\$ 1,375,000	\$ (2,898,651)	\$ (2,750,000)	\$ (5,648,651)	\$ 24,601,349	\$ (3,595,774)	\$ (1,474,267)	\$ 8,250,000	\$ 4,604,842	\$ 4,004,210
2		\$ 367,058	\$ 5,088,566	\$ (51,388)	\$ (4,863,812)	\$ -	\$ -	\$ -	\$ 540,424	\$ 2,612,500	\$ (3,188,516)	\$ (2,460,135)	\$ (5,648,651)	\$ 21,412,832	\$ (4,532,211)	\$ (1,858,207)	\$ -	\$ (3,250,021)	\$ (2,457,483)
3		\$ 374,825	\$ 5,196,234	\$ (52,475)	\$ (4,966,725)	\$ -	\$ -	\$ -	\$ 551,858	\$ 2,351,250	\$ (3,507,368)	\$ (2,141,283)	\$ (5,648,651)	\$ 17,905,464	\$ (3,940,675)	\$ (1,615,677)	\$ -	\$ (3,481,116)	\$ (2,288,890)
4		\$ 382,755	\$ 5,306,181	\$ (53,586)	\$ (5,071,815)	\$ -	\$ -	\$ -	\$ 563,535	\$ 2,117,500	\$ (3,858,035)	\$ (1,790,546)	\$ (5,648,651)	\$ 14,047,360	\$ (3,344,511)	\$ (1,371,250)	\$ -	\$ (3,713,867)	\$ (2,123,415)
5		\$ 390,854	\$ 5,418,454	\$ (54,720)	\$ (5,179,129)	\$ -	\$ -	\$ -	\$ 575,459	\$ 1,905,750	\$ (4,243,915)	\$ (1,404,736)	\$ (5,648,651)	\$ 9,803,444	\$ (2,735,027)	\$ (1,121,361)	\$ -	\$ (3,951,831)	\$ (1,964,759)
6		\$ 399,124	\$ 5,533,102	\$ (55,877)	\$ (5,288,714)	\$ -	\$ -	\$ -	\$ 587,635	\$ 1,713,250	\$ (4,668,307)	\$ (980,344)	\$ (5,648,651)	\$ 5,135,137	\$ (2,105,960)	\$ (863,443)	\$ -	\$ (4,197,573)	\$ (1,814,727)
7		\$ 407,569	\$ 5,650,177	\$ (57,060)	\$ (5,400,617)	\$ -	\$ -	\$ -	\$ 600,069	\$ 1,622,500	\$ (5,135,137)	\$ (513,514)	\$ (5,648,651)	\$ 0	\$ (1,535,945)	\$ (629,738)	\$ -	\$ (4,418,845)	\$ (1,661,208)
8		\$ 416,193	\$ 5,769,728	\$ (58,267)	\$ (5,514,889)	\$ -	\$ -	\$ -	\$ 612,765	\$ 1,622,500				\$ (1,009,735)	\$ (413,991)	\$ -	\$ -	\$ 1,026,757	\$ 335,649
9		\$ 424,999	\$ 5,891,809	\$ (59,500)	\$ (5,631,578)	\$ -	\$ -	\$ -	\$ 625,731	\$ 1,622,500				\$ (999,519)	\$ (409,803)	\$ -	\$ -	\$ 1,035,534	\$ 294,363
10		\$ 433,992	\$ 6,016,473	\$ (60,759)	\$ (5,750,756)	\$ -	\$ -	\$ -	\$ 638,971	\$ 1,622,500				\$ (983,529)	\$ (403,247)	\$ -	\$ -	\$ 1,042,218	\$ 257,620
11		\$ 443,174	\$ 6,143,775	\$ (62,044)	\$ (5,872,245)	\$ -	\$ -	\$ -	\$ 652,491	\$ 1,622,500				\$ (972,759)	\$ (398,831)	\$ -	\$ -	\$ 1,051,322	\$ 225,975
12		\$ 452,551	\$ 6,273,771	\$ (63,357)	\$ (5,996,669)	\$ -	\$ -	\$ -	\$ 666,297	\$ 1,622,500				\$ (956,203)	\$ (392,043)	\$ -	\$ -	\$ 1,058,340	\$ 197,811
13		\$ 462,127	\$ 6,406,517	\$ (64,698)	\$ (6,123,552)	\$ -	\$ -	\$ -	\$ 680,395	\$ 1,622,500				\$ (944,855)	\$ (387,391)	\$ -	\$ -	\$ 1,067,785	\$ 173,545
14		\$ 471,905	\$ 6,542,072	\$ (66,067)	\$ (6,253,119)	\$ -	\$ -	\$ -	\$ 694,791	\$ 1,622,500				\$ (927,709)	\$ (380,361)	\$ -	\$ -	\$ 1,075,152	\$ 151,950
15		\$ 481,890	\$ 6,680,495	\$ (67,465)	\$ (6,385,428)	\$ -	\$ -	\$ -	\$ 709,492	\$ 1,622,500				\$ (915,758)	\$ (375,461)	\$ -	\$ -	\$ 1,084,953	\$ 133,335
16		\$ 492,086	\$ 6,821,847	\$ (68,892)	\$ (6,520,537)	\$ -	\$ -	\$ -	\$ 724,504	\$ 811,250				\$ (86,746)	\$ (35,566)	\$ -	\$ -	\$ 760,070	\$ 81,225
17		\$ 502,498	\$ 6,966,190	\$ (70,350)	\$ (6,659,504)	\$ -	\$ -	\$ -	\$ 739,834	\$ -				\$ (79,834)	\$ (303,332)	\$ -	\$ -	\$ 436,502	\$ 40,563
18		\$ 513,131	\$ 7,113,587	\$ (71,838)	\$ (6,799,391)	\$ -	\$ -	\$ -	\$ 755,488	\$ -				\$ (75,488)	\$ (309,750)	\$ -	\$ -	\$ 445,738	\$ 36,018
19		\$ 523,988	\$ 7,264,102	\$ (73,358)	\$ (6,943,259)	\$ -	\$ -	\$ -	\$ 771,473	\$ -				\$ (71,473)	\$ (316,304)	\$ -	\$ -	\$ 455,169	\$ 31,983
20		\$ 535,075	\$ 7,417,803	\$ (74,910)	\$ (7,090,170)	\$ -	\$ -	\$ -	\$ 787,797	\$ -				\$ (77,797)	\$ (322,997)	\$ -	\$ -	\$ 464,800	\$ 28,399
																		NPV	\$ (6,317,837)

Table 11 - ESCO's NPV output from the model in a deterministic environment

ENERGY SERVICE COMPANY (ESCO)															
End of Year	Transportation Cost	Installation Cost	Maintenance Cost	Operation Cost	Penalty Cost For Not Realizing The Guaranteed Value	Shared Revenue with Client	Total Before Tax and Loan Cash Flow B+C+D+E+F+G	Loan				Taxable Income H+J	Income Tax M×TR	After Tax Cash Flow (ATCF) H+K-N	Present Value of ATCF P
								Principal Payment I	Interest Payment J	Total Payment K	Principal L				
A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
0	\$ (1,000,000)	\$ (1,500,000)						\$ 2,500,000			\$ 2,500,000			\$ -	\$ -
1			\$ (388,785)	\$ (3,887,851)	\$ -	\$ 4,763,031	\$ 486,395	\$ (263,514)	\$ (250,000)	\$ (513,514)	\$ 2,236,486	\$ 236,395	\$ 96,922	\$ (124,041)	\$ (107,861)
2			\$ (401,279)	\$ (4,012,792)	\$ -	\$ 4,863,812	\$ 449,740	\$ (289,865)	\$ (223,649)	\$ (513,514)	\$ 1,946,621	\$ 226,092	\$ 92,698	\$ (156,471)	\$ (118,315)
3			\$ (414,175)	\$ (4,141,749)	\$ -	\$ 4,966,725	\$ 410,801	\$ (318,852)	\$ (194,662)	\$ (513,514)	\$ 1,627,769	\$ 216,139	\$ 88,617	\$ (191,329)	\$ (125,802)
4			\$ (427,485)	\$ (4,274,849)	\$ -	\$ 5,071,815	\$ 369,481	\$ (350,737)	\$ (162,777)	\$ (513,514)	\$ 1,277,033	\$ 206,704	\$ 84,749	\$ (228,781)	\$ (130,806)
5			\$ (441,223)	\$ (4,412,227)	\$ -	\$ 5,179,129	\$ 325,680	\$ (385,810)	\$ (127,703)	\$ (513,514)	\$ 891,222	\$ 197,976	\$ 81,170	\$ (269,004)	\$ (133,743)
6			\$ (455,402)	\$ (4,554,020)	\$ -	\$ 5,288,714	\$ 279,292	\$ (424,392)	\$ (89,122)	\$ (513,514)	\$ 466,831	\$ 190,170	\$ 77,970	\$ (312,191)	\$ (134,969)
7			\$ (470,037)	\$ (4,700,369)	\$ -	\$ 5,400,617	\$ 230,211	\$ (466,831)	\$ (46,683)	\$ (513,514)	\$ 0	\$ 183,528	\$ 75,247	\$ (358,549)	\$ (134,792)
8			\$ (485,142)	\$ (4,851,422)	\$ -	\$ 5,514,889	\$ 178,325					\$ 178,325	\$ 73,113	\$ 105,212	\$ 34,394
9			\$ (500,733)	\$ (5,007,329)	\$ -	\$ 5,631,578	\$ 123,516					\$ 123,516	\$ 50,642	\$ 72,874	\$ 20,715
10			\$ (516,825)	\$ (5,168,246)	\$ -	\$ 5,750,736	\$ 65,665					\$ 65,665	\$ 26,923	\$ 38,743	\$ 9,577
11			\$ (533,433)	\$ (5,334,334)	\$ -	\$ 5,872,415	\$ 4,647					\$ 4,647	\$ 1,905	\$ 2,742	\$ 589
12			\$ (550,576)	\$ (5,505,760)	\$ -	\$ 5,996,669	\$ (59,667)					\$ (59,667)	\$ (24,464)	\$ (35,204)	\$ (6,580)
13			\$ (568,269)	\$ (5,682,695)	\$ -	\$ 6,123,552	\$ (127,413)					\$ (127,413)	\$ (52,239)	\$ (75,173)	\$ (12,218)
14			\$ (586,532)	\$ (5,865,316)	\$ -	\$ 6,253,119	\$ (198,728)					\$ (198,728)	\$ (81,478)	\$ (117,250)	\$ (16,571)
15			\$ (605,381)	\$ (6,053,805)	\$ -	\$ 6,385,428	\$ (273,757)					\$ (273,757)	\$ (112,241)	\$ (161,517)	\$ (19,850)
16			\$ (624,835)	\$ (6,248,352)	\$ -	\$ 6,520,537	\$ (352,651)					\$ (352,651)	\$ (144,587)	\$ (208,064)	\$ (22,235)
17			\$ (644,915)	\$ (6,449,151)	\$ -	\$ 6,658,504	\$ (435,562)					\$ (435,562)	\$ (178,580)	\$ (256,982)	\$ (23,880)
18			\$ (665,640)	\$ (6,656,403)	\$ -	\$ 6,799,391	\$ (522,653)					\$ (522,653)	\$ (214,288)	\$ (308,365)	\$ (24,917)
19			\$ (687,032)	\$ (6,870,316)	\$ -	\$ 6,943,259	\$ (614,088)					\$ (614,088)	\$ (251,776)	\$ (362,312)	\$ (25,458)
20			\$ (709,110)	\$ (7,091,102)	\$ -	\$ 7,090,170	\$ (710,042)					\$ (710,042)	\$ (291,117)	\$ (418,925)	\$ (25,596)
														NPV	\$ (998,318)

Application of the Model in a Probabilistic Environment

The relationship between the client and the ESCO in the deterministic environment is the same as in the probabilistic environment. Therefore, the names of the inputs are the same in both environments. An improvement over the deterministic analysis is the probabilistic impact of the model inputs on the model outputs. In this case, the inputs of the model can be described as deterministic and probabilistic. Further, the deterministic inputs can be referred to as either a deterministic value or a discrete array. The characteristics of the inputs have been presented in Table 7.

The Subchapter "Simulation of Probabilistic Inputs" described how to simulate the probabilistic inputs. Uncertainty propagation through the logical model of economic analysis can give results which can be interpreted in accordance with probability theory. The distribution which best fits the historical data of the industrial electricity price in Oklahoma, is identified using the Individual Distribution Identification function in Minitab software. Once the distribution is determined, it will be used in the model to simulate the unit cost of energy purchased from the utility. Based on an expert opinion, the demand/capacity of the system will be simulated in accordance with a triangular distribution. The general inflation rate and the specific commodity cost/volatility that will be used in the model are simulated by the correlation coefficient of their historical data.

The model applies the multiple scenario analysis. In each scenario, all probabilistic inputs are simulated, and two values are randomly picked from two deterministic inputs which are referred to as the discrete arrays. Then the simulated values and the two deterministic values are combined and entered in the model. With each simulation, a calculation is made in the scenario to yield a pair of NPV outputs of

the client and ESCO. These outputs determine the range of the NPV values and provide probability distributions which show the relative likelihood of the occurrence of each possible outcome. All of these will help the users of the model make a better decision about feasibility of energy efficiency upgrades.

Development of Probabilistic Inputs

Simulation of the Unit Cost of Energy Purchased from the Utility

The industrial electricity prices in Oklahoma from 1990 to 2007 are presented in Table 12 and drawn in Figure 5. It is shown that the electricity prices vary from year to year and increase from 2003 to 2006.

Table 12 – Industrial electricity prices in Oklahoma from 1990 to 2007

Year	State	Average Retail Price Industrial (¢/kWH)
1990	OK	3.63
1991	OK	3.85
1992	OK	3.86
1993	OK	4.14
1994	OK	4.07
1995	OK	3.75
1996	OK	3.78
1997	OK	3.63
1998	OK	3.65
1999	OK	3.60
2000	OK	4.09
2001	OK	4.29
2002	OK	3.81
2003	OK	4.59
2004	OK	4.76
2005	OK	5.11
2006	OK	5.42
2007	OK	5.09

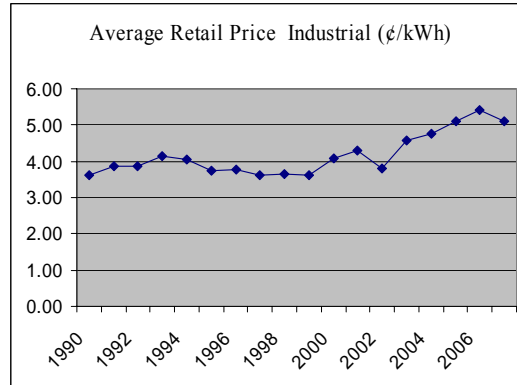


Figure 5 - The industrial electricity prices in Oklahoma from 1990 to 2007

To simulate the unit cost of the energy purchased from the utility, the distribution which best fits the historical industrial electricity price needs to be determined first. The following steps describe this process.

In Step 1, identify the best fit distribution of historical industrial electricity price in Oklahoma.

Based on the historical data of the industrial electricity price in Oklahoma, the Individual Distribution Identification function in Minitab software is used to determine the best fit distribution of those historical data. This function is used to evaluate the optimal distribution for the data based on the probability plots and the goodness-of-fit tests. The following tables and graphs are the results from the Minitab software. They consist of the descriptive statistics, Goodness-of-Fit test, and probability plots.

Descriptive Statistics:

N	N*	Mean	StDev	Median	Minimum	Maximum	Skewness	Kurtosis
18	0	4.17333	0.578212	3.965	3.6	5.42	0.993388	-0.244128

Goodness-of-Fit Test:

Distribution	AD	P	LRT P
Normal	1.002	0.009	
Lognormal	0.850	0.023	
3-Parameter Lognormal	0.338	*	0.002
Exponential	6.368	<0.003	
2-Parameter Exponential	0.296	>0.250	0.000
Weibull	1.152	<0.010	
3-Parameter Weibull	0.287	>0.500	0.000
Smallest Extreme Value	1.316	<0.010	
Largest Extreme Value	0.734	0.048	
Gamma	0.940	0.019	
3-Parameter Gamma	0.289	*	0.001
Logistic	0.911	0.009	
Loglogistic	0.788	0.022	
3-Parameter Loglogistic	0.323	*	0.003

ML Estimates of Distribution Parameters:

Distribution	Location	Shape	Scale	Threshold
Normal*	4.17333	0.57821		
Lognormal*	1.42021	0.13206		
3-Parameter Lognormal	-1.04522	1.16528	3.56400	
Exponential	4.17333			

2-Parameter Exponential	0.60933	3.56400
Weibull	7.29862	4.43106
3-Parameter Weibull	1.02534	0.61567 3.56400
Smallest Extreme Value	4.47591	0.61663
Largest Extreme Value	3.92296	0.38861
Gamma	58.98031	0.07076
3-Parameter Gamma	1.04451	0.58337 3.56400
Logistic	4.09396	0.32138
Loglogistic	1.40427	0.07472
3-Parameter Loglogistic	-0.98875	0.69461 3.56400

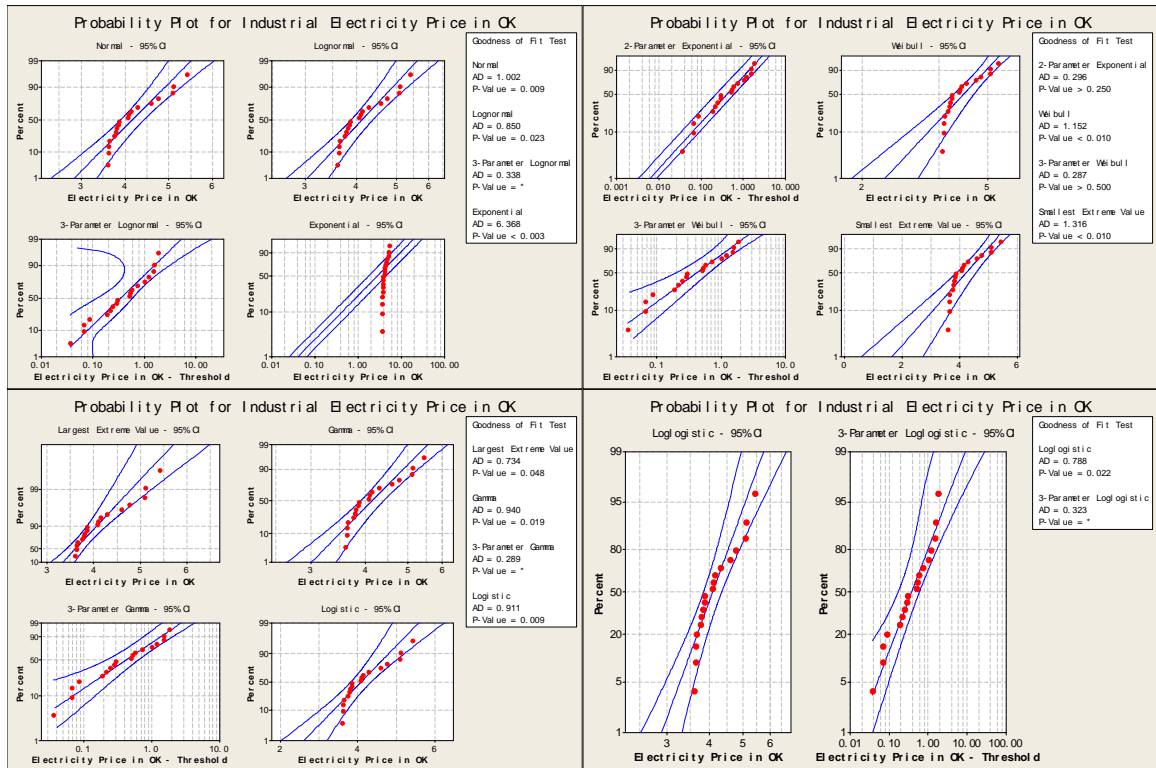


Figure 6 - The probability plots for industrial electricity prices in Oklahoma

In Step 2, interpret the results.

The table of the descriptive statistics provides the summary information for the entire data set. All the statistics are based on the non-missing (N=18) values. The mean μ of these values is 2.92307 and the standard deviation σ is 1.78597.

The table of the Goodness-of-fit test includes Anderson-Darling (A-D) statistic and the corresponding p-value for each distribution. The A-D statistic is a measure of how far the plot points fall from the fitted line in a probability plot. The statistic is a weighted squared distance from the plot points to the fitted line, with larger weights in the tails of the distribution. A smaller A-D statistic indicates that the distribution fits the data better. A p-value greater than a critical value α (0.05) suggests that the data follow that distribution.

Minitab also includes a p-value for the Likelihood ratio test (LRT P), which tests whether a 2-parameter distribution would fit the data equally well compared to its 3-parameter counterpart. In this case, the p-values of 0.25 and 0.5 indicate that the 2-parameter Exponential and the 3-parameter Weibull distributions fit the data well. The LRT P value of 0.000 suggests that the 3-parameter Weibull distribution does significantly improve the fit compared to the 2-parameter Weibull distribution.

The probability plot (Figure 6) includes the percentile points for the corresponding probabilities of the data. The middle line is the expected percentile from the distribution based on the maximum likelihood parameter estimates. The left and right lines represent the lower and upper bounds for the confidence intervals of each percentile. In this case, the probability plots show that the data points fall approximately on a straight line and within the confidence intervals for the 2-parameter Exponential and 3-

parameter Weibull distributions. Since the p-value of the 3-parameter Weibull distribution is greater than that of the 2-parameter Exponential distribution, the 3-parameter Weibull distribution is chosen as the best fit distribution of the historical industrial electricity price in Oklahoma; and use this best fit distribution to simulate the unit cost of energy purchased from the utility. The shape parameter, the scale parameter, and the threshold parameter of the 3-parameter Weibull distribution are 1.02534, 0.61567, and 3.564, respectively.

In Step 3, simulate the unit cost of the energy purchased from the utility using its best fit distribution.

The random number generation function of the 3-parameter Weibull distribution $(scale \times (-\ln(1 - rand()))^{1/shape} + threshold)$ (Law and Kelton, 2000) is used to simulate the unit cost of the energy purchased from the utility (P_c) in Excel. The function $rand()$ generates a uniformly distributed random number between zero and one. Excel's macro feature allows the scenario to run repetitively for the desired simulation runs while automatically recording the data. These generated values will be used as the parameter P_c .

Simulation of General Inflation Rates

The historical data of the general inflation rate and specific commodity cost/volatility are obtained from the Bureau of Labor Statistics Website (BLS, 2007a). The United States Consumer Price Index (CPI) - all items less food and energy (CUUR0000SA0L1E) - is used as the historical data of the general inflation rate, and is presented in Table 13. At the base period of 1982-1984, the CPI rate of inflation percent

change in CPI is calculated in the column "CPI rate of inflation percent change in CPI" of Table 13 and assigned as the annual general inflation rate.

Table 13 - CPI as an indicator of the United States inflation rates

Year	Consumer Price Index 1984=100.0	CPI Rate of Inflation Percent Change in CPI
1983	99.6	
1984	104.6	5.0
1985	109.1	4.3
1986	113.5	4.0
1987	118.2	4.1
1988	123.4	4.4
1989	129	4.5
1990	135.5	5.0
1991	142.1	4.9
1992	147.3	3.7
1993	152.2	3.3
1994	156.5	2.8
1995	161.2	3.0
1996	165.6	2.7
1997	169.5	2.4
1998	173.4	2.3
1999	177	2.1
2000	181.3	2.4
2001	186.1	2.6
2002	190.5	2.4
2003	193.2	1.4
2004	196.6	1.8
2005	200.9	2.2
2006	205.9	2.5

The correlation coefficient of the historical general inflation rates needs to be determined to simulate the general inflation rates that will be used in the model. After the general inflation rates is simulated with the correlation coefficient from the historical data, a hypothesis test will be performed to determine whether or not the correlation coefficient from the simulated data is significantly different from the correlation coefficient from the historical data. The following steps describe this process.

In Step 1, determine the correlation coefficient of the historical general inflation rates.

The correlation coefficient of the historical general inflation rates is calculated using the Autocorrelation function in Minitab software. It is in the "Stat," "Times series," and "Autocorrelation" menu. The results are shown in the following section.

Autocorrelation Function for CPI Rate of inflation percent change in CPI

Lag	ACF	T	LBQ
1	0.844349	4.05	18.63
2	0.688002	2.12	31.59
3	0.561959	1.47	40.67
4	0.459276	1.10	47.06
5	0.370417	0.84	51.44
6	0.269741	0.60	53.90

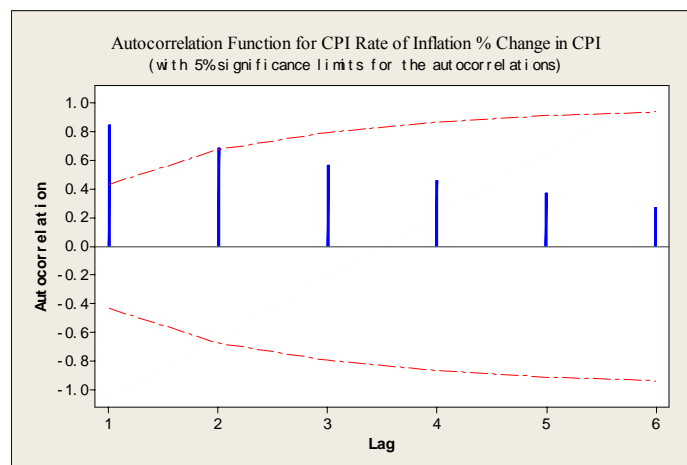


Figure 7 - Autocorrelation function for CPI rate of inflation % change in CPI

In Step 2, interpret the results.

Minitab displays the autocorrelation, associated t-statistics, and Ljung-Box Q statistics. Minitab generates an autocorrelation function (ACF) with the critical α value of 0.05 for the hypothesis that the correlations are equal to zero. In this case, the ACF is 0.844349 at the lag of one, which means that the correlation coefficient of the historical general inflation rates in two continuous years is 0.844349.

In Step 3, simulate the general inflation rates using the correlation coefficient from the historical general inflation rates

Using the equations in Subchapter "Simulation of General Inflation Rates" and the correlation coefficient of the historical general inflation rates, the general inflation rates can be simulated. The simulated data are presented in Table 14. They are applied in the Excel model to calculate the benefits and costs with inflation concerns.

Table 14 - Simulated general inflation rates

Year	Simulated general inflation rates
1	2.267
2	1.848
3	1.628
4	2.015
5	1.652
6	1.093
7	1.195
8	1.842
9	2.418
10	3.507
11	2.383
12	2.595
13	1.901
14	2.986
15	3.327
16	3.72
17	3.716
18	3.124
19	2.584
20	2.82

In Step 4, perform a hypothesis test for the correlation coefficient of the simulated general inflation rates

The "accuracy" of the simulated general inflation rates needs to be tested, which means the correlation coefficient of the simulated general inflation rates needs to be verified. In this part, a hypothesis test will be implemented to test whether or not the correlation coefficient of the simulated general inflation rates is significantly different from the correlation coefficient of the historical general inflation rates.

The correlation coefficient of the historical general inflation rates at the lag of one r_1 is 0.844. Similar to the steps described in the Subchapter "Simulation of General Inflation Rates", the correlation coefficient of the simulated general inflation rates can be

determined via Minitab. The results in the following section show that the correlation coefficient of the simulated general inflation rates at the lag of one r_2 is 0.713.

Autocorrelation Function: Simulated general inflation rates

Lag	ACF	T	LBQ
1	0.713464	3.19	11.79
2	0.477754	1.50	17.37
3	0.181740	0.52	18.22
4	0.149386	0.42	18.84
5	0.160448	0.45	19.59

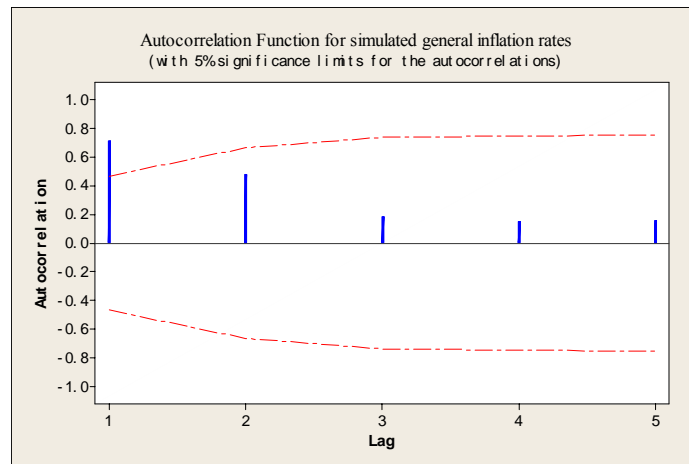


Figure 8 - Autocorrelation function for simulated general inflation rates

At the significance level of p (0.05), the hypothesis test is performed to determine whether or not these two correlation coefficients are significantly different.

$$N = 20$$

$$H_0: r_1 = r_2$$

$$H_1: r_1 \neq r_2$$

The two correlation coefficients are transformed using the Fisher Z-transform formula $z_f = \frac{1}{2} \ln\left(\frac{1+r}{1-r}\right)$. At r_1 of 0.844, the Fisher Z-transform z_{f1} is equal to 1.235. At r_2 of 0.713, the Fisher Z-transform z_{f2} is equal to 0.893. Then the z value is calculated using the equation $\frac{z_{f1} - z_{f2}}{\sqrt{\frac{2}{N-3}}}$ and find z is equal to 0.997.

The significance level p is calculated using the Normsdist function in Excel. With a z value of 0.997, the p value is 0.841. Because this value is greater than 0.05, the hypothesis H_0 at the significance level of 0.05 fails to be rejected. Therefore, the correlation coefficient from the historical general inflation rates r_1 and the correlation coefficient from the simulated general inflation rates r_2 are not significantly different at 0.05 significance level.

Simulation of Specific Commodity Cost/Volatility

The Producer Price Index (PPI) finished goods -Energy (WPUSOP3510) is used as the historical data of the specific commodity cost/volatility, and is presented in Table 15. At the base period of 1982, the annual rate of the percent changes in the PPI is calculated in the column "PPI rate of inflation percent change in PPI" of Table 15, and it is assigned to the annual specific commodity cost/volatility rate.

Table 15 - PPI as an indicator of specific commodity cost/volatility

Year	Producer Price Index (1982 =100.0)	PPI Rate of Volatility Percent Change in PPI
1982	100	
1983	95.2	-4.8
1984	91.2	-4.2
1985	87.6	-3.9
1986	63	-28.1
1987	61.8	-1.9
1988	59.8	-3.2
1989	65.7	9.9
1990	75	14.2
1991	78.1	4.1
1992	77.8	-0.4
1993	78	0.3
1994	77	-1.3
1995	78.1	1.4
1996	83.2	6.5
1997	83.4	0.2
1998	75.1	-10.0
1999	78.8	4.9
2000	94.1	19.4
2001	96.7	2.8
2002	88.8	-8.2
2003	102	14.9
2004	113	10.8
2005	132.6	17.3
2006	145.9	10.0

The correlation coefficient of the historical PPI rates needs to be determined to simulate the specific commodity cost/volatility that will be used in the model. After the specific commodity cost/volatility is simulated with the correlation coefficient from the historical PPI rates, a hypothesis test will be performed to determine whether or not the correlation coefficient from the simulated data is significantly different from the correlation coefficient from the historical data. The following steps describe this process.

In Step 1, determine the correlation coefficient of the historical specific commodity cost/volatility.

The correlation coefficient of the historical PPI rates is calculated using the Autocorrelation function in Minitab software. It is in the "Stat," "Times series," and "Autocorrelation" menu. The results are presented as follows:

Autocorrelation Function: PPI Rate of volatility percent change in PPI

Lag	ACF	T	LBQ
1	0.309918	1.52	2.61
2	0.015200	0.07	2.61
3	0.018895	0.08	2.62
4	-0.023055	-0.10	2.64
5	0.005377	0.02	2.64
6	-0.011296	-0.05	2.64

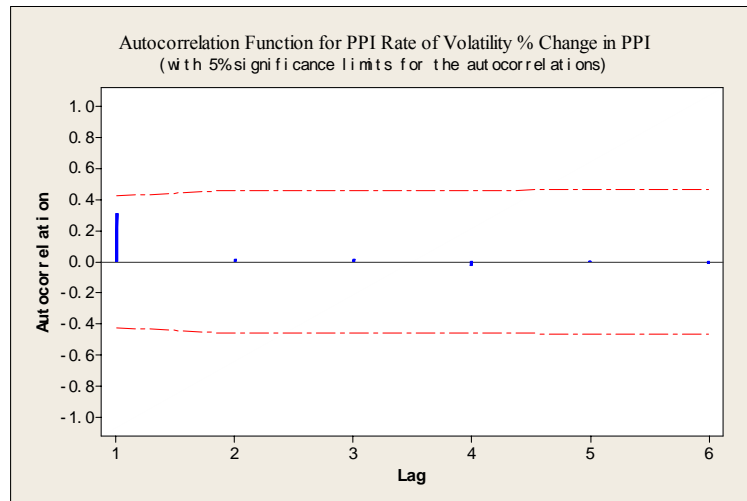


Figure 9 - Autocorrelation function for PPI rate of volatility percent change in PPI

In Step 2, interpret the results.

Minitab displays the autocorrelation, associated t-statistics, and Ljung-Box Q statistics. Minitab generates an autocorrelation function (ACF) with the critical α value of 0.05 for the hypothesis that the correlations are equal to zero. In this case, the ACF is 0.309918 at the lag of one, which means that the correlation coefficient of the historical PPI rates in two continuous years is 0.309918.

In Step 3, simulate the specific commodity cost/volatility rates with the correlation coefficient from the historical data.

Using the equations in Subchapter "Simulation of Specific Commodity Cost/Volatility" and the correlation coefficient of the historical PPI rates, the specific commodity cost/volatility rates can be simulated to be applied in the Excel model to calculate the benefits and costs relative to the energy cost/volatility concerns. The simulated data are presented in Table 16.

Table 16 - Simulated specific commodity cost/volatility

Year	Simulated specific commodity cost/volatility
1	-9.542
2	-12.565
3	1.082
4	-4.666
5	5.751
6	20.083
7	24.842
8	3.272
9	16.177
10	26.846
11	5.074
12	30.357
13	20.009
14	-12.646
15	5.764
16	-4.055
17	7.248
18	26.781
19	12.555
20	16.842

In Step 4, perform a hypothesis test for the correlation coefficient of the simulated specific commodity cost/volatility rates.

Similar to the simulated general inflation rates, the "accuracy" of the simulated specific commodity cost/volatility rates needs to be tested too. In this part, a hypothesis test is performed to determine whether or not if the correlation coefficient of the simulated specific commodity cost/volatility rates is significantly different from the correlation coefficient of the historical specific commodity cost/volatility rates.

The correlation coefficient of the simulated specific commodity cost/volatility rates can be calculated using the Autocorrelation function in Minitab. The results are shown in the following paragraphs.

Autocorrelation Function: Simulated specific commodity cost/volatility

Lag	ACF	T	LBQ
1	0.257804	1.15	1.54
2	0.061640	0.26	1.63
3	0.162426	0.68	2.31
4	-0.380958	-1.56	6.31
5	-0.152244	-0.56	6.99

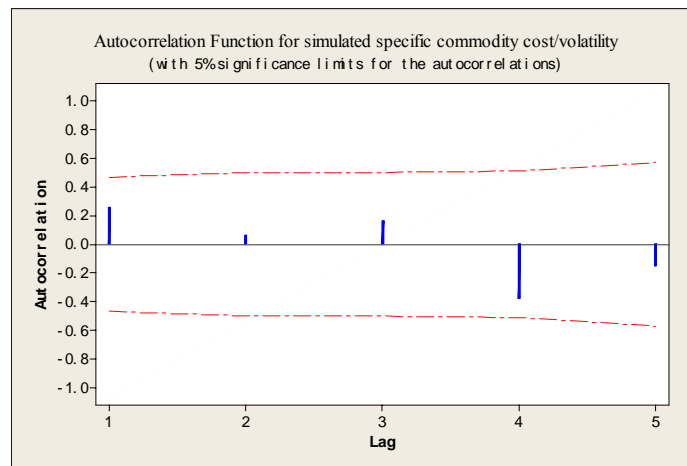


Figure 10 - Autocorrelation function for simulated specific commodity cost/volatility

The session window output shows that the correlation coefficient of the simulated specific commodity cost/volatility rates at the lag of one r_2 is 0.258. The correlation coefficient of the historical specific commodity cost/volatility rates at the lag of one r_1 is 0.310. Now a hypothesis test is performed at the significance level of 0.05.

$$N = 20$$

$$H_0: r_1 = r_2$$

$$H_1: r_1 \neq r_2$$

The two correlation coefficients are transformed with the Fisher Z-transform formula $z_f = \frac{1}{2} \ln\left(\frac{1+r}{1-r}\right)$. At r_1 of 0.310, the Fisher Z-transform z_{f1} is equal to 0.321. At r_2 of 0.258, the Fisher Z-transform z_{f2} is equal to 0.264. Then the z value is calculated using the equation $\frac{z_{f1} - z_{f2}}{\sqrt{\frac{2}{N-3}}}$ and it is 0.166.

The significance level p can be calculated using the Normsdist function in Excel. With the z value of 0.166, the p value is 0.566. Because this value is greater than 0.05, the hypothesis H_0 fails to be rejected at the significance level of 0.05. Therefore, the correlation coefficient from the historical specific commodity cost/volatility rates r_1 and the correlation coefficient from the simulated specific commodity cost/volatility rates r_2 are not significantly different at the 0.05 significance level.

Simulation of the Demand/Capacity of the System

The maximum, minimum and mode values relative to the demand/capacity of the system can be obtained from the experts, the manufacturers of the system, and the users. Based on these values, the demand/capacity of the system can be simulated with a triangular distribution.

A triangular distribution can be described by three parameters: minimum, maximum, and mode. The minimum and maximum define the range of the triangular distribution while the mode is the most likely value. In this hypothesis case, assume the minimum, mode, and maximum values for the demand/capacity of the system are 23,000 kW, 25,000 kW, and 26,000 kW respectively.

The random number generation function of a triangular distribution
 $=\text{IF}(\text{RAND}() < (\text{MODE} - \text{MIN}) / (\text{MAX} - \text{MIN}), \text{MIN} + \text{SQRT}(\text{RAND}() * (\text{MODE} - \text{MIN}) * (\text{MAX} - \text{MIN})), \text{MAX} - \text{SQRT}((1 - \text{RAND}()) * (\text{MAX} - \text{MODE}) * (\text{MAX} - \text{MIN})))$ (Law and Kelton, 2000) is used to simulate the demand/capacity of the system in Excel. The function rand() generates a uniformly distributed random number between zero and one in Excel. The MAX and MIN are the maximum and minimum values of the triangular distribution respectively. The user can change the value of the demand/capacity very easily by pressing the recalculation key, F9. When the recalculation is requested, the value of the input demand/capacity of the system is updated, and a new calculation is performed.

Development of Discrete Inputs

As it has been mentioned earlier in Subchapter "Application of the Model in a Probabilistic Environment", the model inputs can be described as probabilistic and deterministic. Further, the deterministic inputs are separated into deterministic values and discrete arrays. In this section, the development of the deterministic inputs will be presented. There are five deterministic inputs which can be described by the discrete arrays in this project: the relationship between the price of sold energy and the price of purchased energy, the availability/yield of the system, the loan term of the client, the loan term of the ESCO, and the performance contract sharing rate. Based on the literature review and expert opinions, the range of each discrete array can be defined. For illustration purposes, three values are listed in each discrete array. The number of the

values in the discrete array can be increased, depending on the complexity of a project or the preference of the users.

Development of "Relationship between the Price of Sold Energy and the Price of Purchased Energy"

Before the CHP system is installed at the client's site, the client purchases energy from the utility at a price P_c (\$/kWh). After the CHP system is installed, it recovers the waste heat from the stack gas to generate energy; the energy will meet the production requirement of the client first. If there is any excess energy, the client will negotiate with the utility and sell the excess energy back to the utility at a specific price (\$/kWh). There is a relationship between the price of sold energy and the price of purchased energy P_c . This relationship can be described by a percentage rate (PR). Bhattacharyya points out that this rate is usually between 60% to 70% (Bhattacharyya & Thang, 2004). If there is no excess energy, this rate is zero. Since this rate is not a single deterministic value, it is described by a discrete array (60%, 65%, 70%).

Development of "Availability/Yield of the System"

The benefits (\$) from installing the CHP system is determined by its energy output (kWh). The output is the multiplication of two inputs: the demand/capacity of the system and the availability/yield of the system. The demand/capacity of the system is described by a triangular distribution. The availability/yield of the system is referred to as a discrete array (80%, 86%, 90%) based on the user's experience.

Development of "Loan Term of the Client"

The client borrows money in the form of a loan from a financial institution to purchase the CHP system at year zero of the project. The amount of the loan depends on the credit history and financial statements of the client. The client pays the loan principal and the interest on the loan. The client and the financial institution agree on a loan term, the time it takes for the client to pay off the loan. The loan term is fixed and features the amortization of the loan principal. In this case, the client pays an equal amount of money annually to the financial institution. This amount is the sum of annual principal and interest payments. The loan term varies among projects, and is based on the client's circumstances and the useful life of the CHP system. The Oregon Department of Energy administered the Small Scale Energy Loan Program (SELP) in 1981. The term of SELP varies and generally is in the range of 5 to 15 years (DSIRE, 2007). Referring to this case, the values of the discrete array for the client's loan term are (5, 10, 15).

Development of "Performance Contract Sharing Rate"

If the value of the energy (kWh) generated from the system is greater than or equal to the energy value (kWh) guaranteed by the ESCO, the client will share with the ESCO a percentage of the benefit from installing the CHP system. The benefit is calculated as:

$$\text{Benefit} = A + B - C$$

Where A = The savings from the client's internal energy usage

B = The revenue from selling the excess energy back to the utility

C = The cost of the energy that the client purchases from the utility when the system is under maintenance

The percentage (performance contract sharing rate) is an established rate negotiated by both client and ESCO at the time of building the ESPC. The percentage used is usually 80% to 90% of the benefits (Hansen, 1992). In this case, the values of the discrete array for the performance contract sharing rate are (80%, 85%, 90%).

Development of "Loan Term of the ESCO"

The ESCO borrows money in the form of a loan from a financial institution to pay the transportation and installation costs at year zero of the project. Similar to the client's loan, the amount of the ESCO's loan depends on the ESCO's credit history and financial statements. The ESCO pays the loan principal and the interest on the loan. The terms and conditions in the contract between the ESCO and the financial institution determine the time it takes for the ESCO to pay off the loan. This period of time is called the loan term. It is fixed and features the amortization of the loan principal. In this case, the ESCO pays an equal amount of money annually to the financial institution. This amount is the sum of annual principal payment and interest payments. The loan term varies among projects, and is based on the useful life of the system. In this case, the values of the discrete array for the ESCO's loan term are (5, 10, 15).

Model Development in Multiple Scenarios

In this section, the Excel model is developed in multiple scenarios. The probabilistic inputs are developed by the Monte Carlo simulation which relies on random

number generation. The unit cost of energy purchased from the utility P_c is simulated based on its best fit distribution (3-parameter Weibull distribution, in this case). The general inflation rate and the specific commodity cost/volatility are simulated based on the correlation coefficients from their historical data. The demand/capacity of the system is simulated based on a triangular distribution. These simulations are done in Excel using the macro function. With this function, obtaining results from the simulations is rapid and simple. Macros are created for automating re-calculation, varying parameters, and collecting results. The Macro codes used to automate the simulation and record the results are presented in Appendix A. The codes demonstrate how simulation runs are replicated in the spreadsheet "Sum", the results of individual runs are saved and recorded in another spreadsheet "Summary". Except where noted, the macro recording is done automatically as commands are executed using Excel's "Macro" feature in the "Tools" menu. Once the recording is done, the users can later change the number of the simulation runs using the "Macro" and "Edit" commands.

The chosen random values of the simulated probabilistic inputs, combined with the values randomly chosen from two deterministic inputs which make up discrete arrays, are entered in each scenario. Because there are five such deterministic inputs and three values in each discrete array, using the equation $3 \times 3 \times C_2^5$, there will be 90 scenarios. The scenarios are presented in Table 17. Scenario analysis is a description of a possible future state and constructs multiple scenarios of the future.

Table 17 - List of scenarios

	X - DETERMINISTIC INPUT		Y - DETERMINISTIC INPUT	
1	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Availability/yield of the system (AS)	80%
2	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Availability/yield of the system (AS)	86%
3	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Availability/yield of the system (AS)	90%
4	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Availability/yield of the system (AS)	80%
5	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Availability/yield of the system (AS)	86%
6	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Availability/yield of the system (AS)	90%
7	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Availability/yield of the system (AS)	80%
8	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Availability/yield of the system (AS)	86%
9	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Availability/yield of the system (AS)	90%
10	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Loan term of the client (yrs)	5
11	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Loan term of the client (yrs)	10
12	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Loan term of the client (yrs)	15
13	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Loan term of the client (yrs)	5
14	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Loan term of the client (yrs)	10
15	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Loan term of the client (yrs)	15
16	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Loan term of the client (yrs)	5
17	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Loan term of the client (yrs)	10
18	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Loan term of the client (yrs)	15
19	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Performance contract sharing rate (PSR)	80%
20	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Performance contract sharing rate (PSR)	85%
21	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Performance contract sharing rate (PSR)	90%
22	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Performance contract sharing rate (PSR)	80%
23	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Performance contract sharing rate (PSR)	85%
24	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Performance contract sharing rate (PSR)	90%
25	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Performance contract sharing rate (PSR)	80%
26	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Performance contract sharing rate (PSR)	85%
27	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Performance contract sharing rate (PSR)	90%
28	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Loan term of the ESCO (yrs)	5
29	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Loan term of the ESCO (yrs)	10
30	Relationship between the price of sold energy and price of purchased energy (PR)	60%	Loan term of the ESCO (yrs)	15

Table 17 Cont'd - List of scenarios

31	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Loan term of the ESCO (yrs)	5
32	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Loan term of the ESCO (yrs)	10
33	Relationship between the price of sold energy and price of purchased energy (PR)	65%	Loan term of the ESCO (yrs)	15
34	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Loan term of the ESCO (yrs)	5
35	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Loan term of the ESCO (yrs)	10
36	Relationship between the price of sold energy and price of purchased energy (PR)	70%	Loan term of the ESCO (yrs)	15
37	Availability/yield of the system (AS)	80%	Loan term of the client (yrs)	5
38	Availability/yield of the system (AS)	80%	Loan term of the client (yrs)	10
39	Availability/yield of the system (AS)	80%	Loan term of the client (yrs)	15
40	Availability/yield of the system (AS)	86%	Loan term of the client (yrs)	5
41	Availability/yield of the system (AS)	86%	Loan term of the client (yrs)	10
42	Availability/yield of the system (AS)	86%	Loan term of the client (yrs)	15
43	Availability/yield of the system (AS)	90%	Loan term of the client (yrs)	5
44	Availability/yield of the system (AS)	90%	Loan term of the client (yrs)	10
45	Availability/yield of the system (AS)	90%	Loan term of the client (yrs)	15
46	Availability/yield of the system (AS)	80%	Performance contract sharing rate (PSR)	80%
47	Availability/yield of the system (AS)	80%	Performance contract sharing rate (PSR)	85%
48	Availability/yield of the system (AS)	80%	Performance contract sharing rate (PSR)	90%
49	Availability/yield of the system (AS)	86%	Performance contract sharing rate (PSR)	80%
50	Availability/yield of the system (AS)	86%	Performance contract sharing rate (PSR)	85%
51	Availability/yield of the system (AS)	86%	Performance contract sharing rate (PSR)	90%
52	Availability/yield of the system (AS)	90%	Performance contract sharing rate (PSR)	80%
53	Availability/yield of the system (AS)	90%	Performance contract sharing rate (PSR)	85%
54	Availability/yield of the system (AS)	90%	Performance contract sharing rate (PSR)	90%
55	Availability/yield of the system (AS)	80%	Loan term of the ESCO (yrs)	5
56	Availability/yield of the system (AS)	80%	Loan term of the ESCO (yrs)	10
57	Availability/yield of the system (AS)	80%	Loan term of the ESCO (yrs)	15
58	Availability/yield of the system (AS)	86%	Loan term of the ESCO (yrs)	5
59	Availability/yield of the system (AS)	86%	Loan term of the ESCO (yrs)	10
60	Availability/yield of the system (AS)	86%	Loan term of the ESCO (yrs)	15

Table 17 Cont'd - List of scenarios

61	Availability/yield of the system (AS)	90%	Loan term of the ESCO (yrs)	5
62	Availability/yield of the system (AS)	90%	Loan term of the ESCO (yrs)	10
63	Availability/yield of the system (AS)	90%	Loan term of the ESCO (yrs)	15
64	Loan term of the client (yrs)	5	Performance contract sharing rate (PSR)	80%
65	Loan term of the client (yrs)	5	Performance contract sharing rate (PSR)	85%
66	Loan term of the client (yrs)	5	Performance contract sharing rate (PSR)	90%
67	Loan term of the client (yrs)	10	Performance contract sharing rate (PSR)	80%
68	Loan term of the client (yrs)	10	Performance contract sharing rate (PSR)	85%
69	Loan term of the client (yrs)	10	Performance contract sharing rate (PSR)	90%
70	Loan term of the client (yrs)	15	Performance contract sharing rate (PSR)	80%
71	Loan term of the client (yrs)	15	Performance contract sharing rate (PSR)	85%
72	Loan term of the client (yrs)	15	Performance contract sharing rate (PSR)	90%
73	Loan term of the client (yrs)	5	Loan term of the ESCO (yrs)	5
74	Loan term of the client (yrs)	5	Loan term of the ESCO (yrs)	10
75	Loan term of the client (yrs)	5	Loan term of the ESCO (yrs)	15
76	Loan term of the client (yrs)	10	Loan term of the ESCO (yrs)	5
77	Loan term of the client (yrs)	10	Loan term of the ESCO (yrs)	10
78	Loan term of the client (yrs)	10	Loan term of the ESCO (yrs)	15
79	Loan term of the client (yrs)	15	Loan term of the ESCO (yrs)	5
80	Loan term of the client (yrs)	15	Loan term of the ESCO (yrs)	10
81	Loan term of the client (yrs)	15	Loan term of the ESCO (yrs)	15
82	Performance contract sharing rate (PSR)	80%	Loan term of the ESCO (yrs)	5
83	Performance contract sharing rate (PSR)	80%	Loan term of the ESCO (yrs)	10
84	Performance contract sharing rate (PSR)	80%	Loan term of the ESCO (yrs)	15
85	Performance contract sharing rate (PSR)	85%	Loan term of the ESCO (yrs)	5
86	Performance contract sharing rate (PSR)	85%	Loan term of the ESCO (yrs)	10
87	Performance contract sharing rate (PSR)	85%	Loan term of the ESCO (yrs)	15
88	Performance contract sharing rate (PSR)	90%	Loan term of the ESCO (yrs)	5
89	Performance contract sharing rate (PSR)	90%	Loan term of the ESCO (yrs)	10
90	Performance contract sharing rate (PSR)	90%	Loan term of the ESCO (yrs)	15

In each scenario, 500-time simulations are run initially as mentioned in Subchapter "Determination of Simulation Runs". After the simulation is completed, the NPV outputs of the client and the ESCO are transferred from each simulation run into a row of another spreadsheet "Summary" in the same workbook for further processing. The "Summary" table in a scenario is used as an example (Table 18). The first two columns, "Unit cost of energy purchased from the utility" and "Demand/capacity of the system", depict the values of these two probabilistic inputs from each simulation. The columns, "General inflation" and "Specific commodity cost/volatility", present the average value of these two probabilistic inputs simulated over 20 years. The columns, "Client's NPV" and "ESCO's NPV", store the NPV values of the client and the ESCO from each simulation. Additional rows represent additional Monte Carlo runs, which as a result generate 500 rows of NPVs of the client and the ESCO. In each row, the "IF" function in Excel is used to segregate the positive NPV value from the negative values. If the NPV value of the client is positive, the column "Client's positive NPV" shows one; otherwise, the column shows zero. The same function is used in the column "ESCO's positive NPV". If the NPVs of both client and ESCO are positive, the column, "Both positive" shows one. Otherwise, the column shows zero. Since the results of individual Monte Carlo runs are recorded in successive rows in a single column, the "1"s are counted in the column, and then the sum is divided by the number of simulation runs. Then the percentage of the ESPC which indicates a win-win strategy for both client and ESCO in each scenario is obtained.

Table 18 - Items in spreadsheet "Summary"

Unit cost of energy purchased from the utility	Demand/capacity of the system	General inflation	Specific commodity cost/volatility	Client's NPV	ESCO's NPV	Client's positive NPV	ESCO's positive NPV	Both positive

Results of Scenarios after 500 Simulation Runs

A Macro code (Appendix A.1) was written to run the simulation 500 times and automatically tabulate the data. Each 500 simulations take 30 seconds to run on a Pentium M 1.86 GHz desktop computer. The NPV outputs of the client and ESCO, their mean, standard deviation, half width of a two-side confidence interval (CI), and the rate "half width of a two-side CI/mean in %" are presented in Table 19. The maximum absolute value of "half width of a two-side CI/mean in %" is 191.83%, which is taken from Scenario 5.

Table 19 - List of scenario results after 500 simulation runs

Confidence level in % 95%
Trial size 500

SCENARIOS	Party	Mean	Standard Deviation	Half Width of a Two-Side Confidence Interval (CI)	Half Width of a Two-Side CI/Mean in %	% of Positive NPV	% of Positive NPV for Both Client and ESCO
1	Client	\$ 17,127,632	\$ 41,210,550	\$ 3,612,198	21.09%	56.80%	0.00%
	ESCO	\$ -16,561,085	\$ 2,414,935	\$ 211,675	-1.28%	0.00%	
2	Client	\$ -692,502	\$ 5,855,810	\$ 513,275	-74.12%	32.20%	8.40%
	ESCO	\$ 3,844,638	\$ 46,381,015	\$ 4,065,401	105.74%	34.20%	
3	Client	\$ -4,678,796	\$ 4,773,089	\$ 418,372	-8.94%	10.80%	10.80%
	ESCO	\$ 8,481,325	\$ 43,592,025	\$ 3,820,939	45.05%	36.60%	
4	Client	\$ 20,357,143	\$ 46,669,925	\$ 4,090,724	20.09%	62.20%	0.20%
	ESCO	\$ -16,385,023	\$ 2,662,637	\$ 233,386	-1.42%	0.20%	
5	Client	\$ 288,145	\$ 6,306,226	\$ 552,755	191.83%	39.40%	10.20%
	ESCO	\$ 5,717,860	\$ 46,563,761	\$ 4,081,419	71.38%	37.00%	
6	Client	\$ -4,487,987	\$ 5,583,804	\$ 489,433	-10.91%	10.40%	10.00%
	ESCO	\$ 10,953,472	\$ 50,577,464	\$ 4,433,229	40.47%	39.20%	
7	Client	\$ 21,198,544	\$ 43,395,152	\$ 3,803,683	17.94%	67.80%	0.20%
	ESCO	\$ -16,621,208	\$ 2,340,107	\$ 205,116	-1.23%	0.20%	
8	Client	\$ 1,181,395	\$ 6,868,649	\$ 602,053	50.96%	44.80%	10.40%
	ESCO	\$ 7,757,565	\$ 53,185,075	\$ 4,661,792	60.09%	37.60%	
9	Client	\$ -3,854,054	\$ 7,416,818	\$ 650,101	-16.87%	12.40%	12.20%
	ESCO	\$ 16,213,774	\$ 67,111,232	\$ 5,882,451	36.28%	40.20%	
10	Client	\$ -2,243,120	\$ 7,036,378	\$ 616,754	-27.50%	23.60%	5.80%
	ESCO	\$ 5,297,751	\$ 61,675,011	\$ 5,405,954	102.04%	36.20%	
11	Client	\$ 1,040,704	\$ 6,079,526	\$ 532,884	51.20%	41.60%	10.40%
	ESCO	\$ 4,666,032	\$ 48,390,461	\$ 4,241,533	90.90%	36.60%	
12	Client	\$ 3,402,804	\$ 5,084,088	\$ 445,632	13.10%	71.20%	23.40%
	ESCO	\$ 3,737,454	\$ 40,955,221	\$ 3,589,817	96.05%	35.60%	
13	Client	\$ -1,169,407	\$ 7,311,495	\$ 640,869	-54.80%	30.80%	8.20%
	ESCO	\$ 7,753,137	\$ 63,481,133	\$ 5,564,264	71.77%	33.60%	
14	Client	\$ 1,833,305	\$ 6,130,798	\$ 537,378	29.31%	50.40%	11.60%
	ESCO	\$ 3,972,329	\$ 45,537,545	\$ 3,991,468	100.48%	36.40%	
15	Client	\$ 3,643,077	\$ 5,718,977	\$ 501,281	13.76%	72.60%	22.40%
	ESCO	\$ 3,913,311	\$ 45,964,283	\$ 4,028,873	102.95%	37.40%	
16	Client	\$ -1,693,772	\$ 5,557,197	\$ 487,101	-28.76%	29.40%	9.80%
	ESCO	\$ 10,537,208	\$ 48,425,126	\$ 4,244,571	40.28%	45.40%	
17	Client	\$ 2,301,130	\$ 6,583,519	\$ 577,060	25.08%	52.40%	12.20%
	ESCO	\$ 3,743,585	\$ 48,130,135	\$ 4,218,715	112.69%	38.40%	
18	Client	\$ 4,184,803	\$ 5,637,011	\$ 494,097	11.81%	77.20%	26.20%
	ESCO	\$ 7,792,326	\$ 46,520,854	\$ 4,077,658	52.33%	41.00%	
19	Client	\$ 2,119,487	\$ 9,420,171	\$ 825,699	38.96%	44.80%	22.40%
	ESCO	\$ 3,125,046	\$ 41,944,592	\$ 3,676,538	117.65%	37.20%	
20	Client	\$ 518,806	\$ 7,440,736	\$ 652,197	125.71%	38.20%	15.40%
	ESCO	\$ 2,303,130	\$ 44,129,965	\$ 3,868,091	167.95%	32.80%	
21	Client	\$ -541,465	\$ 5,757,553	\$ 504,663	-93.20%	35.80%	10.20%
	ESCO	\$ 5,697,990	\$ 49,517,464	\$ 4,340,317	76.17%	36.00%	
22	Client	\$ 3,246,691	\$ 10,925,151	\$ 957,614	29.50%	54.00%	25.40%
	ESCO	\$ 3,736,297	\$ 48,022,101	\$ 4,209,245	112.66%	35.00%	
23	Client	\$ 1,200,314	\$ 9,399,047	\$ 823,848	68.64%	40.80%	13.80%
	ESCO	\$ 3,126,589	\$ 56,210,136	\$ 4,926,945	157.58%	32.80%	
24	Client	\$ -345,523	\$ 5,927,356	\$ 519,546	-150.37%	34.40%	8.20%
	ESCO	\$ 3,610,785	\$ 46,547,569	\$ 4,079,999	112.99%	37.00%	
25	Client	\$ 3,309,872	\$ 8,995,040	\$ 788,436	23.82%	54.40%	25.40%
	ESCO	\$ 3,712,888	\$ 40,895,479	\$ 3,584,581	96.54%	35.20%	
26	Client	\$ 2,942,733	\$ 9,150,023	\$ 802,020	27.25%	49.80%	17.40%
	ESCO	\$ 6,666,922	\$ 55,083,187	\$ 4,828,165	72.42%	35.00%	
27	Client	\$ 309,948	\$ 6,419,029	\$ 562,642	181.53%	41.20%	8.60%
	ESCO	\$ 3,718,291	\$ 49,288,891	\$ 4,320,282	116.19%	35.20%	
28	Client	\$ -859,554	\$ 5,338,040	\$ 467,891	-54.43%	33.40%	9.20%
	ESCO	\$ 3,211,520	\$ 46,084,261	\$ 4,039,389	125.78%	32.40%	
29	Client	\$ -460,957	\$ 5,942,168	\$ 520,844	-112.99%	35.00%	8.00%
	ESCO	\$ 4,272,454	\$ 50,009,493	\$ 4,383,445	102.60%	34.40%	
30	Client	\$ -771,638	\$ 5,632,429	\$ 493,695	-63.98%	32.80%	8.00%
	ESCO	\$ 3,142,042	\$ 44,038,566	\$ 3,860,080	122.85%	35.60%	

Table 19 Cont'd - List of scenario results after 500 simulation runs

	Client	\$ -282,630	\$ 5,855,892	\$ 513,282	-181.61%	35.40%	
31	ESCO	\$ 3,677,181	\$ 44,170,429	\$ 3,871,638	105.29%	37.80%	9.00%
	Client	\$ -441,954	\$ 5,921,275	\$ 519,013	-117.44%	34.20%	
32	ESCO	\$ 6,954,443	\$ 50,292,809	\$ 4,408,278	63.39%	40.00%	9.80%
	Client	\$ -562,093	\$ 5,238,370	\$ 459,155	-81.69%	36.60%	
33	ESCO	\$ 2,186,379	\$ 39,571,431	\$ 3,468,525	158.64%	35.40%	8.40%
	Client	\$ 398,241	\$ 5,748,220	\$ 503,844	126.52%	41.40%	
34	ESCO	\$ 7,289,584	\$ 47,932,005	\$ 4,201,348	57.63%	38.60%	11.00%
	Client	\$ 413,982	\$ 6,005,066	\$ 526,358	127.14%	41.20%	
35	ESCO	\$ 5,279,785	\$ 46,481,974	\$ 4,074,250	77.17%	37.00%	9.20%
	Client	\$ 679,093	\$ 6,701,072	\$ 587,364	86.49%	39.80%	
36	ESCO	\$ 9,272,630	\$ 56,878,858	\$ 4,985,560	53.77%	37.40%	10.60%
	Client	\$ 18,892,078	\$ 44,475,905	\$ 3,898,413	20.64%	55.80%	
37	ESCO	\$ -16,431,762	\$ 2,540,117	\$ 222,647	-1.35%	0.00%	0.00%
	Client	\$ 24,388,484	\$ 51,126,485	\$ 4,481,352	18.37%	73.00%	
38	ESCO	\$ -16,390,754	\$ 2,710,487	\$ 237,580	-1.45%	0.20%	0.20%
	Client	\$ 23,618,985	\$ 40,479,469	\$ 3,548,117	15.02%	88.00%	
39	ESCO	\$ -16,597,144	\$ 2,322,483	\$ 203,571	-1.23%	0.00%	0.00%
	Client	\$ -1,485,549	\$ 5,638,959	\$ 494,267	-33.27%	31.00%	
40	ESCO	\$ 4,022,149	\$ 43,626,915	\$ 3,823,997	95.07%	34.60%	8.40%
	Client	\$ 1,786,046	\$ 6,025,457	\$ 528,145	29.57%	49.60%	
41	ESCO	\$ 4,387,026	\$ 43,748,658	\$ 3,834,668	87.41%	36.60%	14.00%
	Client	\$ 3,944,934	\$ 5,627,779	\$ 493,287	12.50%	72.80%	
42	ESCO	\$ 5,852,718	\$ 48,857,643	\$ 4,282,483	73.17%	36.40%	21.00%
	Client	\$ -6,055,625	\$ 4,417,346	\$ 387,190	-6.39%	8.80%	
43	ESCO	\$ 8,101,170	\$ 40,063,001	\$ 3,511,612	43.35%	36.60%	8.40%
	Client	\$ -2,156,764	\$ 6,300,814	\$ 552,281	-25.61%	18.60%	
44	ESCO	\$ 14,314,166	\$ 57,281,368	\$ 5,020,841	35.08%	42.40%	16.80%
	Client	\$ -454,013	\$ 4,125,794	\$ 361,635	-79.65%	30.80%	
45	ESCO	\$ 6,791,002	\$ 37,073,456	\$ 3,249,572	47.85%	38.40%	22.00%
	Client	\$ 17,395,231	\$ 39,634,434	\$ 3,474,048	19.97%	60.60%	
46	ESCO	\$ -16,705,999	\$ 2,226,468	\$ 195,155	-1.17%	0.00%	0.00%
	Client	\$ 22,415,729	\$ 50,329,783	\$ 4,411,519	19.68%	63.60%	
47	ESCO	\$ -16,298,287	\$ 2,777,482	\$ 243,453	-1.49%	0.20%	0.20%
	Client	\$ 19,748,563	\$ 48,034,323	\$ 4,210,317	21.32%	63.00%	
48	ESCO	\$ -16,495,571	\$ 2,547,305	\$ 223,277	-1.35%	0.40%	0.40%
	Client	\$ 3,111,013	\$ 11,338,920	\$ 993,882	31.95%	48.60%	
49	ESCO	\$ 5,847,073	\$ 50,616,890	\$ 4,436,685	75.88%	38.60%	25.00%
	Client	\$ 1,340,495	\$ 7,117,479	\$ 623,863	46.54%	42.60%	
50	ESCO	\$ 4,647,001	\$ 44,054,122	\$ 3,861,443	83.10%	36.80%	16.80%
	Client	\$ 387,628	\$ 7,687,630	\$ 673,838	173.84%	38.40%	
51	ESCO	\$ 7,326,543	\$ 64,688,879	\$ 5,670,126	77.39%	35.40%	10.20%
	Client	\$ -771,676	\$ 10,499,174	\$ 920,276	-119.26%	25.40%	
52	ESCO	\$ 7,497,624	\$ 42,462,903	\$ 3,721,969	49.64%	37.80%	24.60%
	Client	\$ -2,259,536	\$ 9,150,859	\$ 802,093	-35.50%	18.60%	
53	ESCO	\$ 10,123,533	\$ 52,688,055	\$ 4,618,227	45.62%	36.40%	17.40%
	Client	\$ -4,704,501	\$ 4,761,256	\$ 417,335	-8.87%	9.80%	
54	ESCO	\$ 7,540,101	\$ 43,221,921	\$ 3,788,499	50.24%	37.00%	9.60%
	Client	\$ 21,076,461	\$ 45,837,218	\$ 4,017,735	19.06%	62.80%	
55	ESCO	\$ -16,604,430	\$ 2,578,409	\$ 226,003	-1.36%	0.20%	0.20%
	Client	\$ 18,364,787	\$ 39,804,089	\$ 3,488,918	19.00%	62.20%	
56	ESCO	\$ -16,421,053	\$ 2,325,164	\$ 203,806	-1.24%	0.20%	0.20%
	Client	\$ 23,647,310	\$ 55,393,358	\$ 4,855,353	20.53%	61.20%	
57	ESCO	\$ -15,991,090	\$ 2,886,700	\$ 253,026	-1.58%	0.80%	0.80%
	Client	\$ -282,152	\$ 5,463,922	\$ 478,925	-169.74%	37.20%	
58	ESCO	\$ 3,590,081	\$ 42,731,121	\$ 3,745,479	104.33%	34.80%	9.00%
	Client	\$ -542,344	\$ 5,607,654	\$ 491,524	-90.63%	35.00%	
59	ESCO	\$ 4,595,849	\$ 42,940,435	\$ 3,763,826	81.90%	38.80%	8.80%
	Client	\$ -599,802	\$ 5,797,024	\$ 508,122	-84.72%	33.40%	
60	ESCO	\$ 4,161,466	\$ 45,849,022	\$ 4,018,770	96.57%	36.60%	7.80%

Macro code used to run 5,000 simulations is presented in the Appendix A.2. The results from the scenarios after 5,000 simulation runs are presented in Table 20. It takes 90 seconds to run 5,000 simulations for each scenario on a Pentium M 1.86 GHz desktop computer. The maximum absolute value of "half width of a two-side CI/mean in %" is 120.35%, which is from Scenario 5.

Table 21 Cont'd - List of scenario results after 32,767 simulation runs

61	Client	\$ -4,500,524	\$ 5,642,727	\$ 61,097	-1.36%	10.45%	9.95%
	ESCO	\$ 9,869,734	\$ 51,082,413	\$ 553,097	5.60%	37.83%	
62	Client	\$ -4,545,241	\$ 5,356,758	\$ 58,001	-1.28%	10.12%	9.73%
	ESCO	\$ 9,764,313	\$ 48,543,954	\$ 525,612	5.38%	38.02%	
63	Client	\$ -4,475,389	\$ 5,404,962	\$ 58,522	-1.31%	10.53%	10.04%
	ESCO	\$ 10,621,069	\$ 49,009,295	\$ 530,650	5.00%	39.03%	
64	Client	\$ 1,160,256	\$ 9,863,438	\$ 106,797	9.20%	40.26%	18.57%
	ESCO	\$ 2,110,702	\$ 43,623,753	\$ 472,338	22.38%	34.12%	
65	Client	\$ -297,673	\$ 7,474,254	\$ 80,928	-27.19%	34.36%	13.15%
	ESCO	\$ 3,391,290	\$ 44,733,948	\$ 484,359	14.28%	35.53%	
66	Client	\$ -1,701,608	\$ 6,001,125	\$ 64,977	-3.82%	28.42%	7.20%
	ESCO	\$ 4,912,496	\$ 47,970,975	\$ 519,408	10.57%	36.71%	
67	Client	\$ 4,600,610	\$ 10,142,324	\$ 109,816,407	2.39%	64.67%	28.13%
	ESCO	\$ 2,433,219	\$ 44,758,154	\$ 484,621	19.92%	34.02%	
68	Client	\$ 3,180,993	\$ 7,866,178	\$ 85,171	2.68%	58.02%	21.01%
	ESCO	\$ 3,598,460	\$ 47,099,276	\$ 509,969	14.17%	35.43%	
69	Client	\$ 1,733,989	\$ 6,167,289	\$ 66,777	3.85%	49.76%	13.39%
	ESCO	\$ 5,342,547	\$ 49,626,633	\$ 537,334	10.06%	36.86%	
70	Client	\$ 6,922,503	\$ 9,614,664	\$ 104,103	1.50%	90.91%	34.00%
	ESCO	\$ 2,143,015	\$ 42,743,162	\$ 462,803	21.60%	34.00%	
71	Client	\$ 5,524,601	\$ 7,623,079	\$ 82,539	1.49%	84.29%	32.10%
	ESCO	\$ 3,740,857	\$ 45,811,196	\$ 496,023	13.26%	35.46%	
72	Client	\$ 4,100,105	\$ 5,986,526	\$ 64,819	1.58%	74.76%	22.45%
	ESCO	\$ 5,024,020	\$ 47,678,790	\$ 516,244	10.28%	36.66%	
73	Client	\$ -1,646,685	\$ 6,038,565	\$ 65,383	-3.97%	28.82%	7.35%
	ESCO	\$ 4,874,372	\$ 48,418,779	\$ 524,256	10.76%	36.40%	
74	Client	\$ -1,701,080	\$ 6,019,065	\$ 65,172	-3.83%	28.35%	7.31%
	ESCO	\$ 5,056,386	\$ 47,704,974	\$ 516,527	10.22%	36.89%	
75	Client	\$ -1,733,599	\$ 6,017,557	\$ 65,155	-3.76%	28.21%	7.06%
	ESCO	\$ 5,008,171	\$ 47,708,599	\$ 516,567	10.31%	37.12%	
76	Client	\$ 1,638,922	\$ 6,050,192	\$ 65,509	4.00%	49.29%	13.08%
	ESCO	\$ 4,771,396	\$ 48,051,175	\$ 520,276	10.90%	36.81%	
77	Client	\$ 1,676,657	\$ 5,999,163	\$ 64,956	3.87%	49.95%	13.30%
	ESCO	\$ 5,029,889	\$ 47,914,392	\$ 518,795	10.31%	36.64%	
78	Client	\$ 1,706,140	\$ 6,199,358	\$ 67,124	3.93%	49.92%	13.48%
	ESCO	\$ 5,709,215	\$ 50,133,391	\$ 542,821	9.51%	37.25%	
79	Client	\$ 4,170,110	\$ 6,079,036	\$ 65,821	1.58%	74.76%	22.83%
	ESCO	\$ 5,435,047	\$ 48,843,965	\$ 528,860	9.73%	37.05%	
80	Client	\$ 4,080,268	\$ 6,060,083	\$ 65,616	1.61%	74.61%	22.67%
	ESCO	\$ 5,275,940	\$ 48,646,156	\$ 526,718	9.98%	37.16%	
81	Client	\$ 4,173,357	\$ 6,145,859	\$ 66,545	1.59%	75.19%	22.79%
	ESCO	\$ 5,851,793	\$ 49,552,281	\$ 536,529	9.17%	37.20%	
82	Client	\$ 2,685,750	\$ 9,997,896	\$ 108,253	4.03%	48.64%	21.69%
	ESCO	\$ 2,138,528	\$ 44,187,986	\$ 478,447	22.37%	33.61%	
83	Client	\$ 2,676,091	\$ 9,954,280	\$ 107,780	4.03%	48.91%	22.51%
	ESCO	\$ 2,779,748	\$ 44,040,832	\$ 476,854	17.15%	34.71%	
84	Client	\$ 2,645,615	\$ 9,562,031	\$ 103,533	3.91%	49.86%	22.25%
	ESCO	\$ 2,327,001	\$ 42,492,825	\$ 460,093	19.77%	34.29%	
85	Client	\$ 1,304,882	\$ 7,738,405	\$ 83,788	6.42%	43.53%	16.46%
	ESCO	\$ 3,877,762	\$ 46,656,414	\$ 505,174	13.03%	35.63%	
86	Client	\$ 1,185,455	\$ 7,866,682	\$ 85,177	7.19%	42.68%	15.60%
	ESCO	\$ 3,408,955	\$ 46,821,115	\$ 506,957	14.87%	35.37%	
87	Client	\$ 1,188,175	\$ 7,586,303	\$ 82,141	6.91%	43.24%	16.03%
	ESCO	\$ 3,835,934	\$ 45,579,838	\$ 493,517	12.87%	35.98%	
88	Client	\$ -178,569	\$ 6,091,112	\$ 65,952	-36.93%	36.57%	9.47%
	ESCO	\$ 4,608,777	\$ 48,255,802	\$ 522,492	11.34%	36.28%	
89	Client	\$ -187,154	\$ 6,042,412	\$ 65,424	-34.96%	36.20%	9.34%
	ESCO	\$ 5,142,744	\$ 48,443,068	\$ 524,519	10.20%	36.80%	
90	Client	\$ -125,768	\$ 6,091,612	\$ 65,957	-52.44%	36.63%	9.54%
	ESCO	\$ 5,418,591	\$ 48,492,792	\$ 525,058	9.69%	36.79%	

The maximum absolute value of "half width of a two-side CI/mean in %" is 59.79%, which is from Scenario 5. Although this rate is larger than the stop criteria of 10%, this is the lowest "half width of a two-side CI/mean in %" that can be achieved in a single Excel spreadsheet. According to the formula of calculating the confidence interval, $z \times \left(\frac{\sigma}{\sqrt{n}} \right)$, in which z is the value corresponding to the significance level, σ is the standard deviation of the NPV outputs from each scenario after the simulation runs, and n

is the number of the simulation runs. As n increases, the mean and standard deviation of the NPV outputs from each scenario converge, and the confidence interval is adversely proportional to the square root of n . For example, as the number of simulation runs is increased by ten times, the confidence interval is decreased approximately one third. Therefore, the desired number of the simulation runs can be calculated using this relationship between the number of simulation runs and the confidence interval.

The maximum absolute value of "half width of a two-side CI/mean in %" after 32,767 simulation runs is 59.79%, which is approximately six times the stop criteria of 10%, therefore, the number of simulation runs needs to be increased by 36 times. This can be realized by running 32,767-time simulations in 36 Excel spreadsheets. The following procedure takes Scenario 5 as an example and explains how to implement this procedure step by step. The result is presented in Appendix C.

In Step 1, similar to the Subchapter "Results of Scenarios after 32,767 Simulation Runs", run 32,767 simulations in a single Excel spreadsheet.

In Step 2, repeat the 32,767 simulation runs in 36 Excel spreadsheets. The total simulation runs will be 1,179,612.

In Step 3, calculate the mean and standard deviation of the 1,179,612 client's NPV output and 1,179,612 ESCO's NPV output, respectively.

In Step 4, based on the number of simulation runs (1,179,612), the mean and the standard deviation from the NPV outputs, the half width of a two-side confidence interval (CI) and the "half width of a two-side CI/mean in %" are calculated.

In Step 5, compare the absolute value of "half width of a two-side CI/mean in %" with the stop criteria of 10%. If the value is lower than 10%, then the desired "half width

of a two-side CI/mean in %" is reached. Otherwise, increase the number of the simulation runs until the desired "half width of a two-side CI/mean in %" is reached.

For illustration purposes, the analysis of the model outputs is based on the 32,767 simulation runs in a single Excel spreadsheet.

Model Outputs Analysis

The NPV outputs from all scenarios are helpful for the users to compare different scenarios and make decisions concerning investments in energy management projects. These outputs can be displayed in both tabular and graphic forms, and summary statistical data can be calculated. The outputs are analyzed in the following paragraphs with more details.

1. The rate "Positive NPV values for both client and ESCO" is compared among the scenarios with the same discrete variable inputs. The comparison is presented through 3-D graphs.

The rate "Positive NPV values for both client and ESCO" is compared among the scenarios with the same parameter inputs. By doing so, the user can determine the region of the parameters which can generate a higher "Positive NPV values for both client and ESCO". The comparison is completed via 3-D graphs in which there is "Positive NPV values for both client and ESCO" versus the two discrete input parameters. These 3-D graphs are drawn in Matlab and presented in Figure 11 to 20. The codes used to draw the graphs are written in Appendix B. The information on the variability in the NPV outputs obtained from the graphs tells the users which factors strongly influenced the "Positive NPV values for both client and ESCO".

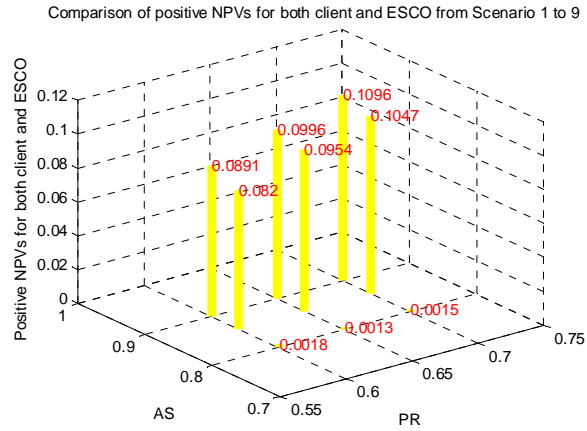


Figure 11 - Positive NPVs for both client and ESCO versus the availability/yield of the system (AS) and the relationship between the price of sold energy and the price of purchased energy (PR) from Scenario 1 to Scenario 9

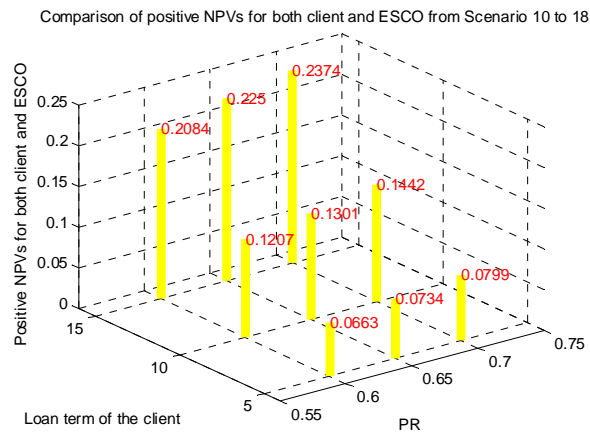


Figure 12 - Positive NPVs for both client and ESCO versus the loan term of the client and the relationship between the price of sold energy and the price of purchased energy (PR) from Scenario 10 to Scenario 18

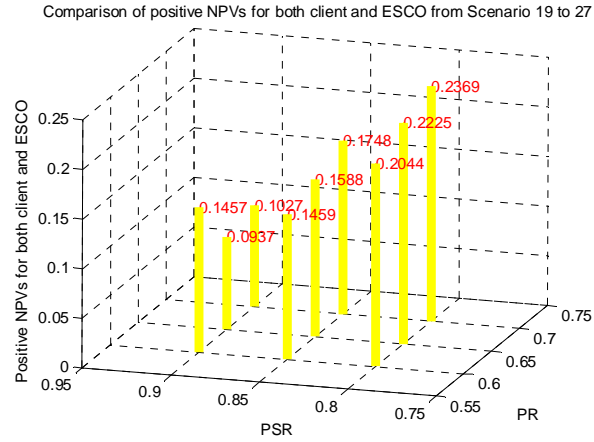


Figure 13 - Positive NPVs for both client and ESCO versus the performance contract sharing rate (PSR) and the relationship between the price of sold energy and the price of purchased energy (PR) from Scenario 19 to Scenario 27

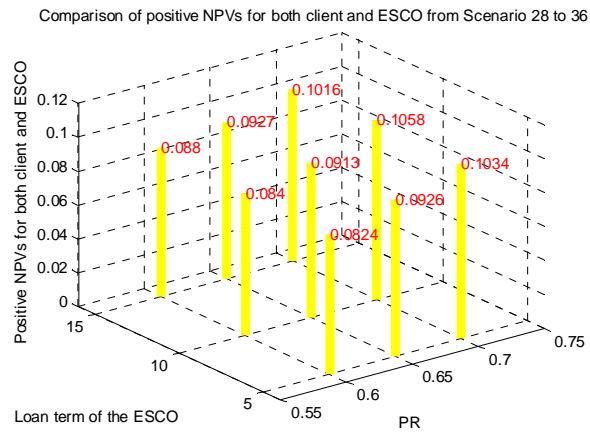


Figure 14 - Positive NPVs for both client and ESCO versus the loan term of the ESCO and the relationship between the price of sold energy and the price of purchased energy (PR) from Scenario 28 to Scenario 36

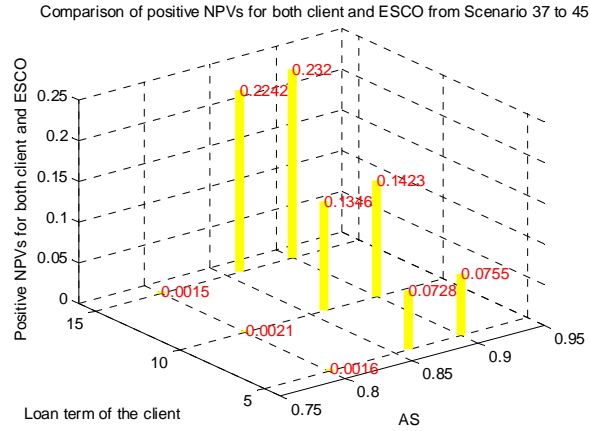


Figure 15 - Positive NPVs for both client and ESCO versus the loan term of the client and the availability/yield of the system (AS) from Scenario 37 to Scenario 45

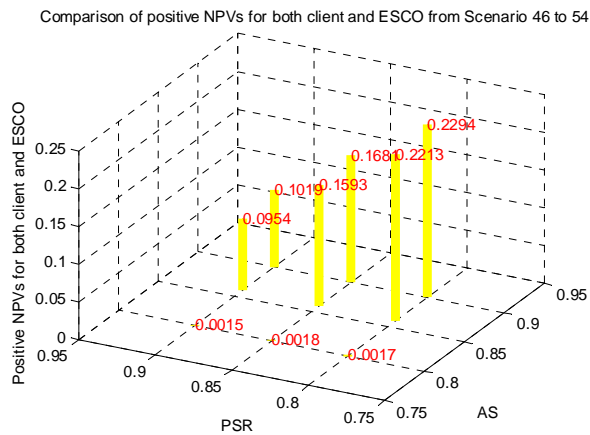


Figure 16 - Positive NPVs for both client and ESCO versus the performance contract sharing rate (PSR) and the availability/yield of the system (AS) from Scenario 46 to Scenario 54

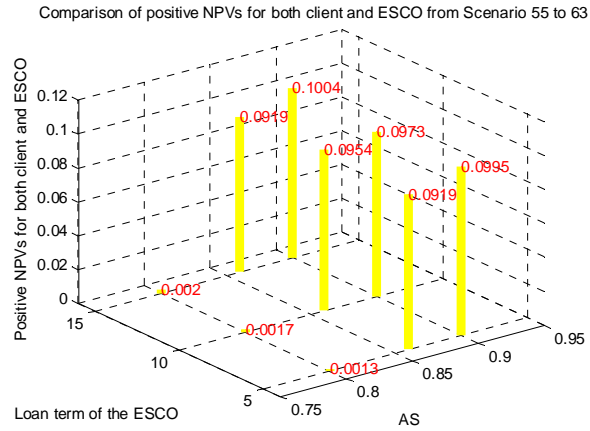


Figure 17 - Positive NPVs for both client and ESCO versus the loan term of the ESCO and the availability/yield of the system (AS) from Scenario 55 to Scenario 63

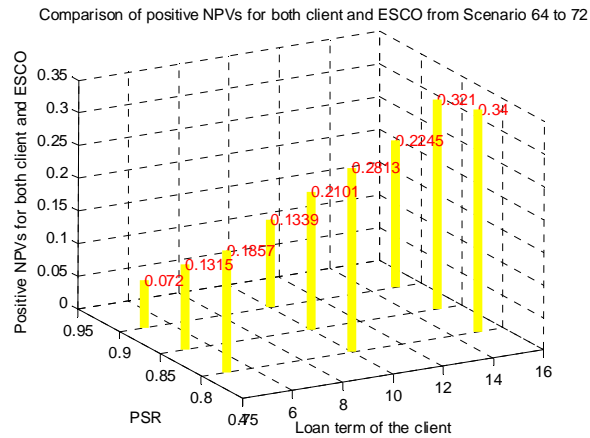


Figure 18 - Positive NPVs for both client and ESCO versus the loan term of the ESCO and the performance contract sharing rate (PSR) from Scenario 64 to Scenario 72

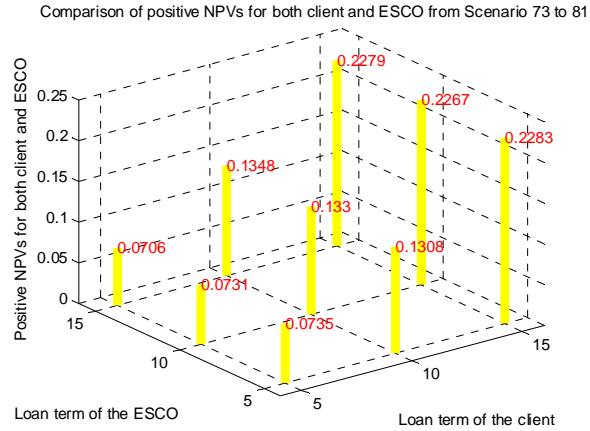


Figure 19 - Positive NPVs for both client and ESCO versus the loan term of the ESCO and the loan term of the client from Scenario 73 to Scenario 81

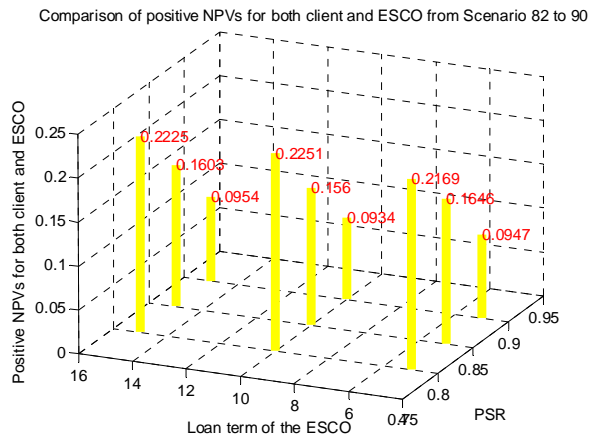


Figure 20 - Positive NPVs for both client and ESCO versus the loan term of the ESCO and the performance contract sharing rate (PSR) from Scenario 82 to Scenario 90

The information obtained from the graphs is presented in the following bullets:

- The "Positive NPVs for both client and ESCO" is strongly affected by the availability/yield of the system. When the availability/yield of the system is

increased from 80% to 86%, this rate is significantly increased from below 1% to above 8%.

- All figures but Figure 13 present that the higher the "relationship between the price of sold energy and the price of purchased energy" is, the higher the "Positive NPVs for both client and ESCO" is. This is reasonable since the higher price of the energy that the client sells back to the utility results in the higher revenues that both the client and the ESCO can receive from installing the CHP system.
- All figures but Figure 15 demonstrate that the longer the loan term of the client is, the higher the "Positive NPVs for both client and ESCO" is. The loan term of the client only influences the percentage of positive NPVs of the client. The longer loan term of the client results in the higher percentage of positive NPV of the client, which increases the "Positive NPVs for both client and ESCO". However, the "Positive NPVs for both client and ESCO" is not sensitive to the loan term of the ESCO.
- When the performance contract rate is between 80% and 90%, the lower the rate is, the higher the "Positive NPV for both client and ESCO" is. The performance contract sharing rate affects both the cost for the client and the revenue of the ESCO. Therefore, this rate has to be determined very carefully to balance the cash flows of the client and ESCO. The graphs in this case show that the "Positive NPVs for both client and ESCO" is the highest when the performance contract sharing rate is around 80%. However, due to the limited values in the discrete array of the performance contract sharing rate, the user is recommended to try

more values of the performance contract sharing rate to maximize the rate "Positive NPVs for both client and ESCO".

2. The probability of the client's positive NPV and ESCO's positive NPV can be determined by the NPV outputs from the simulations.

The empirical distribution is used as the best fit distribution of the client's and the ESCO's NPV outputs from each scenario after 32,767 simulation runs. The average and standard deviation calculated from these 32,767 pairs of NPV outputs are taken as the mean and standard deviation of the NPV outputs distribution. The probability of the client's positive NPV values and the probability of the ESCO's positive NPV values are estimated by the ratio "% of Client's positive ESPC" and "% of ESCO's positive ESPC". The results are shown in Table 22. The third and fourth columns in this table are the mean and standard deviation of the client's and the ESCO's NPV outputs from each scenario after 32,767 simulation runs. The fifth column is the % of the client's positive ESPC and % of the ESCO's positive ESPC. The last column is the probability of the client's positive NPV and the probability of the ESCO's positive NPV in each scenario. By doing this, the risk in each scenario can be assessed more quantitatively.

Table 22- Probability of the client's positive NPV and
probability of the ESCO's positive NPV

Confidence level in % 95%
Trial size 32767

SCENARIOS	Party	Mean	Standard deviation	% of positive ESPC	Probability of positive NPV
1	Client	\$ 17,988,261	\$ 42,229,203	59.80%	59.80%
	ESCO	\$ -16,516,670	\$ 2,513,385	0.18%	0.18%
2	Client	\$ -774,055	\$ 5,657,507	32.73%	32.73%
	ESCO	\$ 2,890,691	\$ 44,725,435	34.60%	34.60%
3	Client	\$ -4,770,673	\$ 5,114,912	9.14%	9.14%
	ESCO	\$ 7,955,917	\$ 46,330,868	36.03%	36.03%
4	Client	\$ 20,009,392	\$ 44,775,041	62.51%	62.51%
	ESCO	\$ -16,519,016	\$ 2,457,784	0.13%	0.13%
5	Client	\$ -110,793	\$ 6,118,086	36.81%	36.81%
	ESCO	\$ 5,193,859	\$ 49,030,844	36.42%	36.42%
6	Client	\$ -4,510,606	\$ 5,288,537	10.34%	10.34%
	ESCO	\$ 10,015,480	\$ 47,946,209	38.52%	38.52%
7	Client	\$ 22,017,678	\$ 47,704,306	65.31%	65.31%
	ESCO	\$ -16,547,001	\$ 2,463,166	0.15%	0.15%
8	Client	\$ 478,354	\$ 6,615,426	40.14%	40.14%
	ESCO	\$ 7,436,733	\$ 53,526,117	38.09%	38.09%
9	Client	\$ -4,231,615	\$ 5,621,306	11.53%	11.53%
	ESCO	\$ 12,192,346	\$ 51,005,756	40.61%	40.61%
10	Client	\$ -2,285,878	\$ 5,604,984	25.20%	25.20%
	ESCO	\$ 3,257,930	\$ 44,962,395	35.05%	35.05%
11	Client	\$ 1,105,278	\$ 5,658,534	45.46%	45.46%
	ESCO	\$ 3,327,512	\$ 45,549,829	35.15%	35.15%
12	Client	\$ 3,533,186	\$ 5,749,641	71.02%	71.02%
	ESCO	\$ 3,254,376	\$ 45,871,586	34.99%	34.99%
13	Client	\$ -1,632,040	\$ 6,128,668	29.09%	29.09%
	ESCO	\$ 4,976,034	\$ 49,057,981	36.60%	36.60%
14	Client	\$ 1,662,085	\$ 5,993,093	49.20%	49.20%
	ESCO	\$ 4,834,124	\$ 47,853,217	36.57%	36.57%
15	Client	\$ 4,090,247	\$ 6,132,036	74.45%	74.45%
	ESCO	\$ 5,241,221	\$ 49,198,322	37.11%	37.11%
16	Client	\$ -1,023,920	\$ 6,652,851	32.17%	32.17%
	ESCO	\$ 6,767,315	\$ 53,468,057	37.87%	37.87%
17	Client	\$ 2,301,697	\$ 6,622,897	53.55%	53.55%
	ESCO	\$ 7,280,690	\$ 53,643,233	38.47%	38.47%
18	Client	\$ 4,716,936	\$ 6,569,022	77.79%	77.79%
	ESCO	\$ 6,730,014	\$ 52,681,731	37.60%	37.60%
19	Client	\$ 1,942,523	\$ 9,445,248	44.98%	44.98%
	ESCO	\$ 988,709	\$ 41,728,484	32.28%	32.28%
20	Client	\$ 501,527	\$ 7,038,636	38.72%	38.72%
	ESCO	\$ 1,706,197	\$ 42,268,908	33.53%	33.53%
21	Client	\$ 540,309	\$ 7,220,221	38.90%	38.90%
	ESCO	\$ 1,924,485	\$ 43,176,207	33.93%	33.93%
22	Client	\$ 2,694,635	\$ 9,696,052	49.32%	49.32%
	ESCO	\$ 2,291,441	\$ 43,109,526	33.98%	33.98%
23	Client	\$ 1,232,869	\$ 7,540,189	43.48%	43.48%
	ESCO	\$ 3,079,895	\$ 45,163,396	34.64%	34.64%
24	Client	\$ -222,440	\$ 6,060,084	35.86%	35.86%
	ESCO	\$ 5,157,533	\$ 48,373,663	36.86%	36.86%
25	Client	\$ 3,516,969	\$ 10,818,611	53.23%	53.23%
	ESCO	\$ 4,164,779	\$ 47,799,595	35.82%	35.82%
26	Client	\$ 1,946,556	\$ 8,301,777	46.95%	46.95%
	ESCO	\$ 5,314,055	\$ 49,594,521	37.12%	37.12%
27	Client	\$ 394,568	\$ 6,482,677	39.88%	39.88%
	ESCO	\$ 6,660,408	\$ 51,629,347	37.97%	37.97%
28	Client	\$ -815,114	\$ 5,652,665	32.15%	32.15%
	ESCO	\$ 2,927,011	\$ 44,984,379	34.67%	34.67%
29	Client	\$ -772,302	\$ 5,726,040	32.45%	32.45%
	ESCO	\$ 3,704,438	\$ 46,383,317	35.31%	35.31%
30	Client	\$ -814,835	\$ 5,584,809	32.52%	32.52%
	ESCO	\$ 4,114,977	\$ 45,169,146	35.92%	35.92%

Table 22 Cont'd - Probability of the client's positive NPV and
probability of the ESCO's positive NPV

31	Client	\$ -197,674	\$ 6,145,375	36.03%	36.03%
	ESCO	\$ 4,711,214	\$ 49,157,391	36.13%	36.13%
32	Client	\$ -148,662	\$ 6,086,672	36.56%	36.56%
	ESCO	\$ 5,083,682	\$ 48,332,193	36.86%	36.86%
33	Client	\$ -168,702	\$ 6,108,476	36.28%	36.28%
	ESCO	\$ 5,496,737	\$ 48,842,264	37.23%	37.23%
34	Client	\$ 469,415	\$ 6,571,038	40.27%	40.27%
	ESCO	\$ 6,695,194	\$ 52,886,342	37.59%	37.59%
35	Client	\$ 485,387	\$ 6,540,877	40.31%	40.31%
	ESCO	\$ 7,484,512	\$ 52,759,967	38.36%	38.36%
36	Client	\$ 444,704	\$ 6,513,707	40.27%	40.27%
	ESCO	\$ 6,980,280	\$ 52,088,944	38.01%	38.01%
37	Client	\$ 18,822,617	\$ 45,565,548	57.50%	57.50%
	ESCO	\$ -16,522,984	\$ 2,507,743	0.16%	0.16%
38	Client	\$ 22,539,492	\$ 47,430,166	71.22%	71.22%
	ESCO	\$ -16,501,126	\$ 2,565,353	0.21%	0.21%
39	Client	\$ 24,321,361	\$ 44,612,345	88.52%	88.52%
	ESCO	\$ -16,534,464	\$ 2,478,040	0.15%	0.15%
40	Client	\$ -1,625,013	\$ 6,185,278	28.85%	28.85%
	ESCO	\$ 4,944,300	\$ 49,316,213	36.44%	36.44%
41	Client	\$ 1,692,011	\$ 6,039,871	50.04%	50.04%
	ESCO	\$ 4,967,438	\$ 48,103,857	36.81%	36.81%
42	Client	\$ 4,112,608	\$ 6,161,103	74.43%	74.43%
	ESCO	\$ 5,182,214	\$ 49,333,181	36.93%	36.93%
43	Client	\$ -6,051,765	\$ 5,235,499	7.64%	7.64%
	ESCO	\$ 9,309,171	\$ 47,432,702	37.72%	37.72%
44	Client	\$ -2,595,924	\$ 5,302,021	16.15%	16.15%
	ESCO	\$ 10,136,527	\$ 48,096,321	38.41%	38.41%
45	Client	\$ -220,855	\$ 5,322,519	30.81%	30.81%
	ESCO	\$ 9,895,410	\$ 48,234,529	38.23%	38.23%
46	Client	\$ 20,233,816	\$ 46,240,484	62.26%	62.26%
	ESCO	\$ -16,524,152	\$ 2,521,582	0.17%	0.17%
47	Client	\$ 20,386,198	\$ 46,213,105	62.93%	62.93%
	ESCO	\$ -16,502,695	\$ 2,532,722	0.18%	0.18%
48	Client	\$ 19,812,688	\$ 44,921,747	62.48%	62.48%
	ESCO	\$ -16,541,399	\$ 2,480,726	0.15%	0.15%
49	Client	\$ 2,700,545	\$ 10,294,233	49.04%	49.04%
	ESCO	\$ 2,461,860	\$ 45,345,327	34.12%	34.12%
50	Client	\$ 1,252,072	\$ 7,916,474	43.29%	43.29%
	ESCO	\$ 3,454,835	\$ 47,248,408	35.04%	35.04%
51	Client	\$ -132,752	\$ 6,165,605	36.77%	36.77%
	ESCO	\$ 5,384,644	\$ 49,742,744	36.72%	36.72%
52	Client	\$ -1,061,840	\$ 10,816,549	23.33%	23.33%
	ESCO	\$ 6,301,635	\$ 43,758,789	35.08%	35.08%
53	Client	\$ -2,731,742	\$ 8,128,824	17.23%	17.23%
	ESCO	\$ 8,315,668	\$ 46,692,173	36.42%	36.42%
54	Client	\$ -4,450,011	\$ 5,448,540	10.61%	10.61%
	ESCO	\$ 10,558,834	\$ 49,401,118	38.68%	38.68%
55	Client	\$ 20,012,835	\$ 44,083,645	62.69%	62.69%
	ESCO	\$ -16,676,535	\$ 2,451,401	0.13%	0.13%
56	Client	\$ 20,257,211	\$ 44,790,663	62.57%	62.57%
	ESCO	\$ -16,343,342	\$ 2,480,225	0.17%	0.17%
57	Client	\$ 20,312,886	\$ 46,387,940	62.42%	62.42%
	ESCO	\$ -16,134,423	\$ 2,541,539	0.20%	0.20%
58	Client	\$ -154,900	\$ 6,133,191	36.38%	36.38%
	ESCO	\$ 4,715,031	\$ 48,578,369	36.29%	36.29%
59	Client	\$ -176,394	\$ 6,022,093	36.34%	36.34%
	ESCO	\$ 5,453,285	\$ 48,180,115	37.05%	37.05%
60	Client	\$ -180,551	\$ 6,168,747	36.49%	36.49%
	ESCO	\$ 5,199,866	\$ 49,248,653	36.71%	36.71%

Table 22 Cont'd - Probability of the client's positive NPV and
probability of the ESCO's positive NPV

61	Client	\$ -4,500,524	\$ 5,642,727	10.45%	10.45%
	ESCO	\$ 9,869,734	\$ 51,082,413	37.83%	37.83%
62	Client	\$ -4,545,241	\$ 5,356,758	10.12%	10.12%
	ESCO	\$ 9,764,313	\$ 48,543,954	38.02%	38.02%
63	Client	\$ -4,475,389	\$ 5,404,962	10.53%	10.53%
	ESCO	\$ 10,621,069	\$ 49,009,295	39.03%	39.03%
64	Client	\$ 1,160,256	\$ 9,863,438	40.26%	40.26%
	ESCO	\$ 2,110,702	\$ 43,623,753	34.12%	34.12%
65	Client	\$ -297,673	\$ 7,474,254	34.36%	34.36%
	ESCO	\$ 3,391,290	\$ 44,733,948	35.53%	35.53%
66	Client	\$ -1,701,608	\$ 6,001,125	28.42%	28.42%
	ESCO	\$ 4,912,496	\$ 47,970,975	36.71%	36.71%
67	Client	\$ 4,600,610	\$ 10,142,324	64.67%	64.67%
	ESCO	\$ 2,433,219	\$ 44,758,154	34.02%	34.02%
68	Client	\$ 3,180,993	\$ 7,866,178	58.02%	58.02%
	ESCO	\$ 3,598,460	\$ 47,099,276	35.43%	35.43%
69	Client	\$ 1,733,989	\$ 6,167,289	49.76%	49.76%
	ESCO	\$ 5,342,547	\$ 49,626,633	36.86%	36.86%
70	Client	\$ 6,922,503	\$ 9,614,664	90.91%	90.91%
	ESCO	\$ 2,143,015	\$ 42,743,162	34.00%	34.00%
71	Client	\$ 5,524,601	\$ 7,623,079	84.29%	84.29%
	ESCO	\$ 3,740,857	\$ 45,811,196	35.46%	35.46%
72	Client	\$ 4,100,105	\$ 5,986,526	74.76%	74.76%
	ESCO	\$ 5,024,020	\$ 47,678,790	36.66%	36.66%
73	Client	\$ -1,646,685	\$ 6,038,565	28.82%	28.82%
	ESCO	\$ 4,874,372	\$ 48,418,779	36.40%	36.40%
74	Client	\$ -1,701,080	\$ 6,019,065	28.35%	28.35%
	ESCO	\$ 5,056,386	\$ 47,704,974	36.89%	36.89%
75	Client	\$ -1,733,599	\$ 6,017,557	28.21%	28.21%
	ESCO	\$ 5,008,171	\$ 47,708,599	37.12%	37.12%
76	Client	\$ 1,638,922	\$ 6,050,192	49.29%	49.29%
	ESCO	\$ 4,771,396	\$ 48,051,175	36.81%	36.81%
77	Client	\$ 1,676,657	\$ 5,999,163	49.95%	49.95%
	ESCO	\$ 5,029,889	\$ 47,914,392	36.64%	36.64%
78	Client	\$ 1,706,140	\$ 6,199,358	49.92%	49.92%
	ESCO	\$ 5,709,215	\$ 50,133,391	37.25%	37.25%
79	Client	\$ 4,170,110	\$ 6,079,036	74.76%	74.76%
	ESCO	\$ 5,435,047	\$ 48,843,965	37.05%	37.05%
80	Client	\$ 4,080,268	\$ 6,060,083	74.61%	74.61%
	ESCO	\$ 5,275,940	\$ 48,646,156	37.16%	37.16%
81	Client	\$ 4,173,357	\$ 6,145,859	75.19%	75.19%
	ESCO	\$ 5,851,793	\$ 49,552,281	37.20%	37.20%
82	Client	\$ 2,685,750	\$ 9,997,896	48.64%	48.64%
	ESCO	\$ 2,138,528	\$ 44,187,986	33.61%	33.61%
83	Client	\$ 2,676,091	\$ 9,954,280	48.91%	48.91%
	ESCO	\$ 2,779,748	\$ 44,040,832	34.71%	34.71%
84	Client	\$ 2,645,615	\$ 9,562,031	49.86%	49.86%
	ESCO	\$ 2,327,001	\$ 42,492,825	34.29%	34.29%
85	Client	\$ 1,304,882	\$ 7,738,405	43.53%	43.53%
	ESCO	\$ 3,877,762	\$ 46,656,414	35.63%	35.63%
86	Client	\$ 1,185,455	\$ 7,866,682	42.68%	42.68%
	ESCO	\$ 3,408,955	\$ 46,821,115	35.37%	35.37%
87	Client	\$ 1,188,175	\$ 7,586,303	43.24%	43.24%
	ESCO	\$ 3,835,934	\$ 45,579,838	35.98%	35.98%
88	Client	\$ -178,569	\$ 6,091,112	36.57%	36.57%
	ESCO	\$ 4,608,777	\$ 48,255,802	36.28%	36.28%
89	Client	\$ -187,154	\$ 6,042,412	36.20%	36.20%
	ESCO	\$ 5,142,744	\$ 48,443,068	36.80%	36.80%
90	Client	\$ -125,768	\$ 6,091,612	36.63%	36.63%
	ESCO	\$ 5,418,591	\$ 48,492,792	36.79%	36.79%

- The comparisons among the scenarios also screen the parameters that significantly affect the "% of positive NPVs for both client and ESCO".

Figure 21 to Figure 30 compare the "% of positive NPVs for both client and ESCO" versus the two discrete parameters in 2-D graphs. These figures present that the "% of positive NPVs for both client and ESCO" is sensitive to the availability/yield of the system, the loan term of the client, the performance contract sharing rate, and the relationship between the price of sold energy and the price of purchased energy. The "% of positive NPVs for both client and ESCO" is not sensitive to the loan term of the ESCO. These findings will help the decision makers be aware of and cautious concerning the variations of these parameters when making decisions, thus making the tool more usable when the resources of the decision makers are limited.

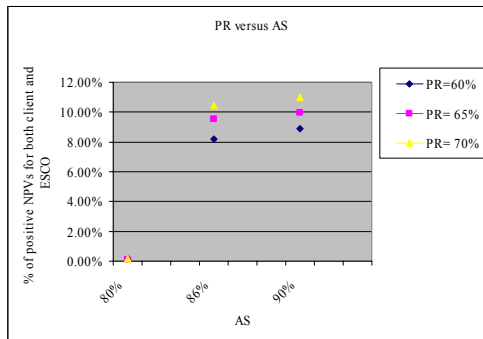


Figure 21 - The relationship between the price of sold energy and the price of purchased energy (PR) versus the availability/yield of the system (AS)

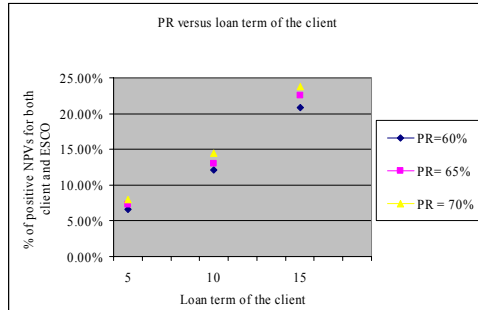


Figure 22 - The relationship between the price of sold energy and the price of purchased energy (PR) versus the loan term of the client

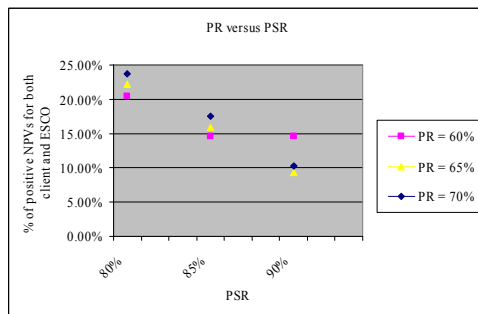


Figure 23 – The relationship between the price of sold energy and the price of purchased energy (PR) versus the performance contract sharing rate (PSR)

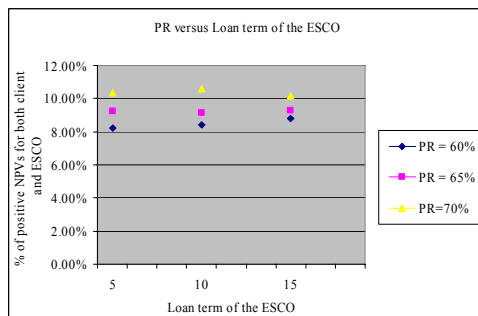


Figure 24 – The relationship between the price of sold energy and the price of purchased energy (PR) versus the loan term of the ESCO

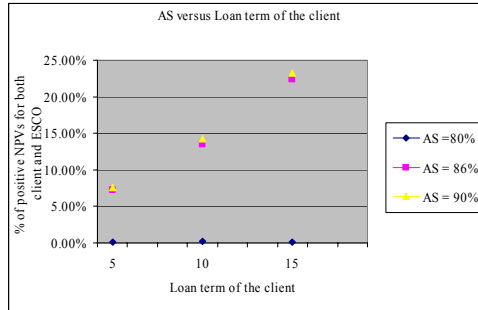


Figure 25 – The availability/yield of the system (AS) versus the loan term of the client

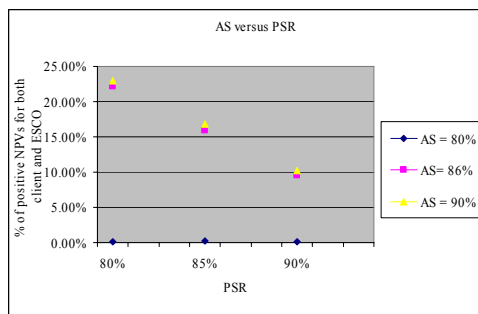


Figure 26 – The availability/yield of the system (AS) versus the performance contract sharing rate (PSR)

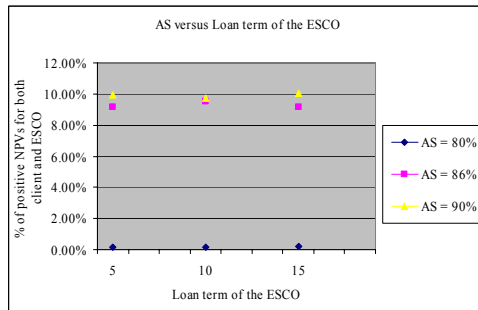


Figure 27 – The availability/yield of the system (AS) versus the loan term of the ESCO

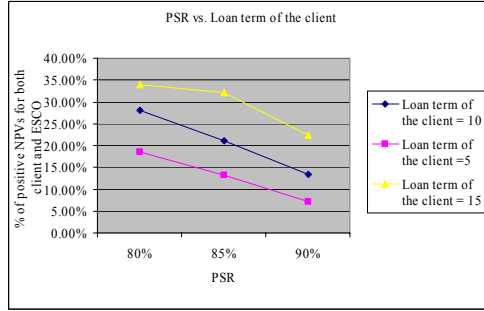


Figure 28 – The performance contract sharing rate (PSR) versus the loan term of the client

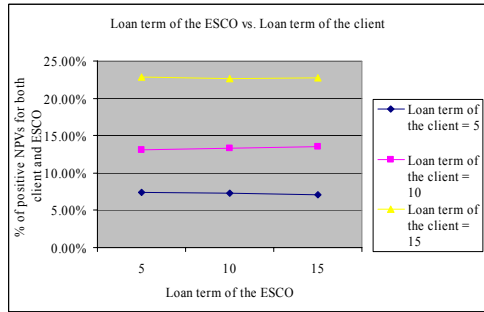


Figure 29 – The loan term of the ESCO versus the loan term of the client

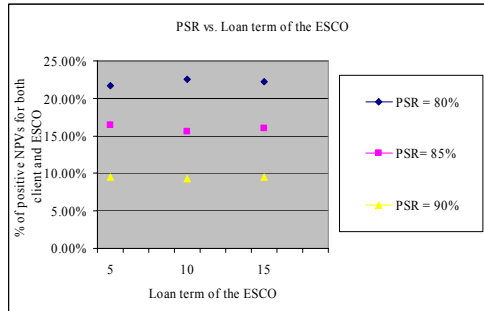


Figure 30 – The performance contract sharing rate (PSR) versus the loan term of the ESCO

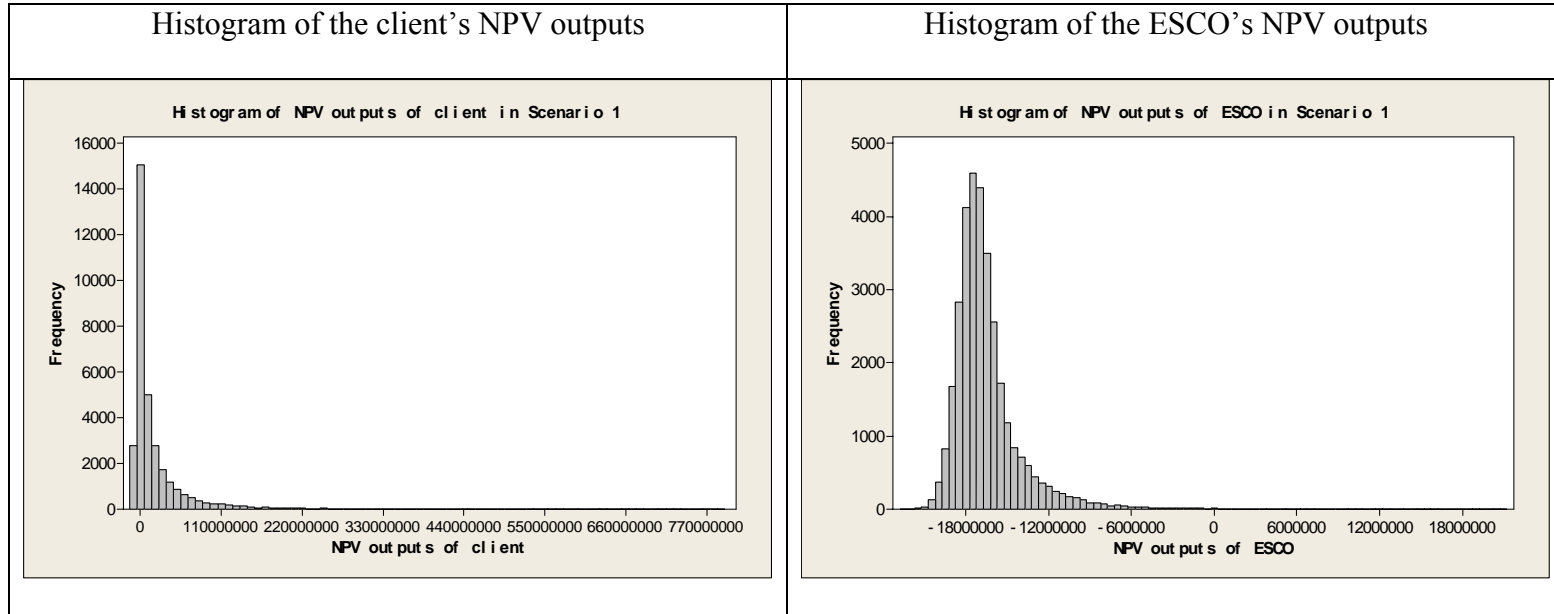
The figures highlight how the variations of the input variables change the “% of positive NPVs for both client and ESCO”, which is most sensitive to the availability/yield of the system and least sensitive to the loan term of the ESCO. When the availability/yield of the system is increased from 80% to 86%, the “% of positive NPVs for both client and ESCO” is significantly increased from lower than 1% to higher than 8%. However, when the availability/yield of the system is increased from 86% to 90%, the “% of positive NPVs for both client and ESCO” is only increased by less than 1%. This is because when the availability/yield of the system is around 80%, the value of the generated energy (kWh) from the CHP system is less than the value of the energy (kWh) guaranteed by the ESCO. Therefore, the ESCO has to pay a penalty cost to the client, which results in a negative NPV for the ESCO. When the availability/yield of the system is around 86%, the value of the generated energy (kWh) from the CHP system is greater than or equivalent to the value of the energy (kWh) guaranteed by the ESCO. Therefore, the ESCO will share the benefits with the client from installing the CHP system. Hence, the % of positive NPV for the ESCO is significantly increased, which results in a higher “% of positive NPVs for both client and ESCO”.

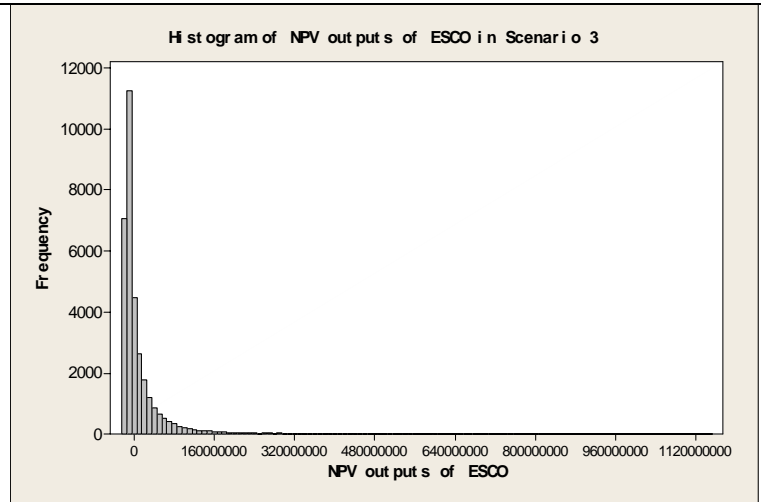
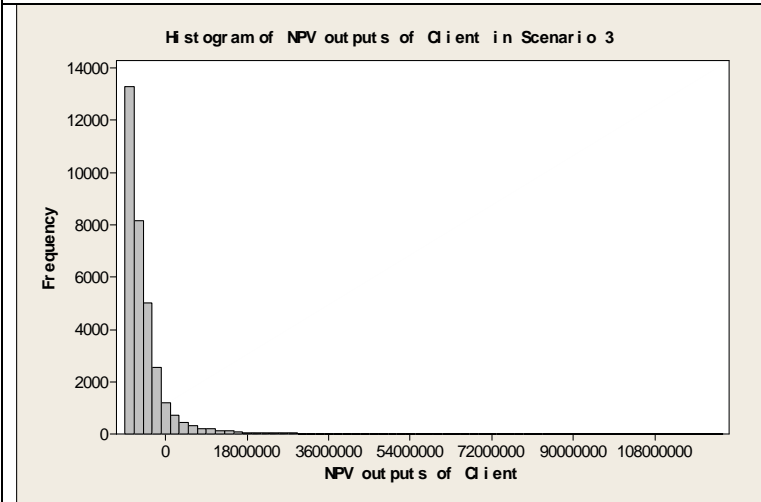
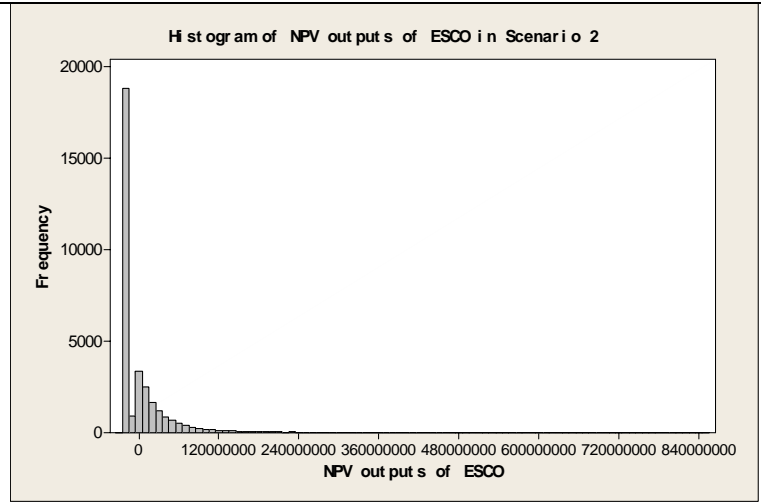
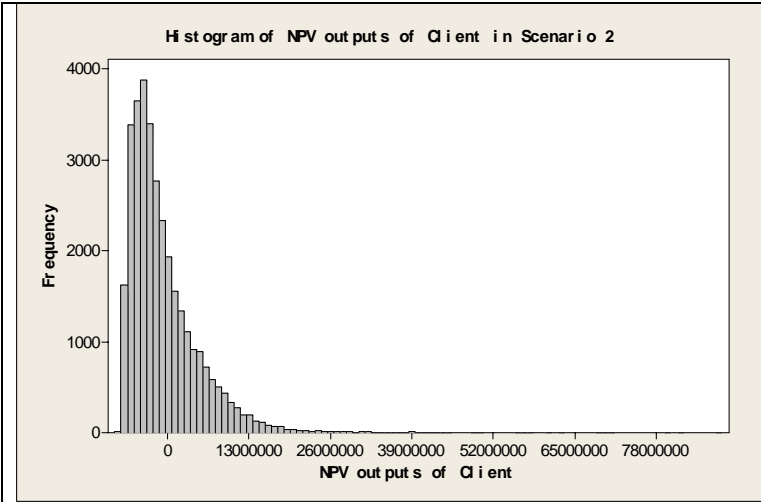
The figures also present that a relatively long loan term of the client, a high availability/yield of the system, and a high relationship between the price of sold energy and the price of purchased energy will result in a high “% of positive NPVs for both client and ESCO”. However, there is an exception. The “% of positive NPVs for both client and ESCO” in Scenario 38, in which the loan term of the client is 10 years and the availability/yield of the system is 80%, is higher than the “% of positive NPVs for both client and ESCO” in Scenario 39, in which the loan term of the client is 15 years and the

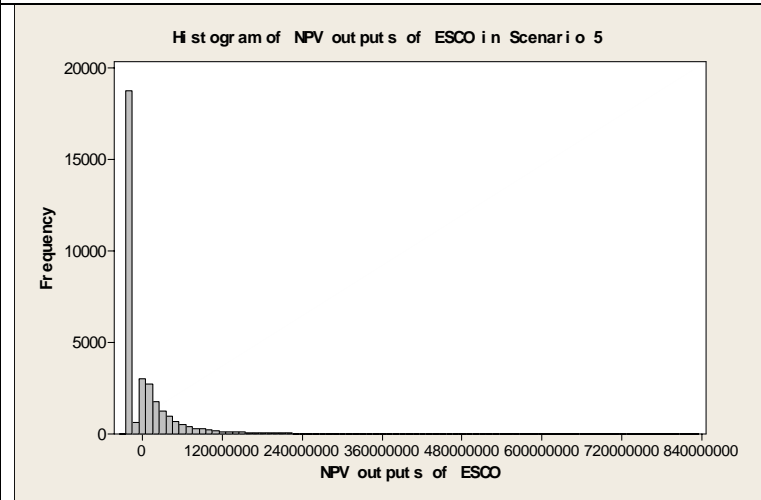
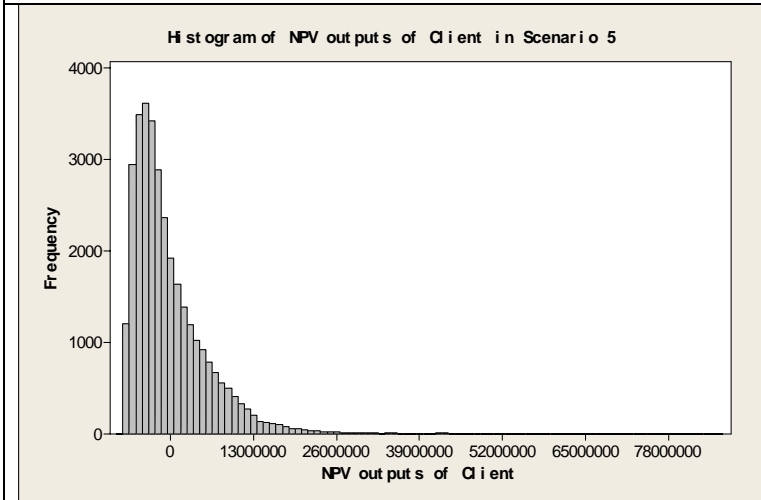
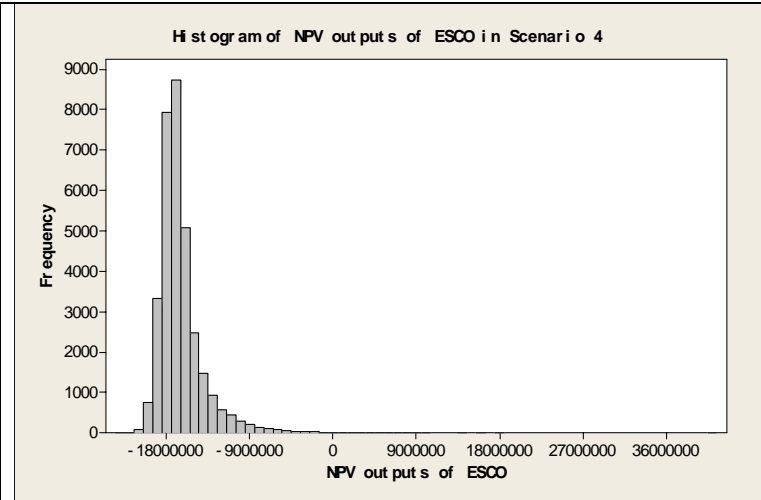
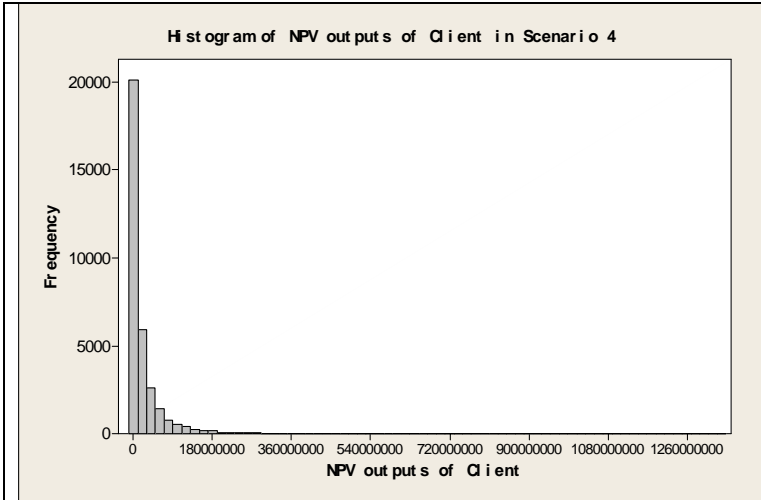
availability/yield of the system is 80%. However, the difference is very trivial, which is approximately four places after the decimal. Therefore, it can be ignored.

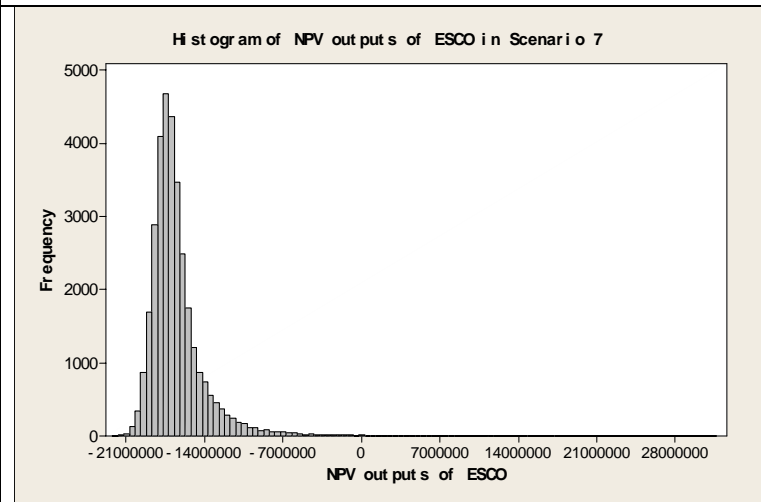
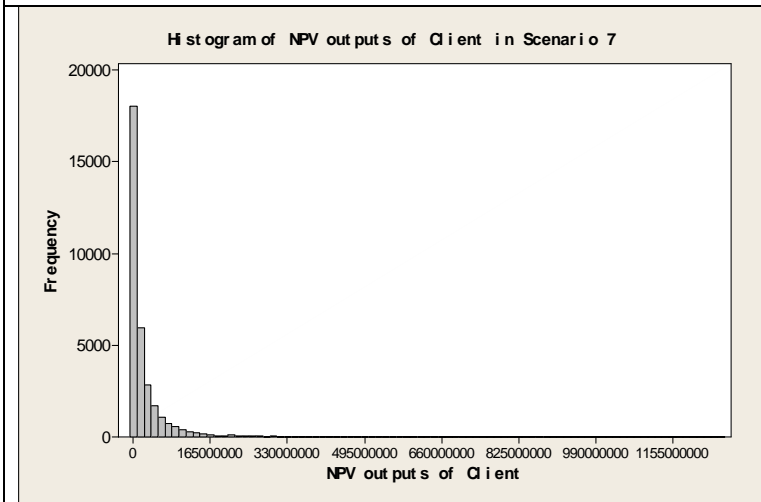
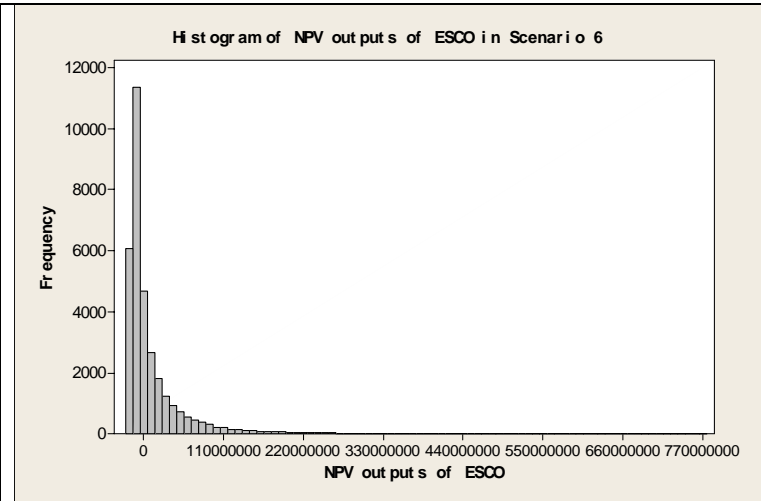
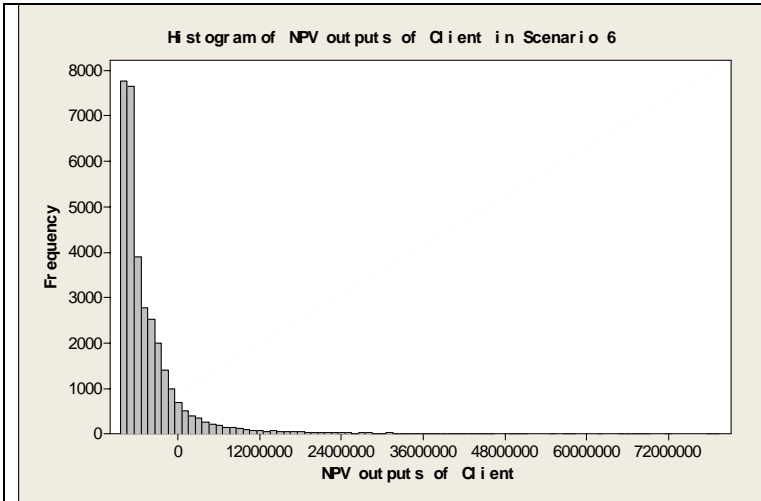
4. The histograms of the client's and the ESCO's NPV outputs are presented in Table 23. The histograms will help the users understand both the frequency of the client's NPV outputs and the frequency of the ESCO's NPV outputs.

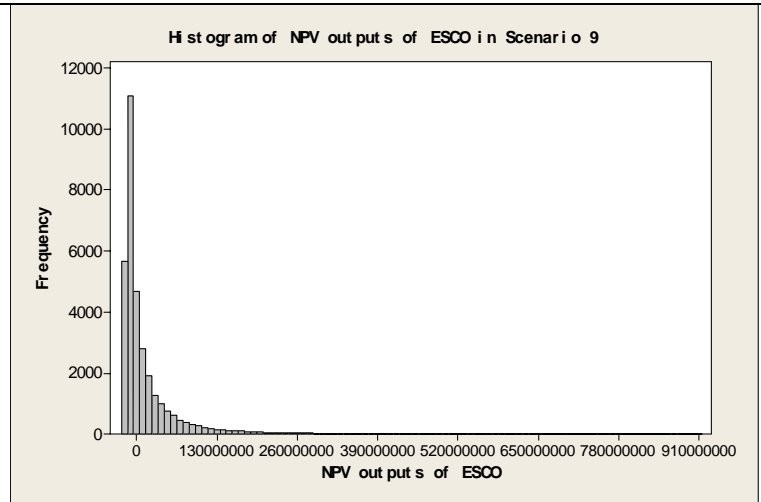
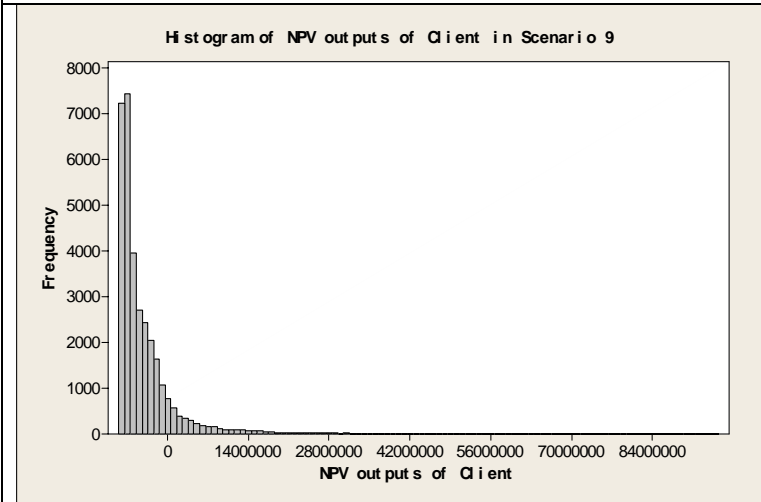
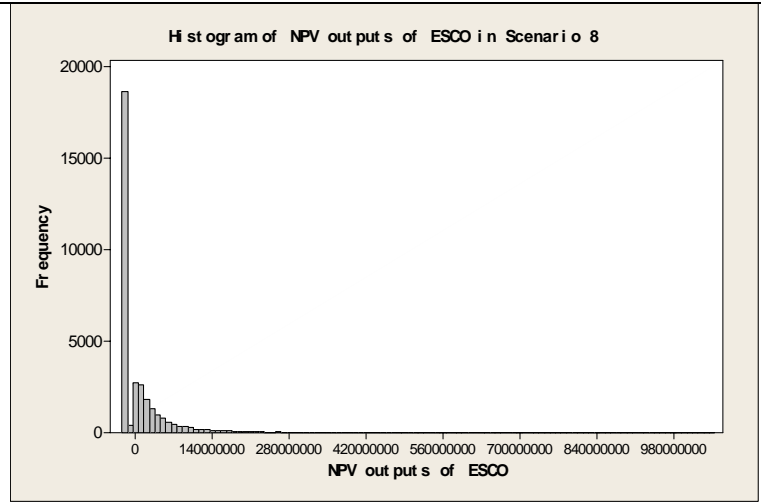
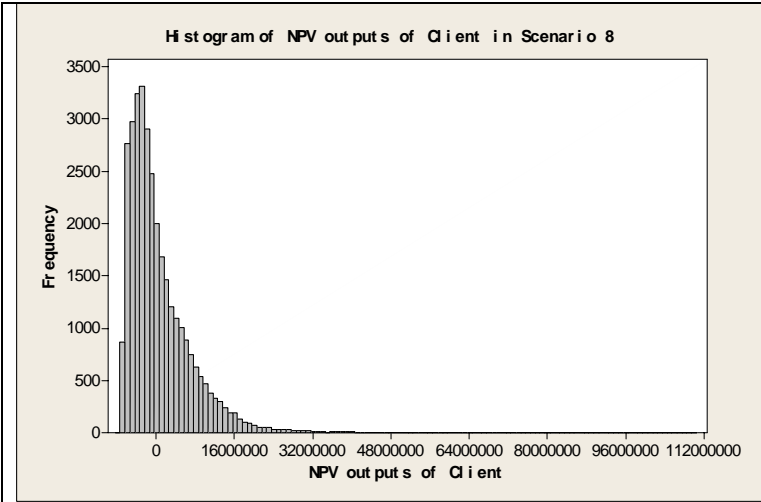
Table 23 - Histograms of the client's and the ESCO's NPV outputs in all scenarios

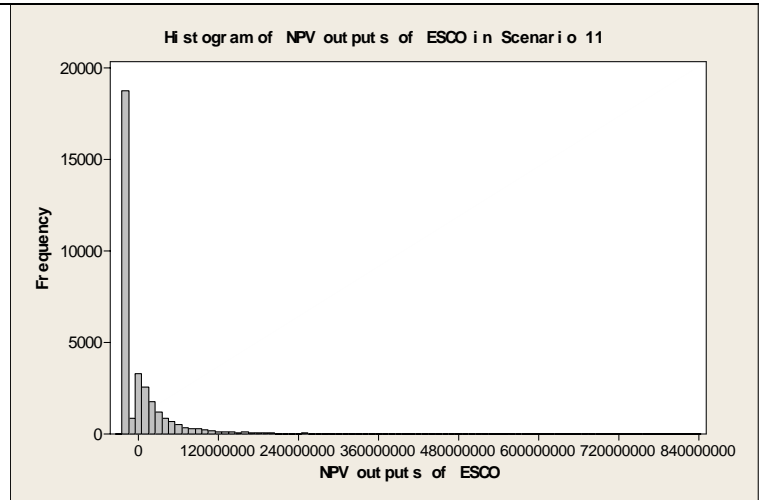
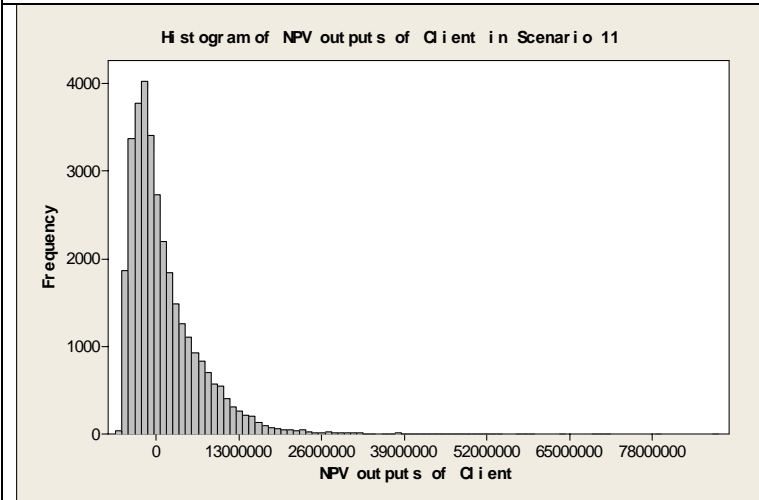
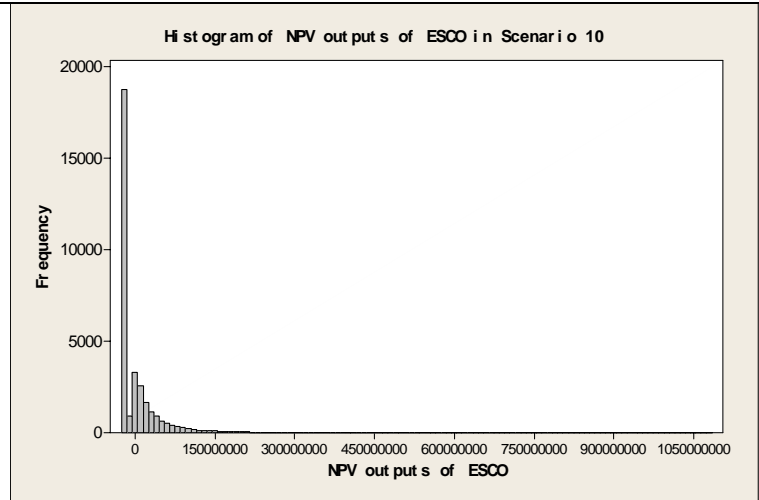
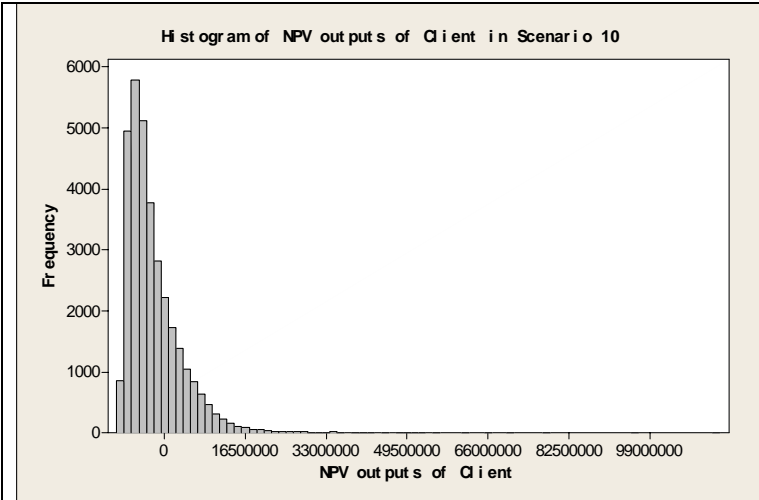


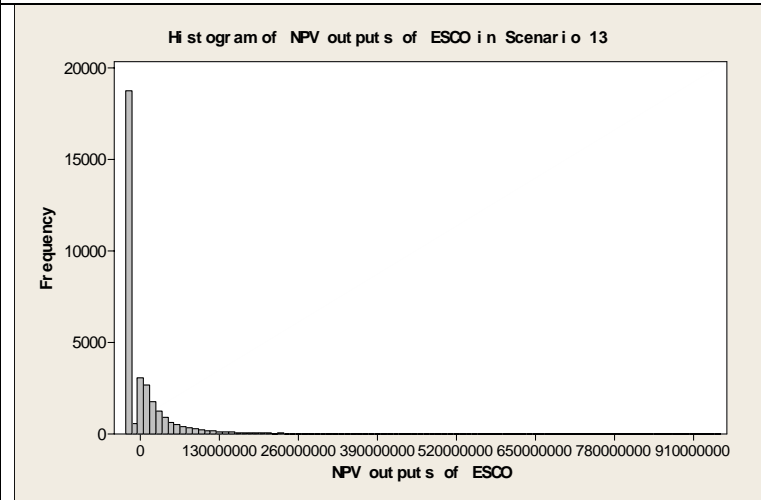
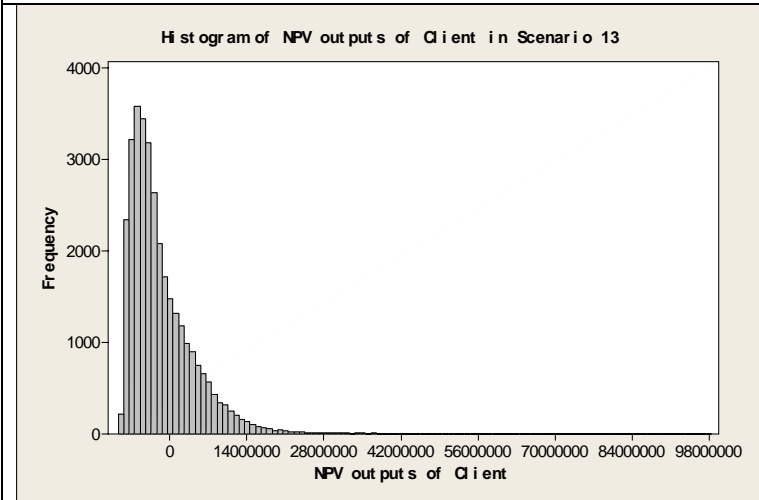
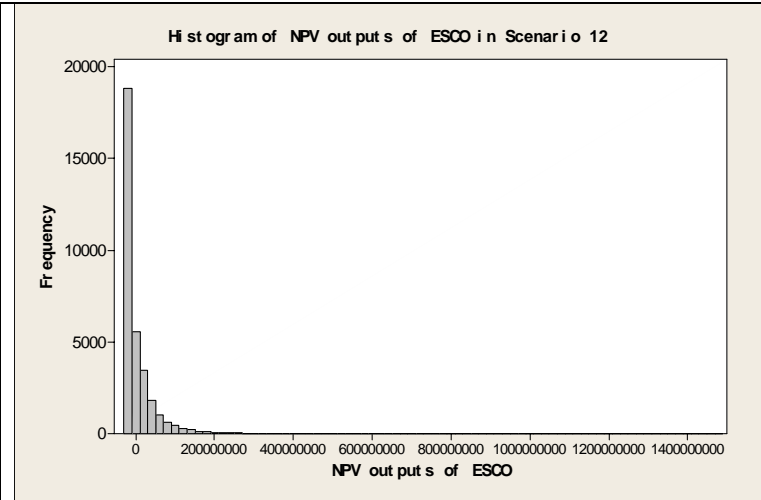
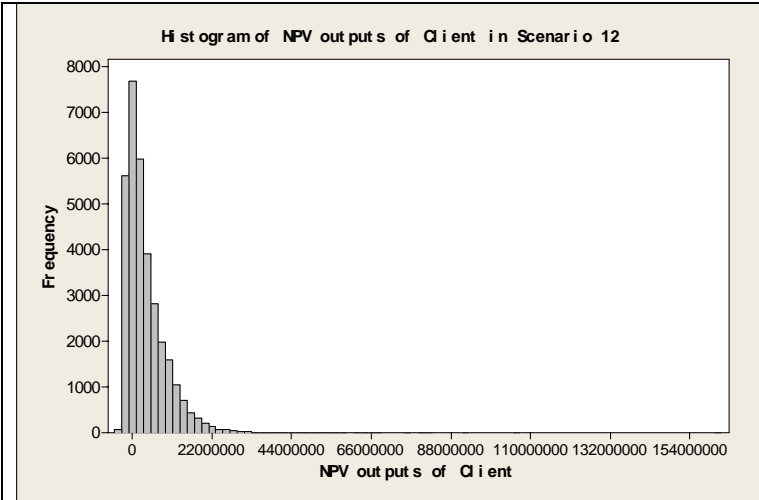


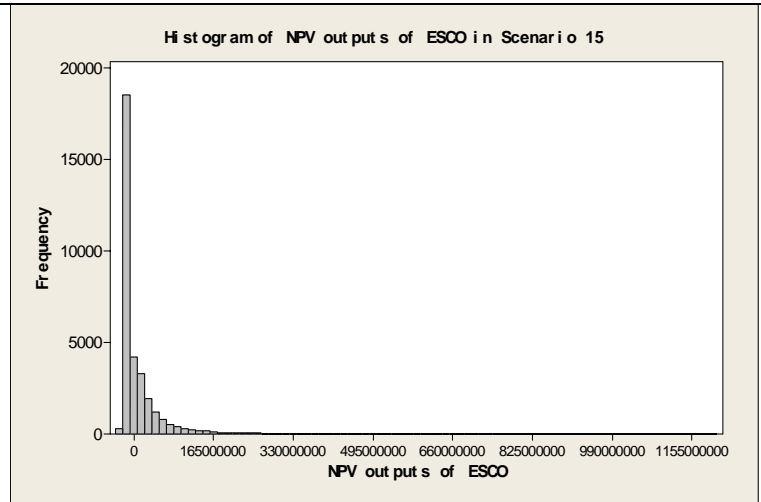
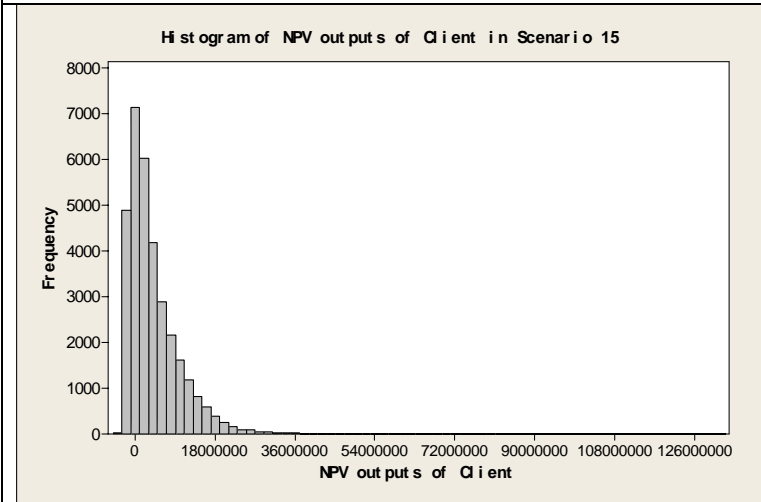
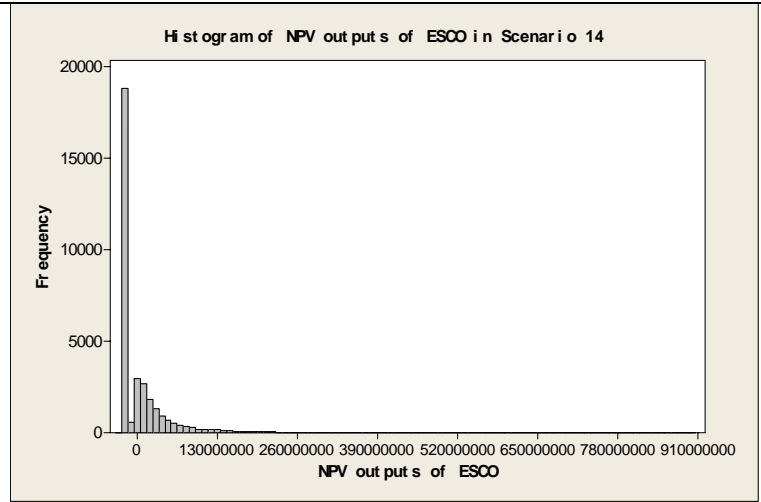
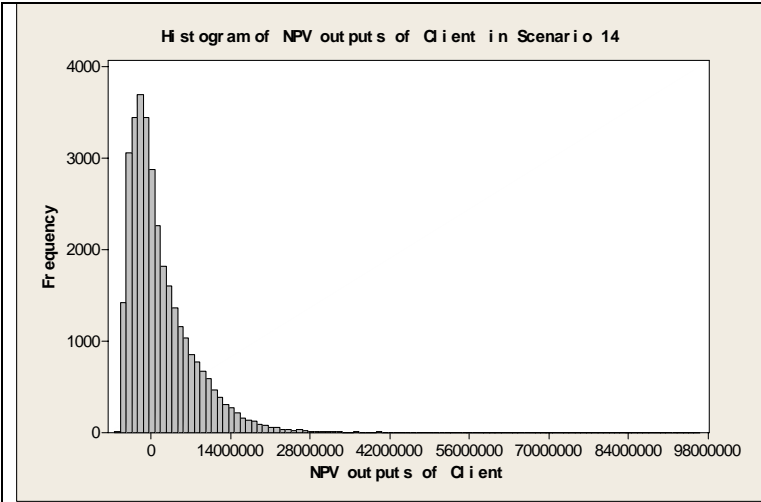


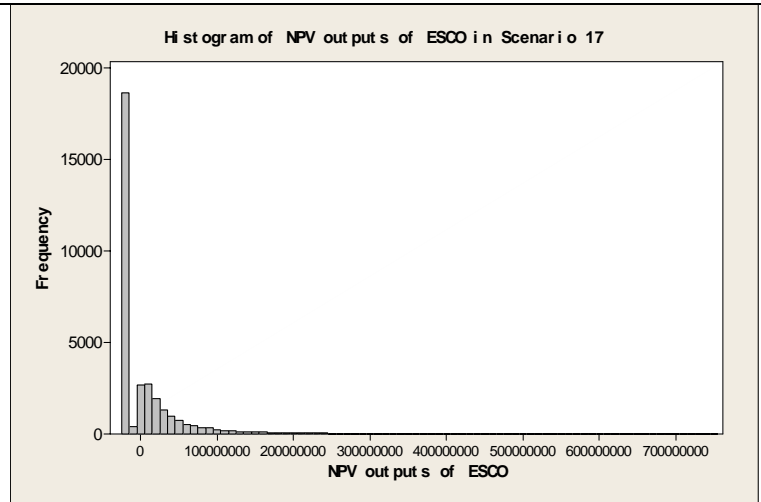
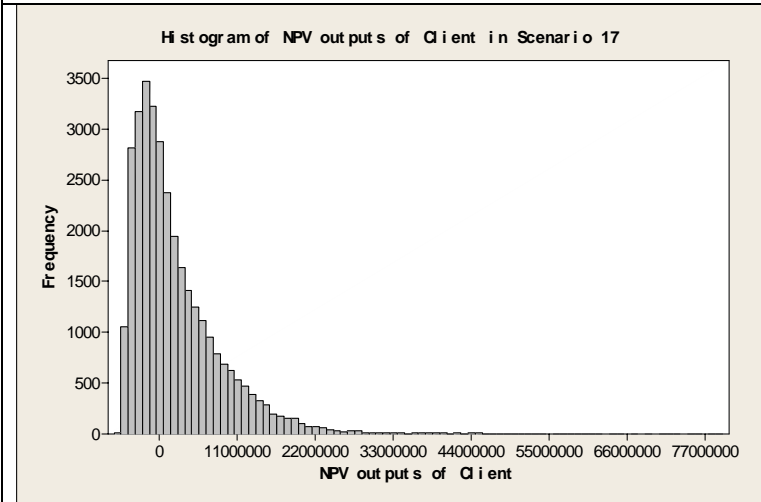
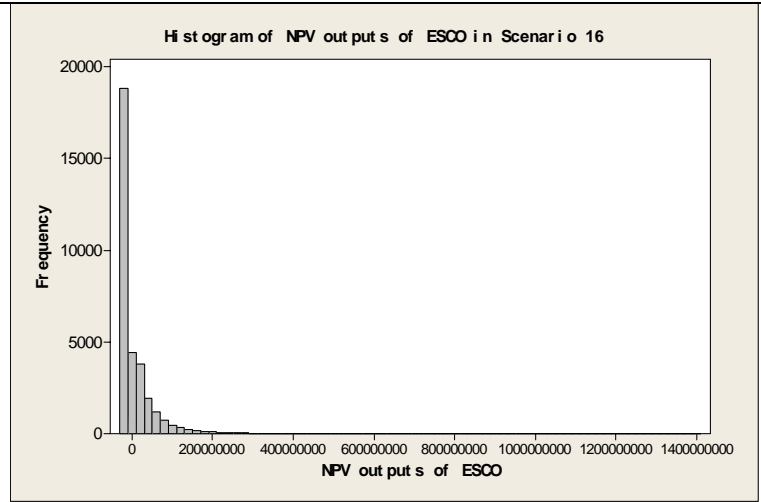
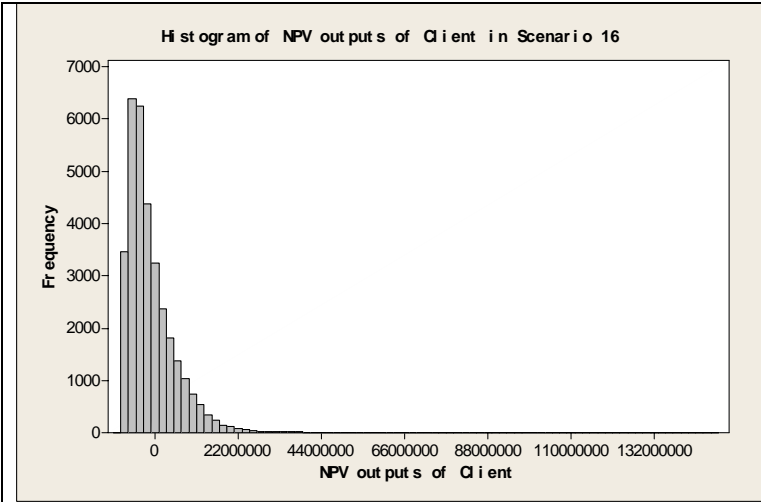


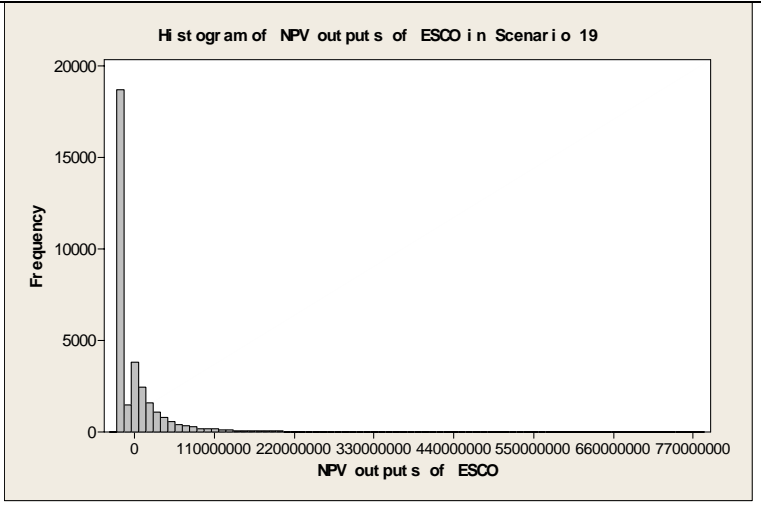
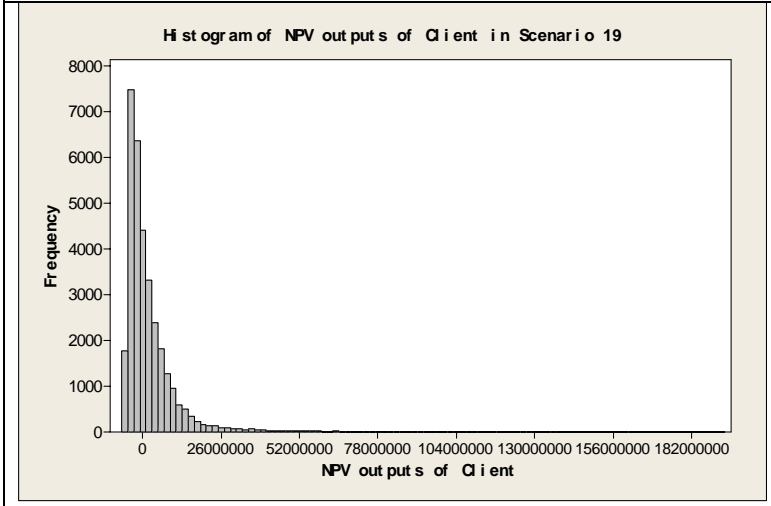
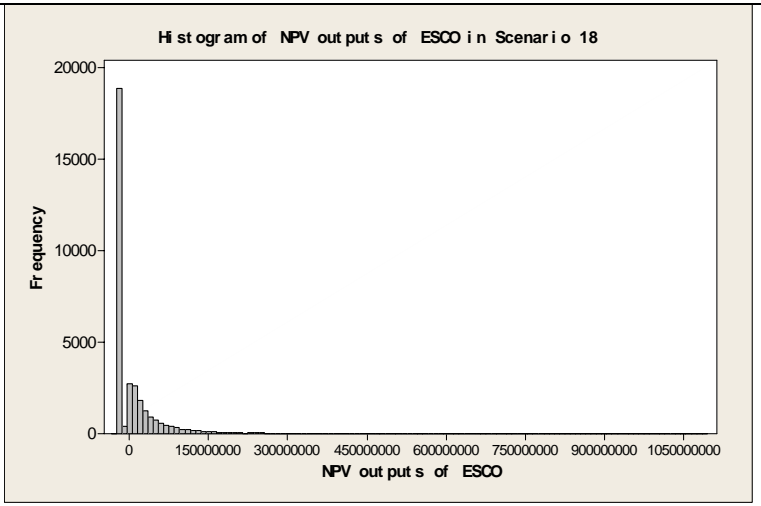
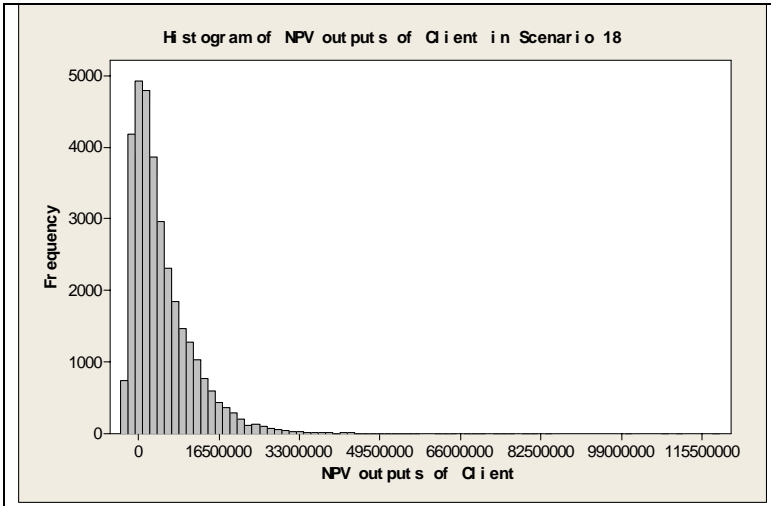


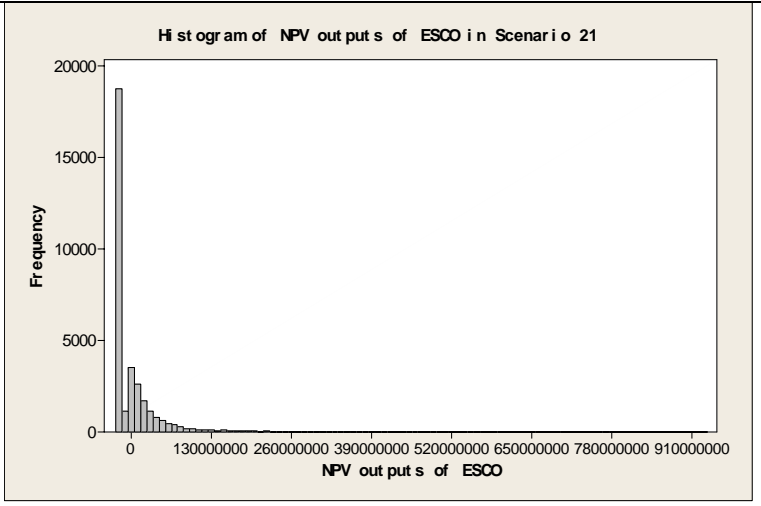
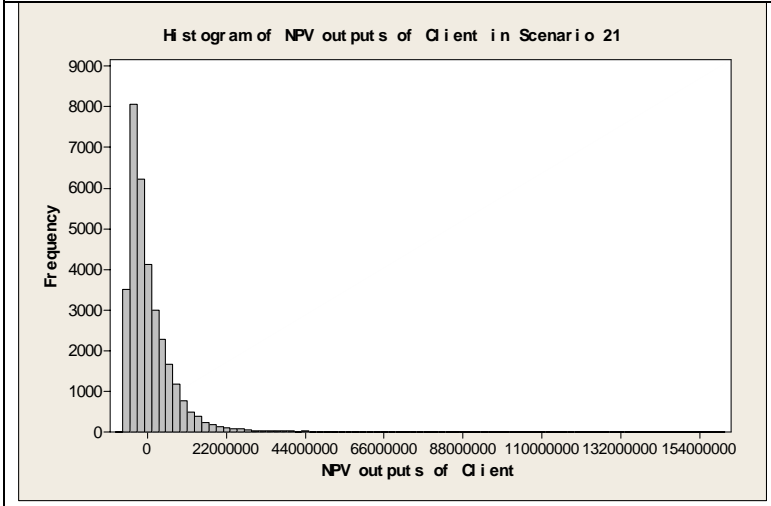
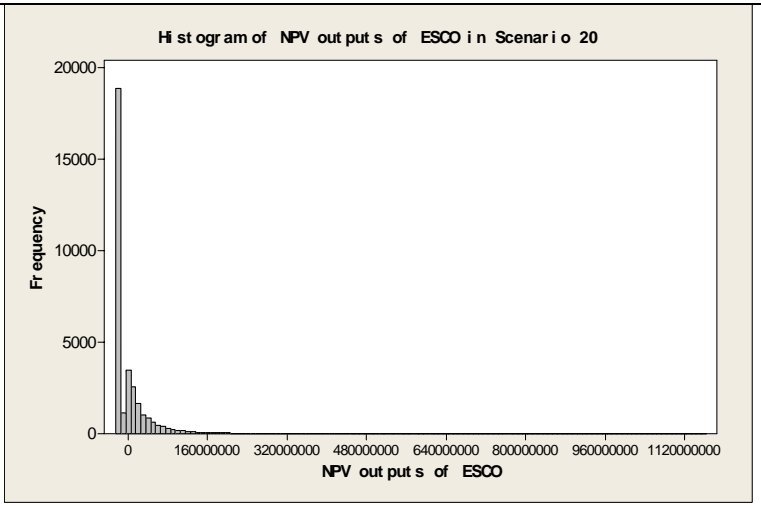
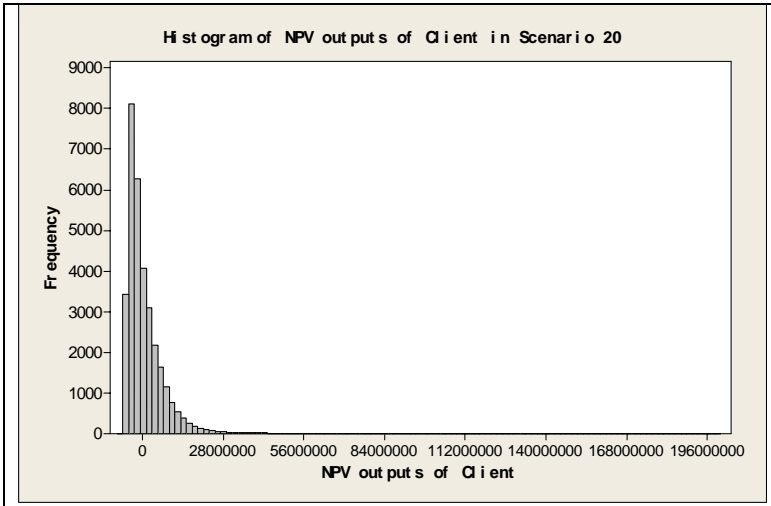


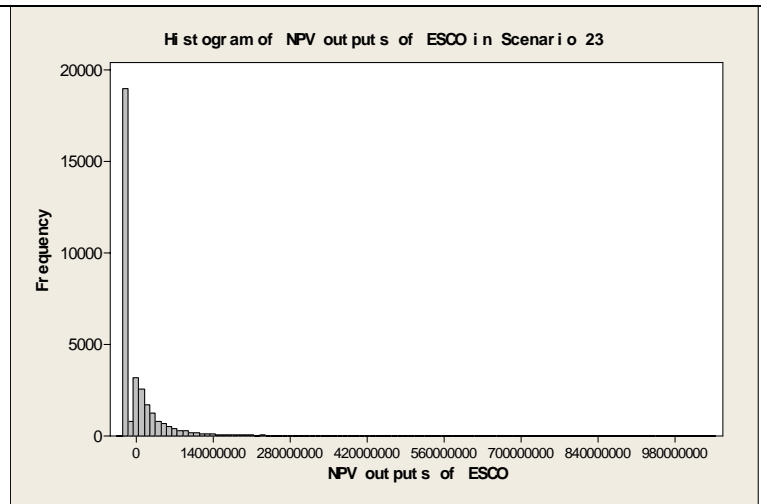
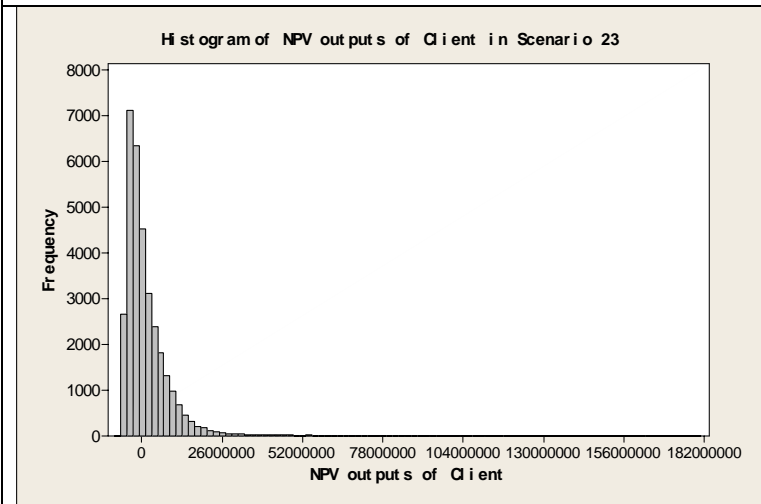
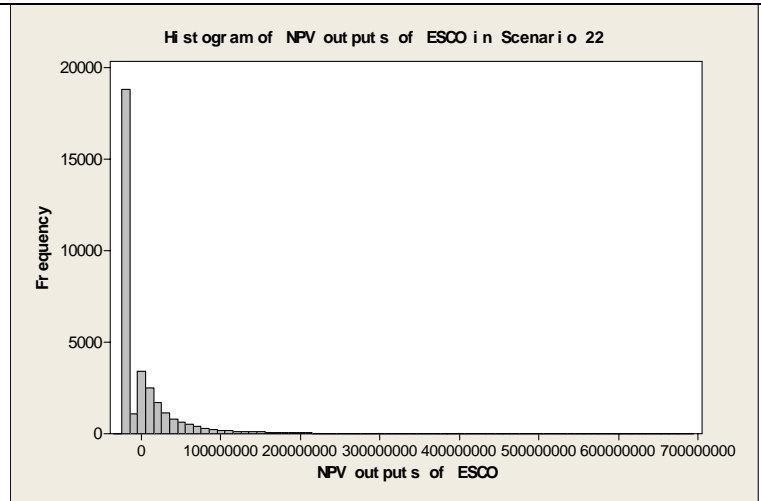
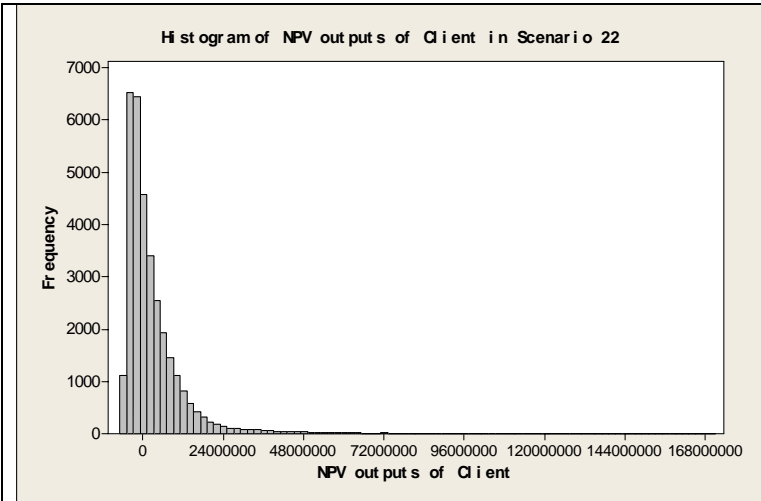


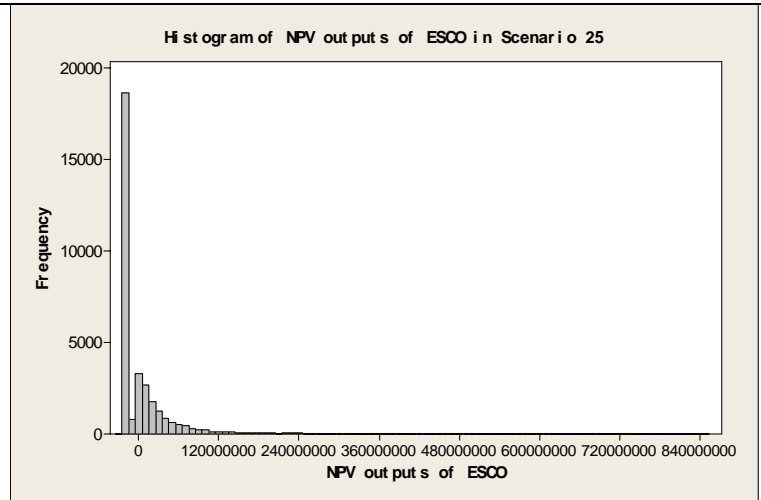
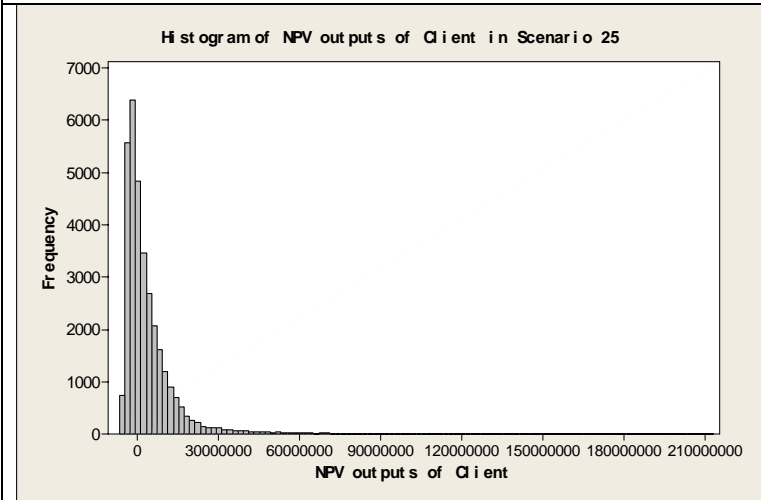
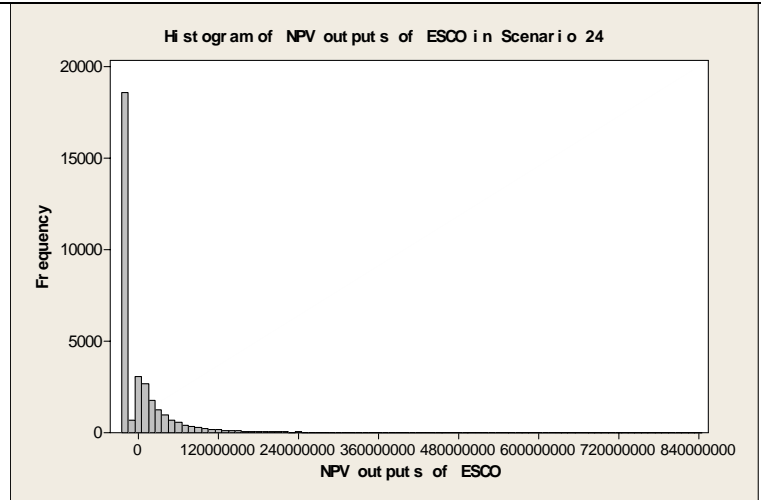
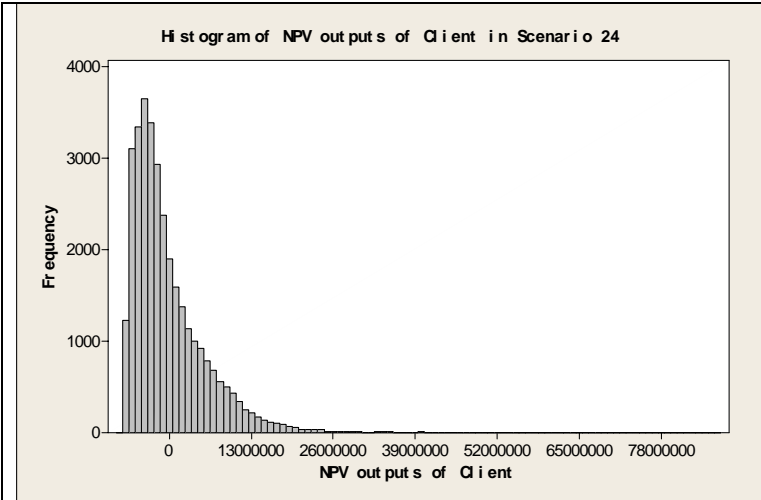


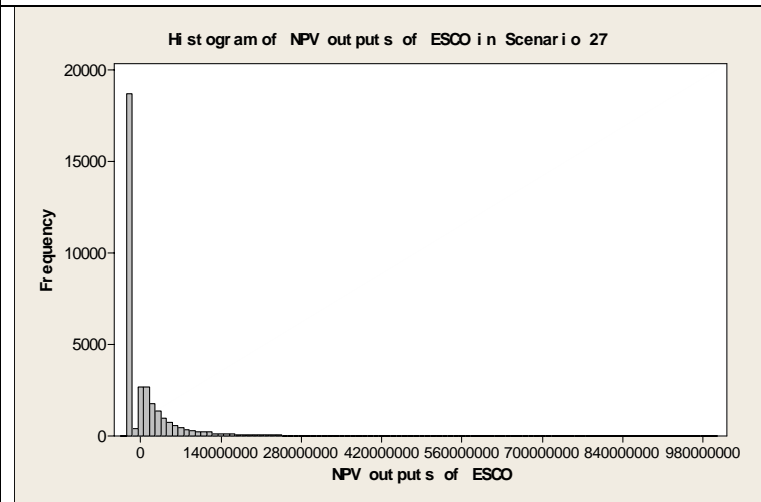
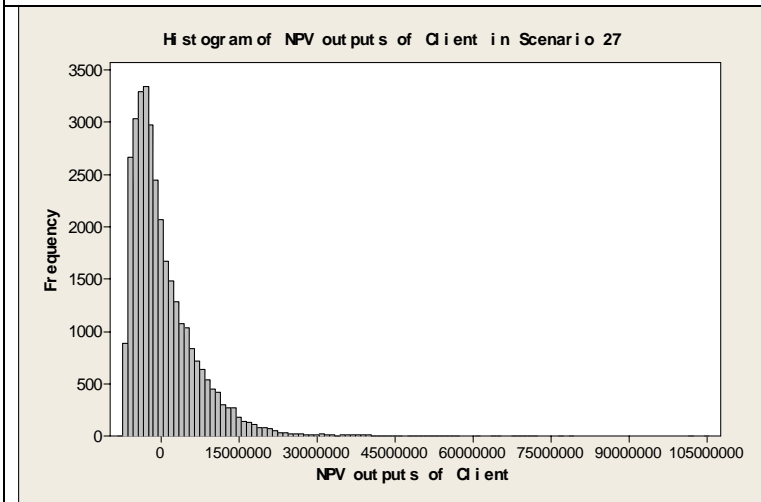
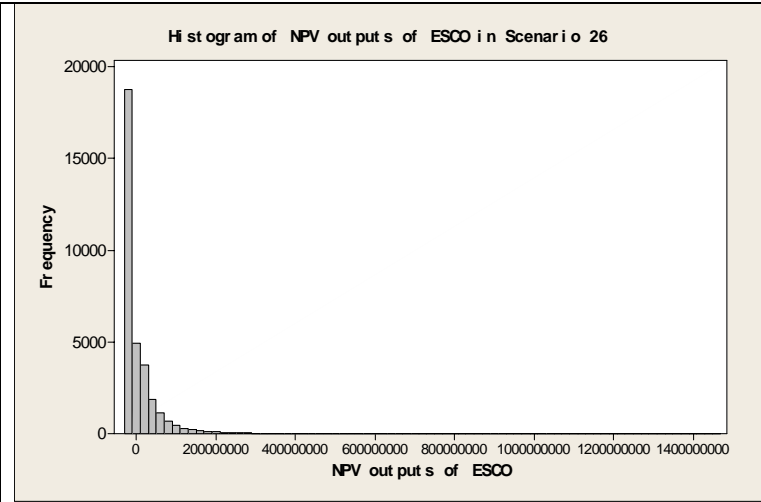
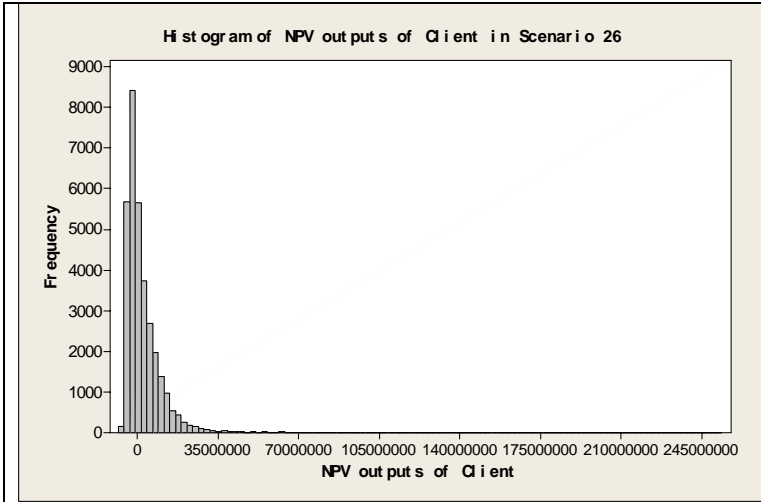


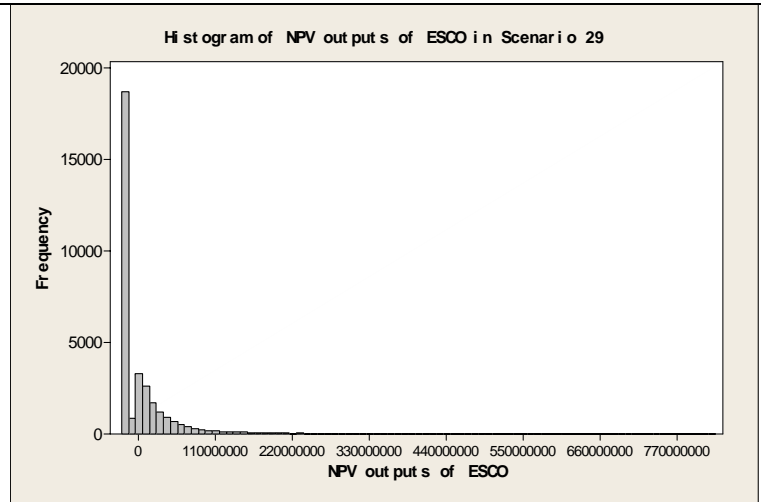
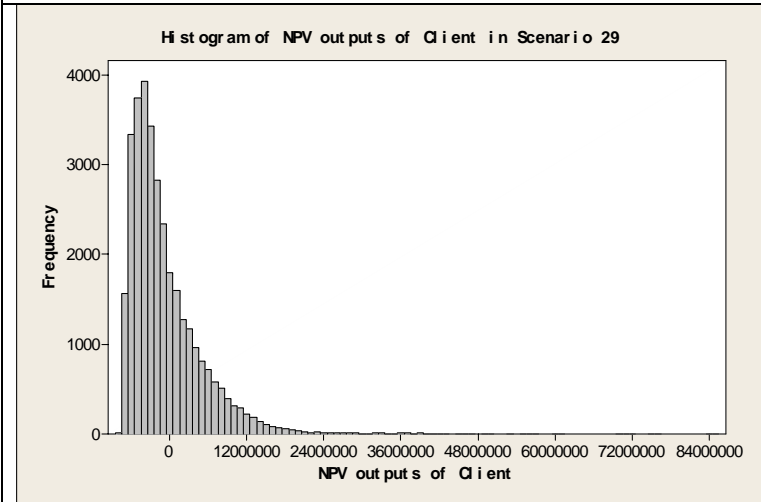
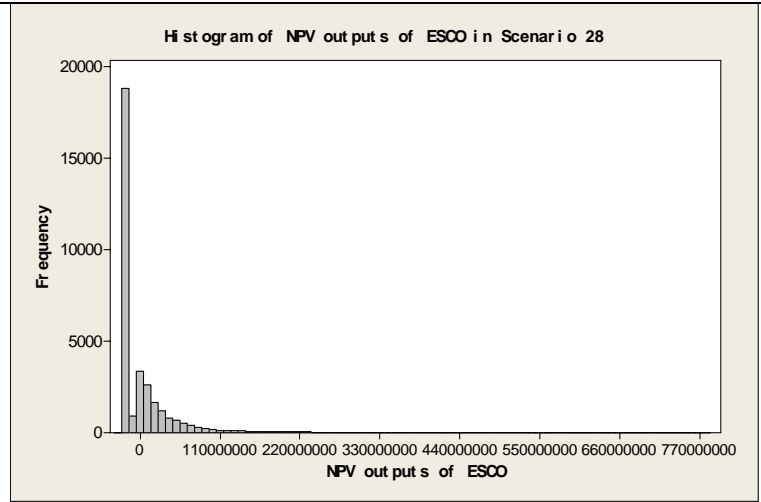
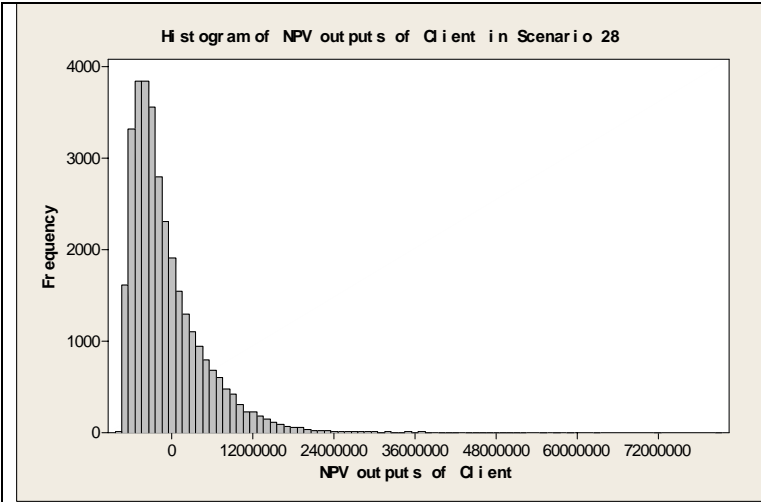


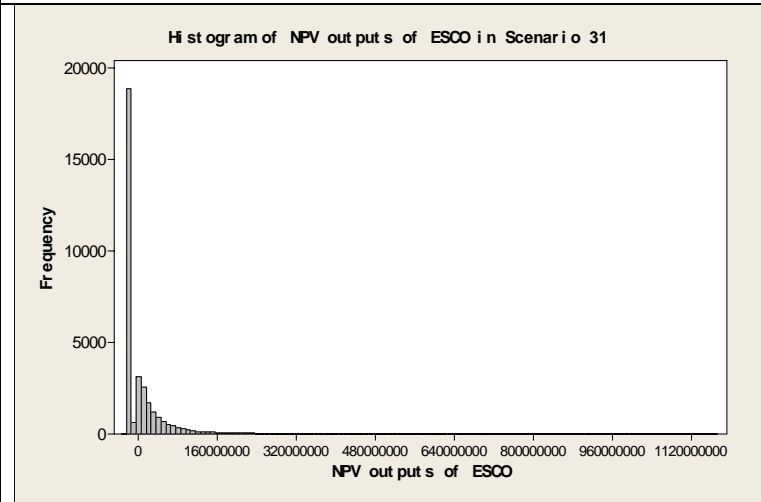
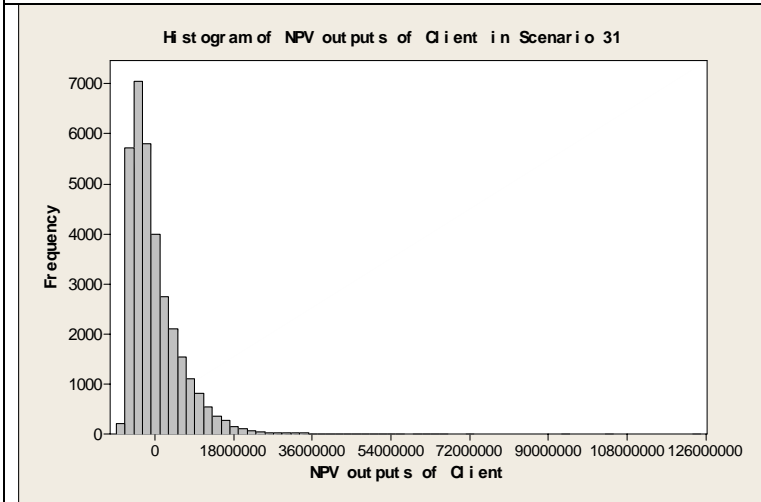
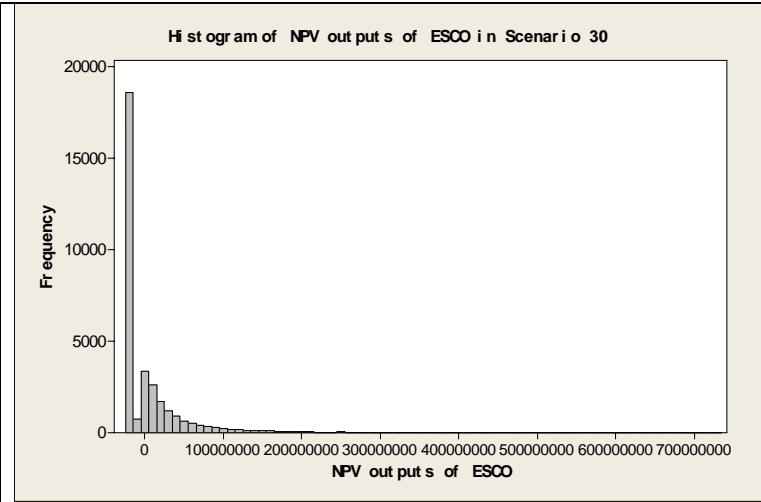
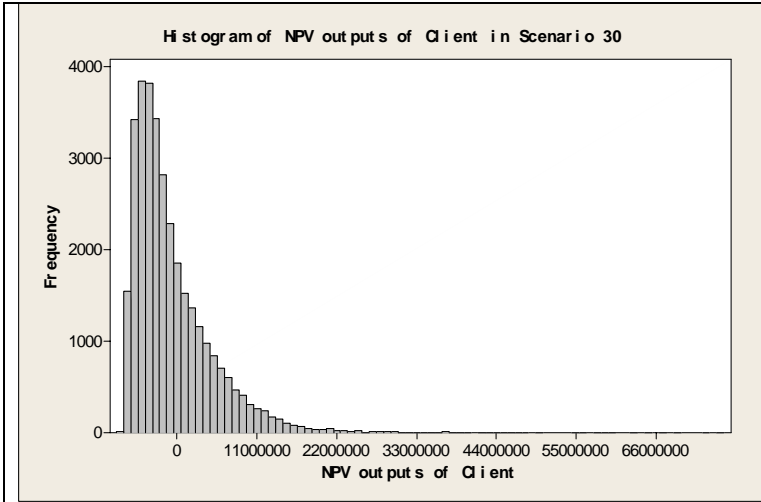


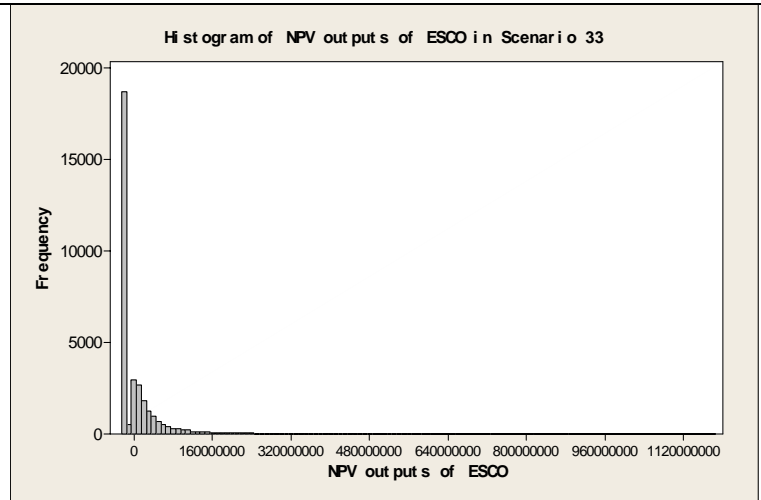
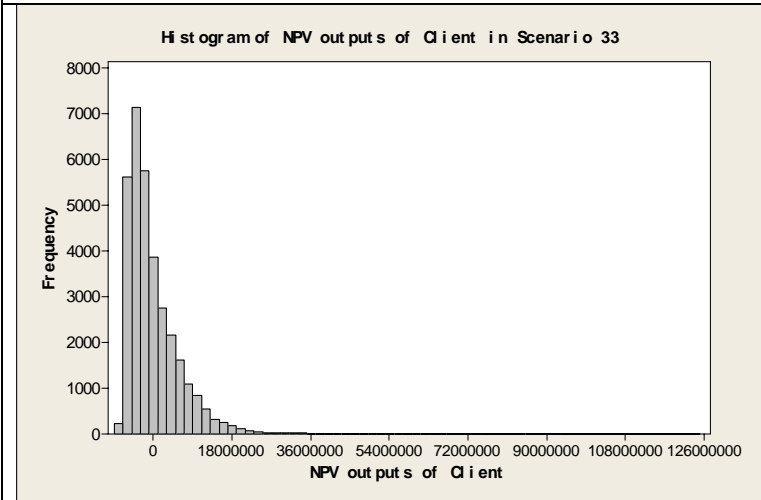
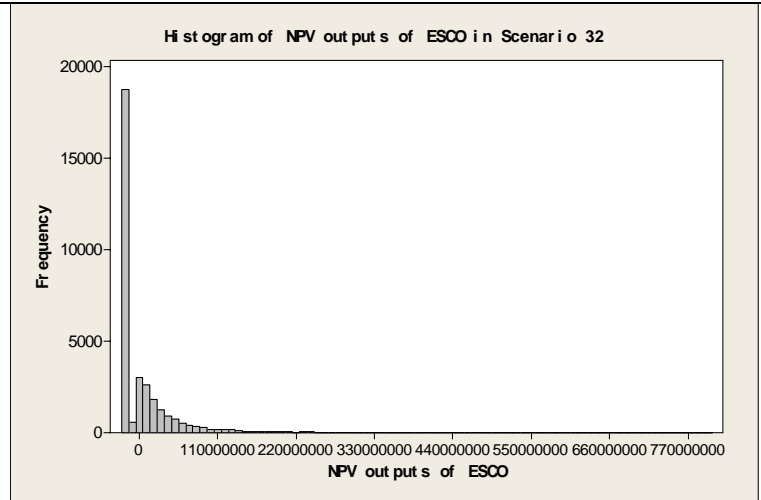
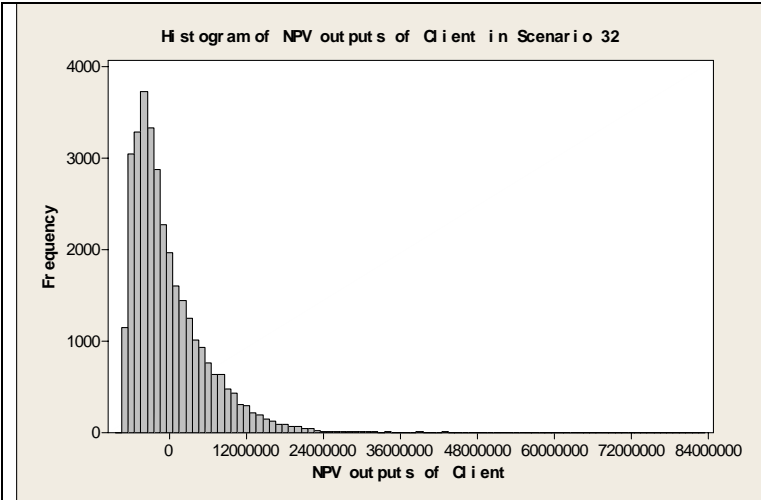


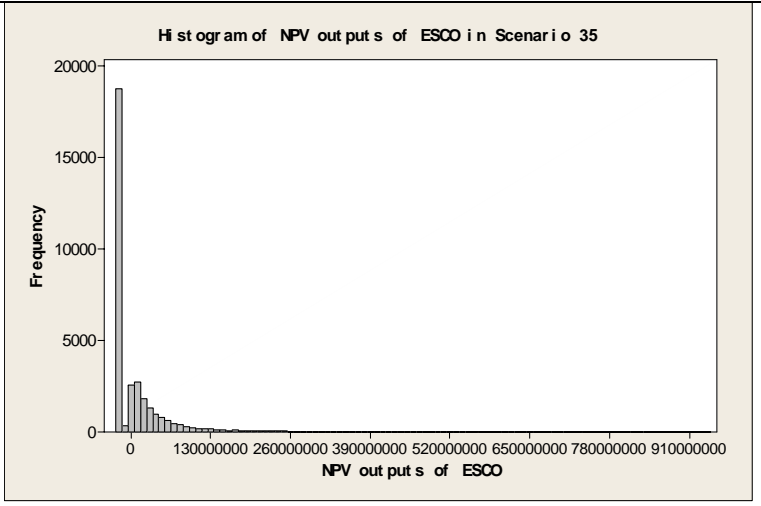
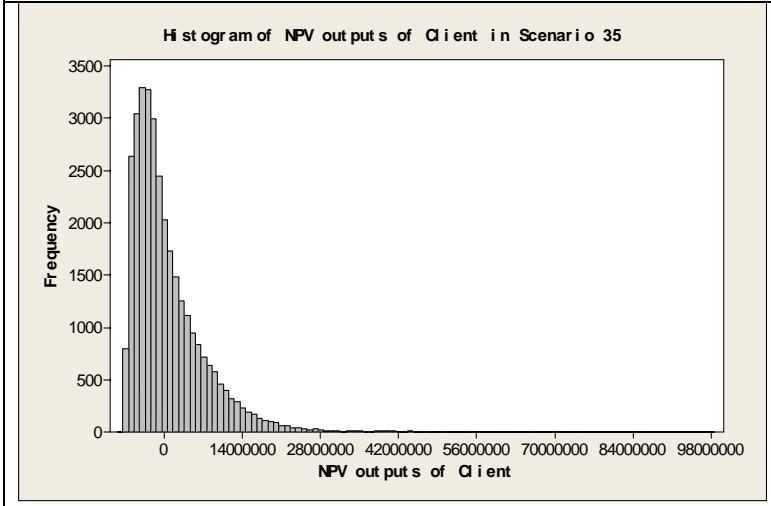
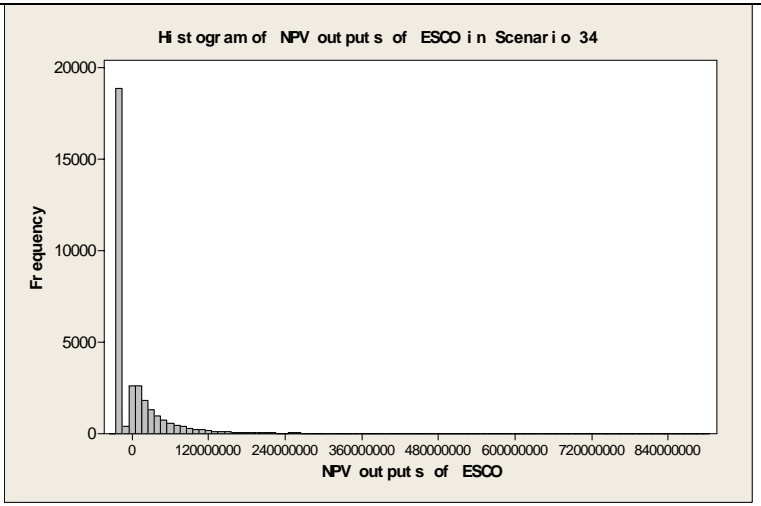
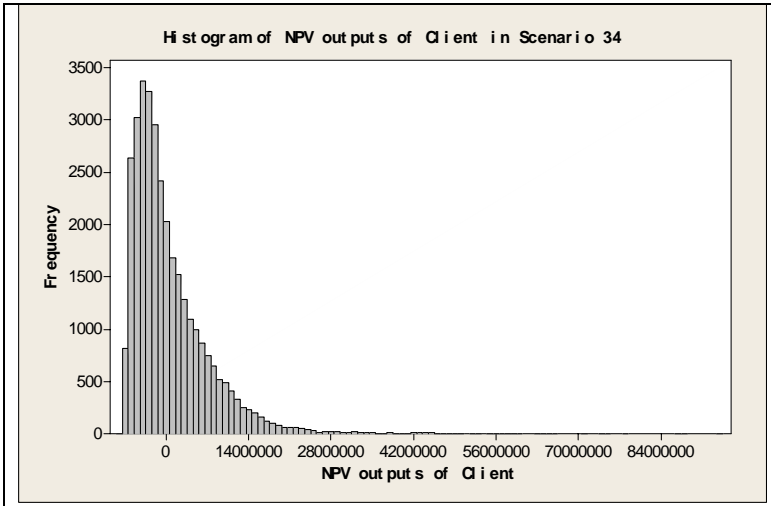


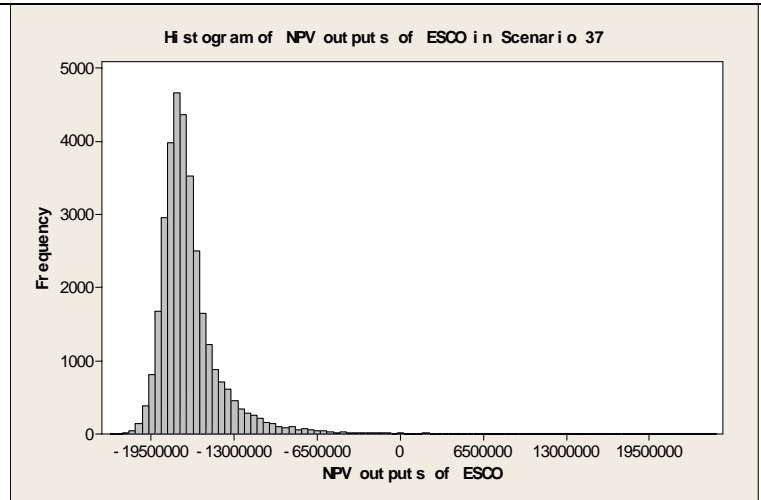
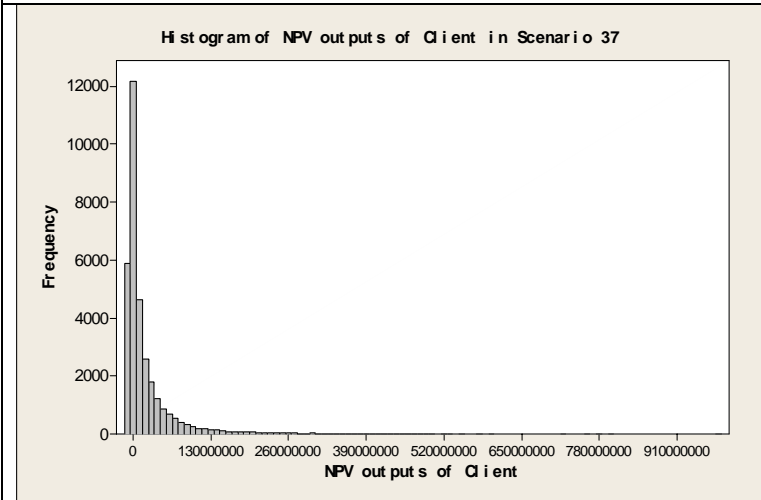
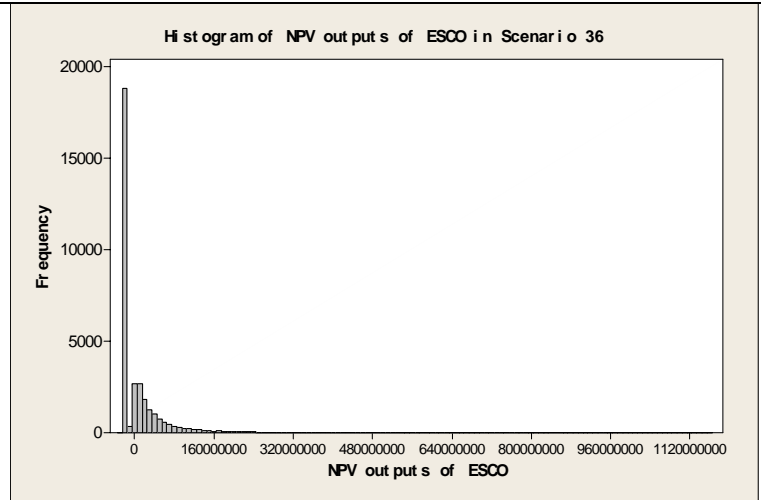
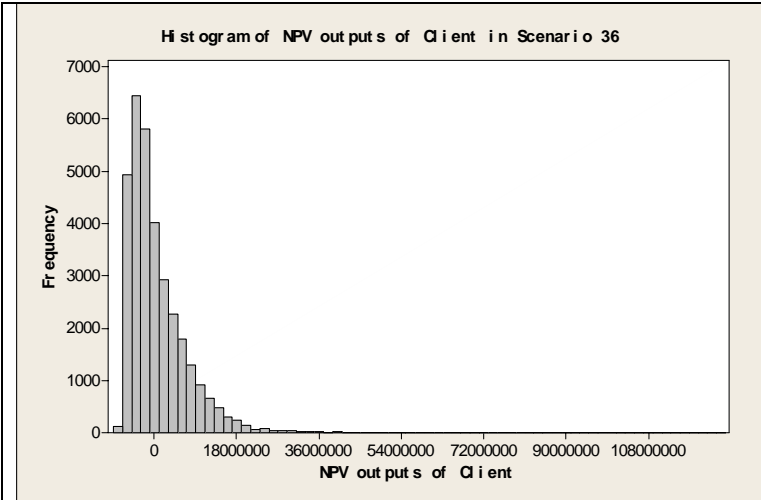


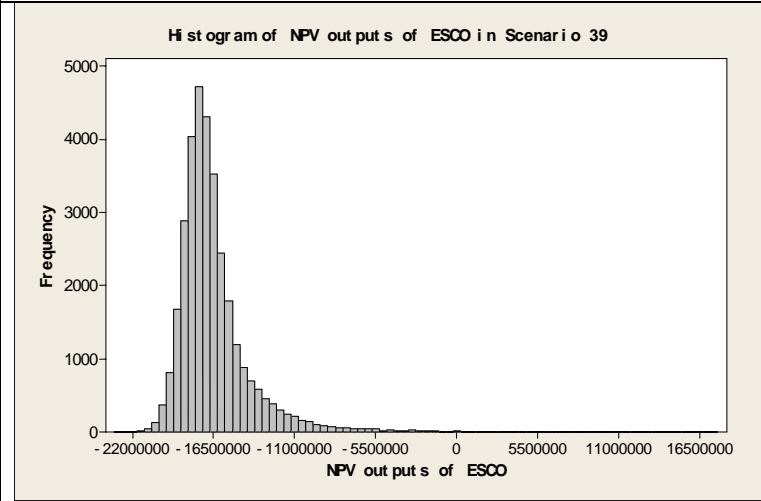
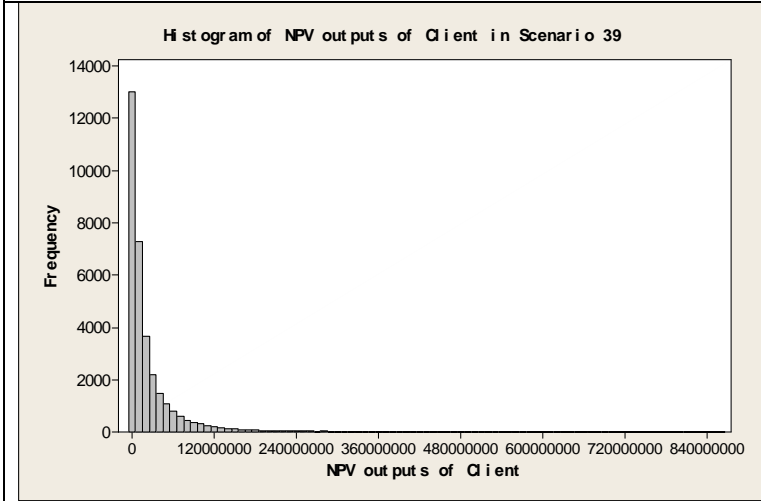
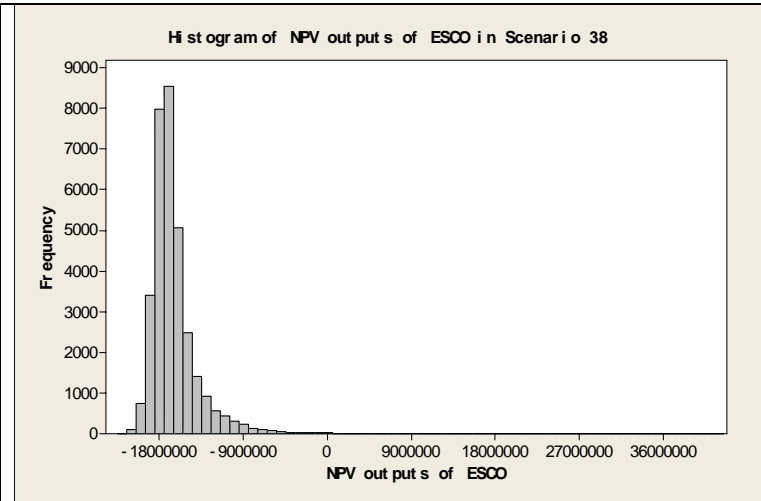
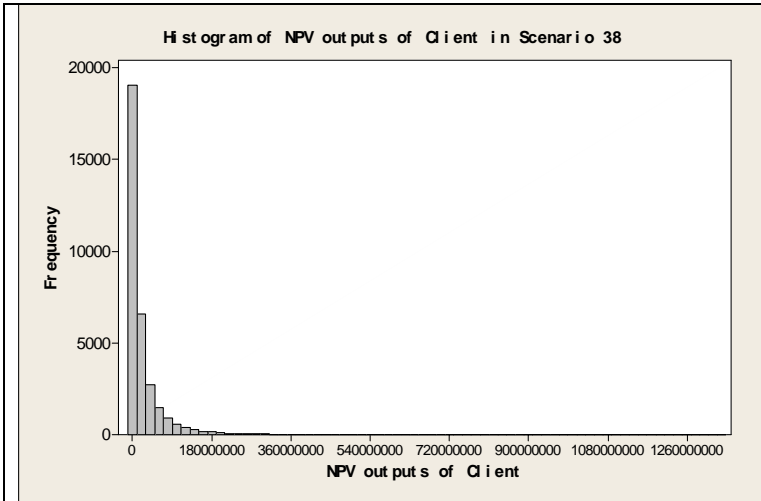


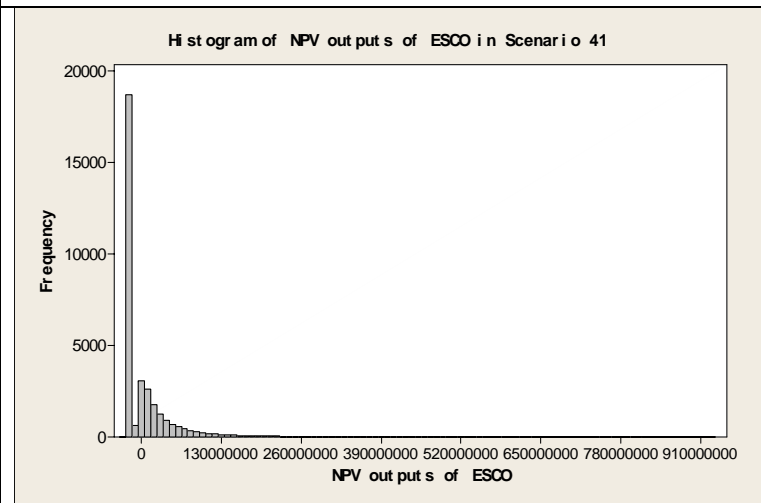
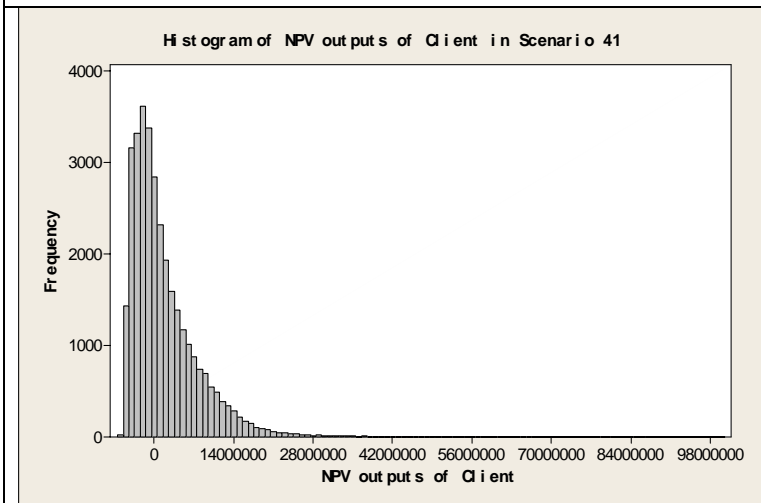
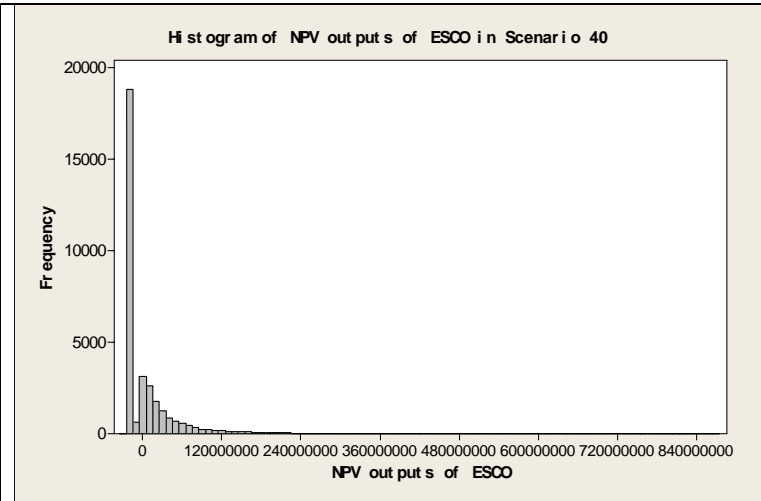
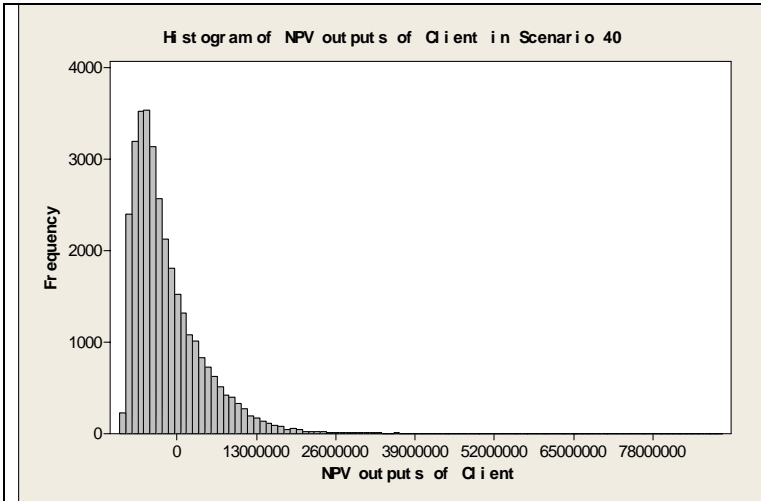


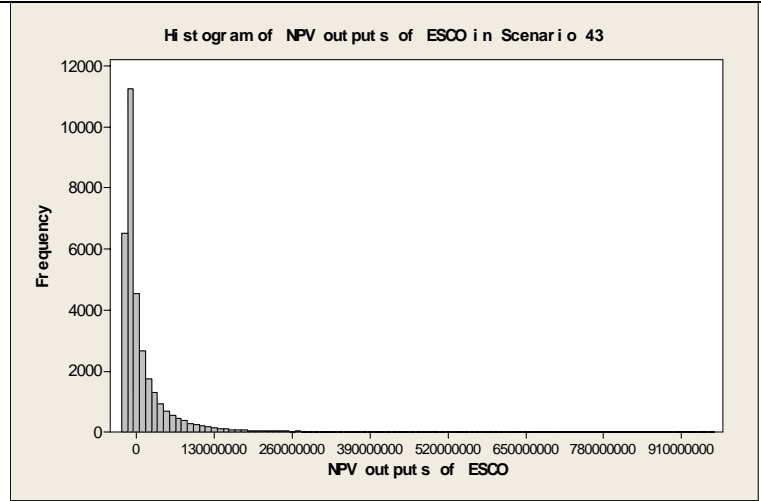
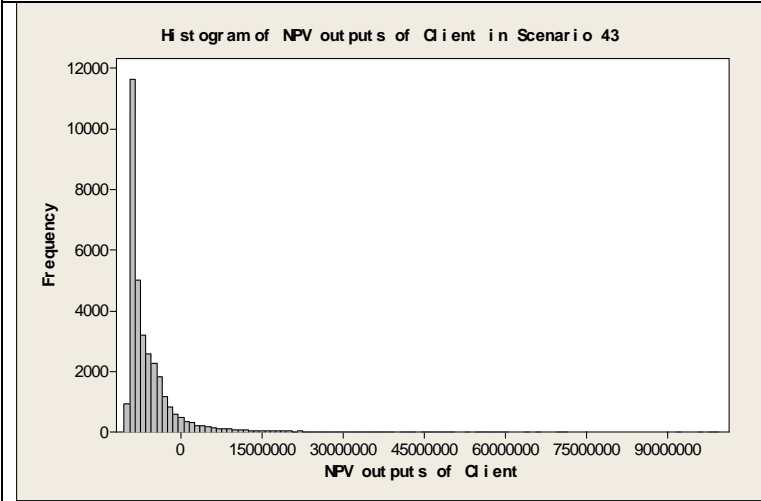
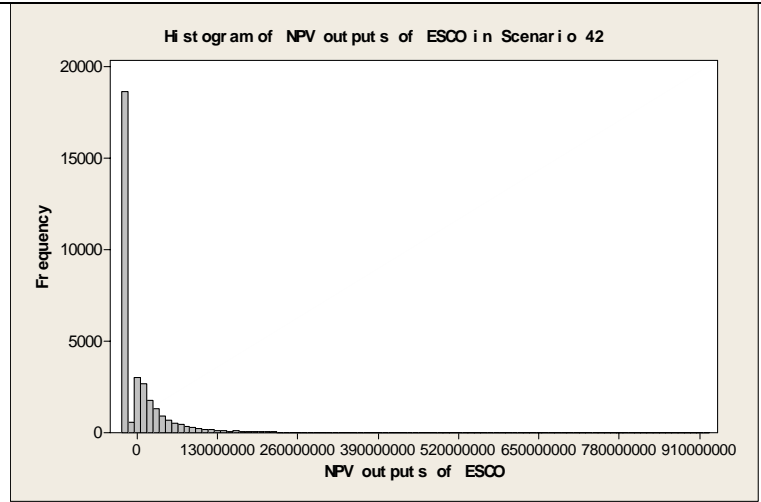
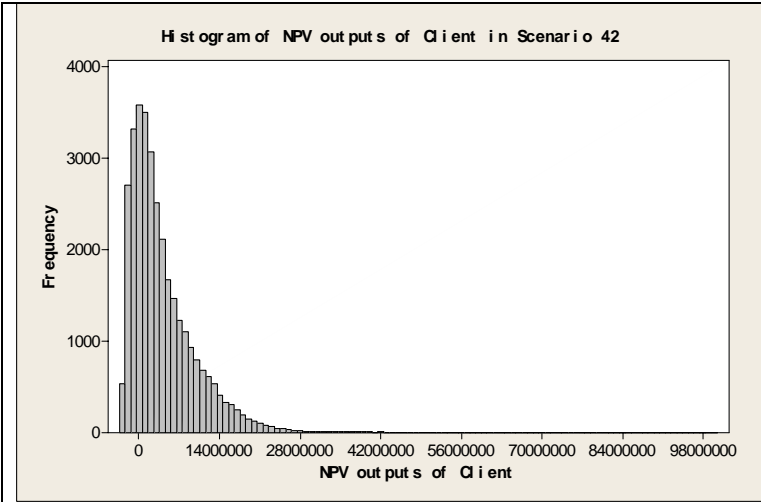


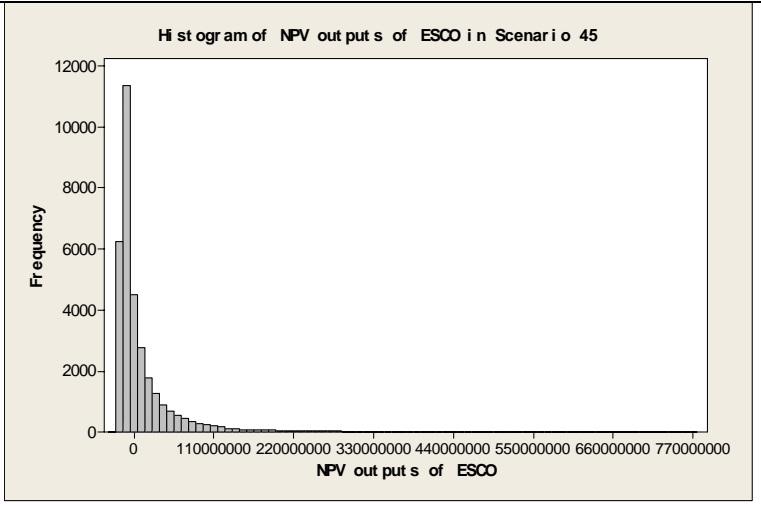
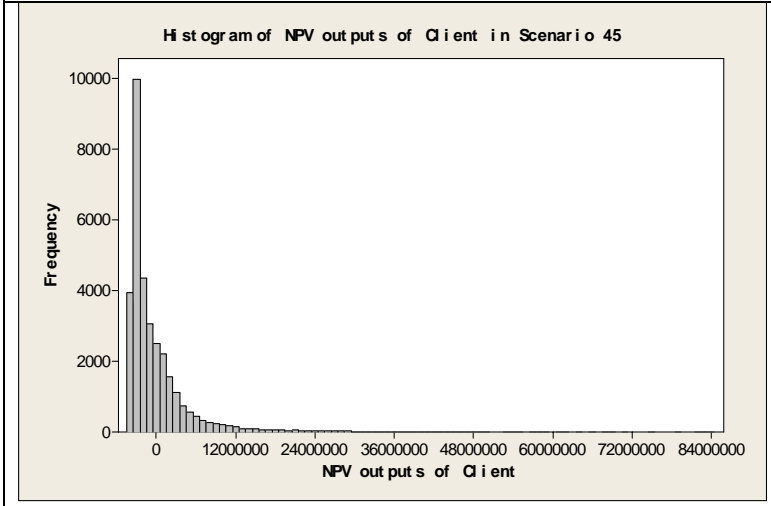
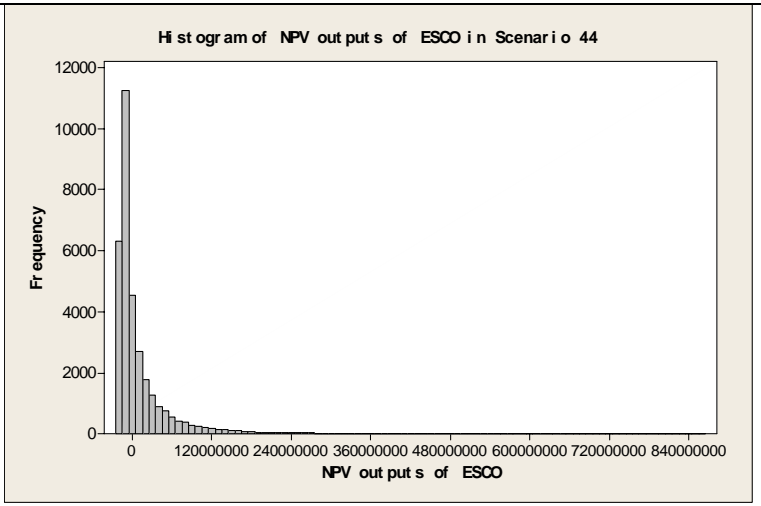
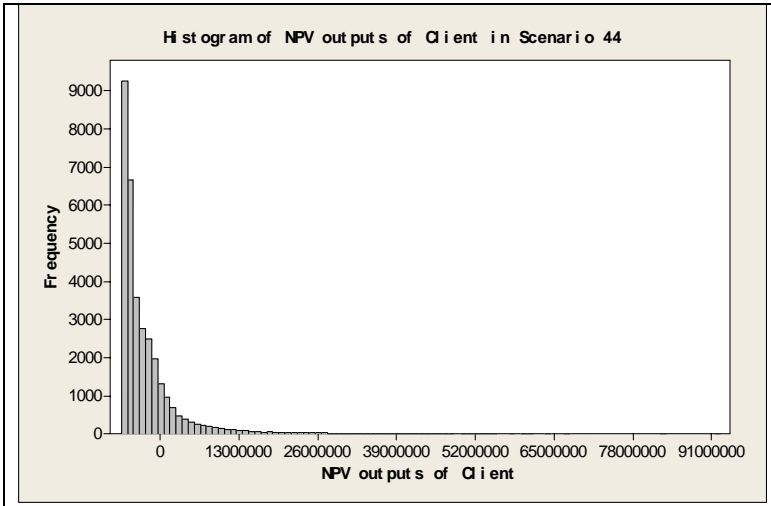


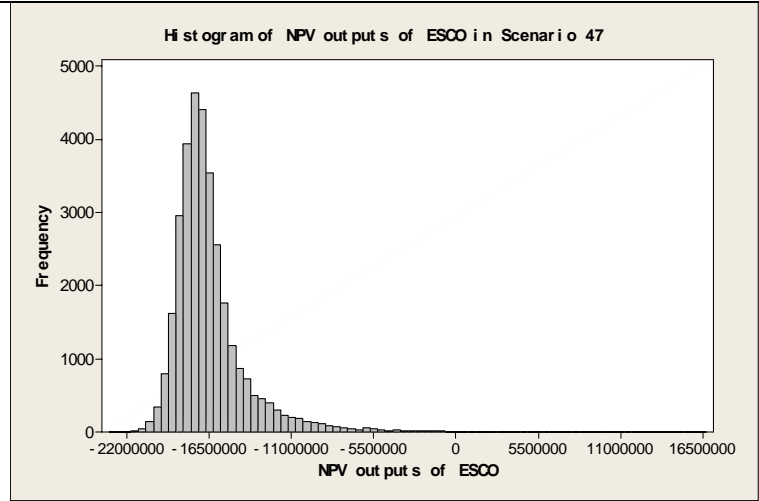
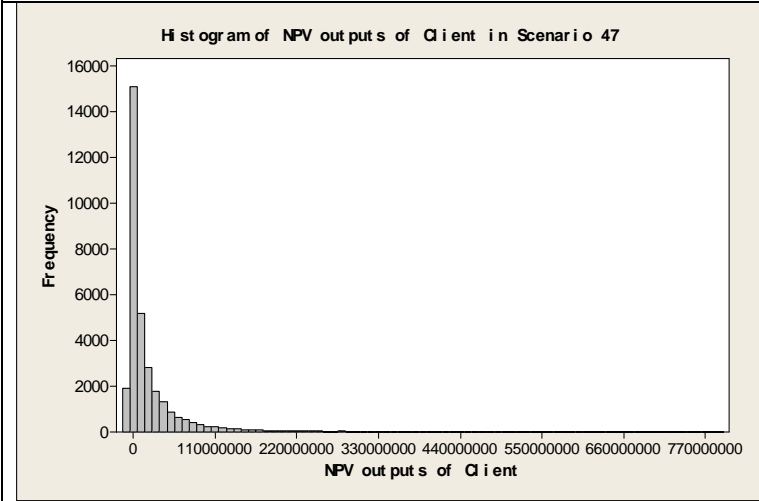
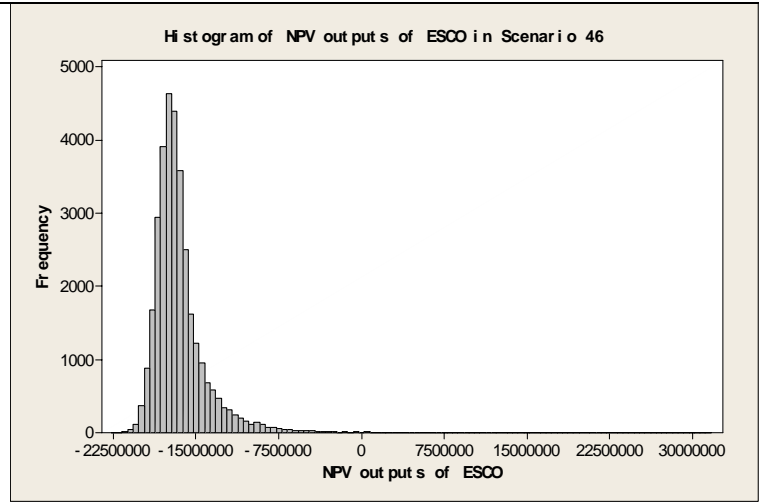
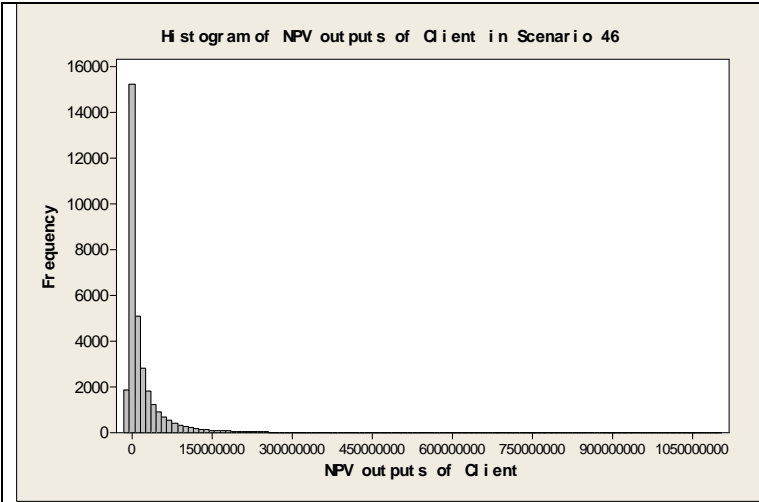


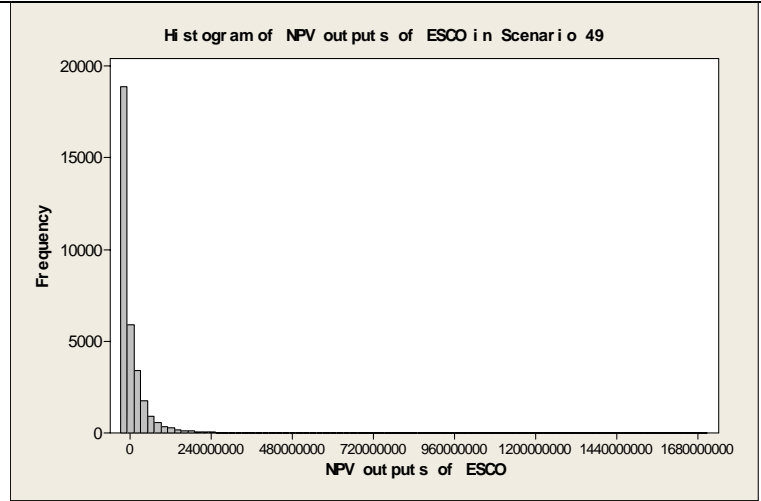
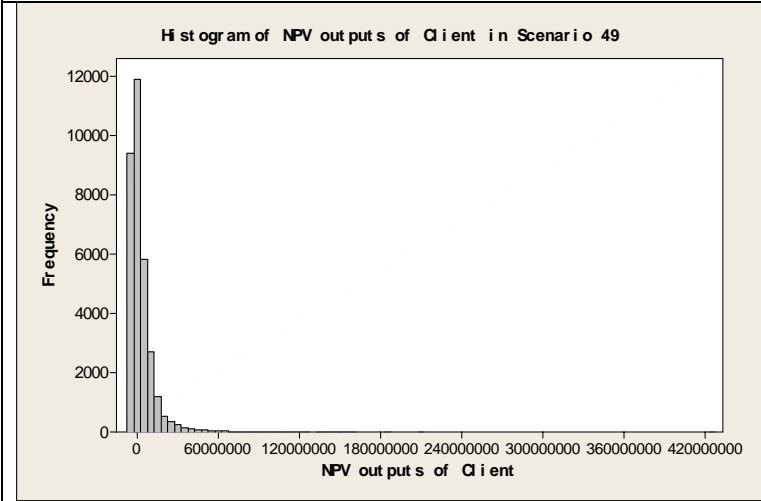
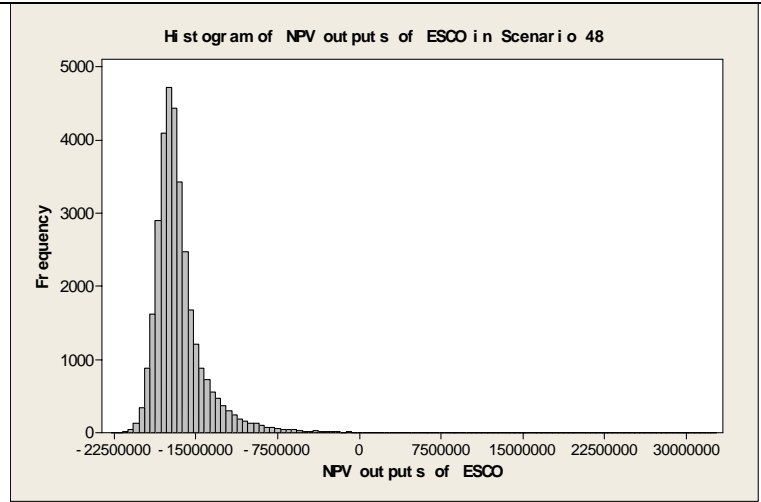
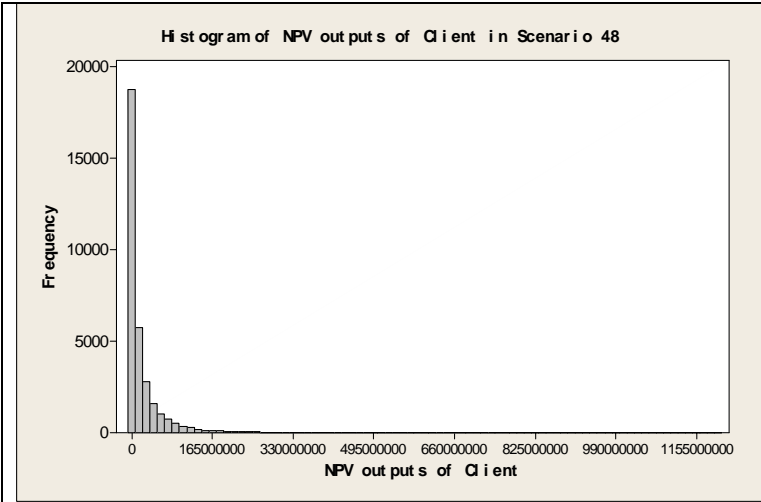


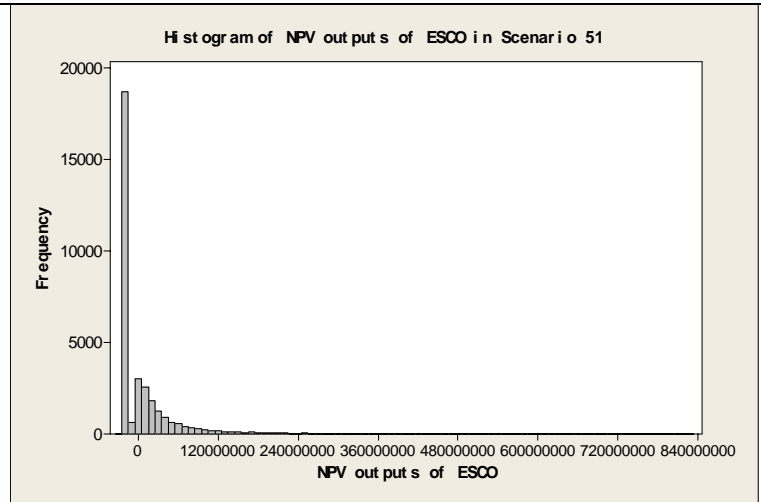
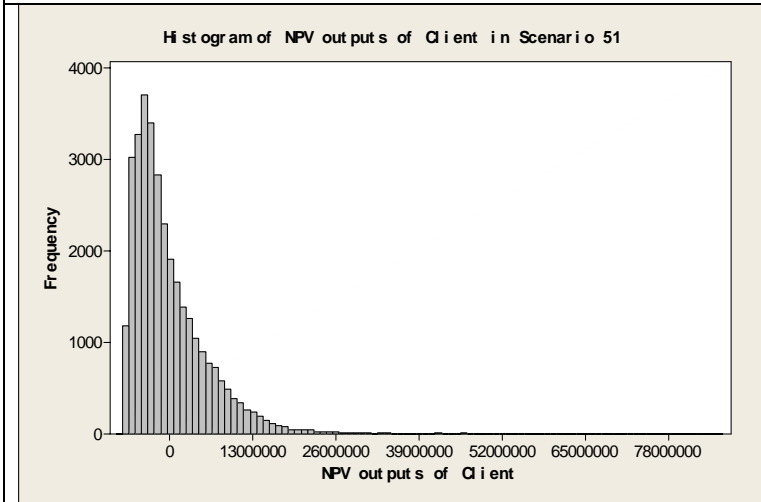
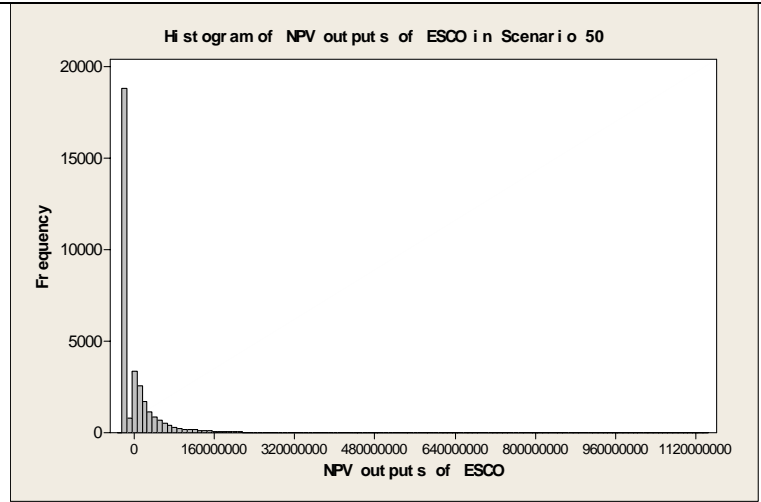
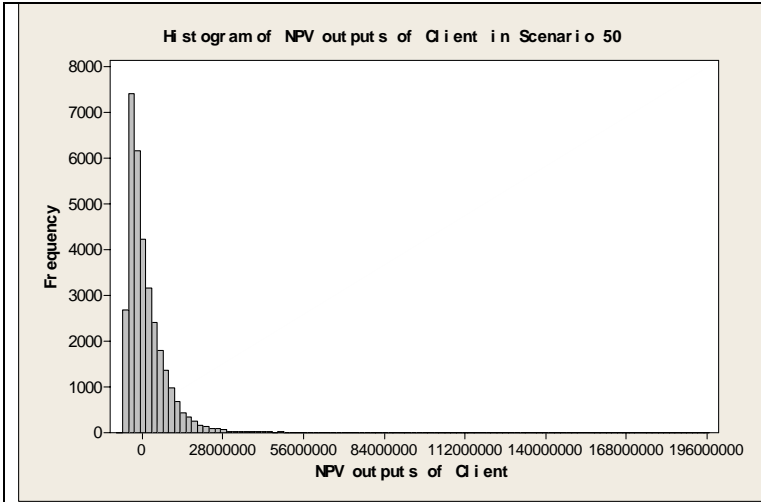


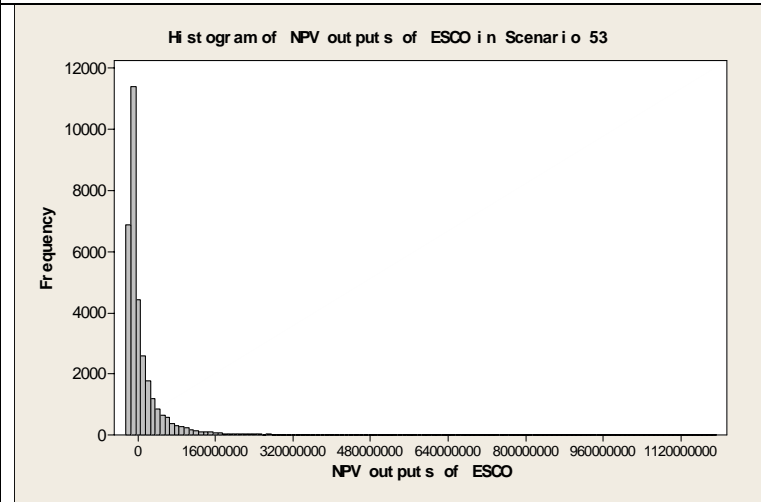
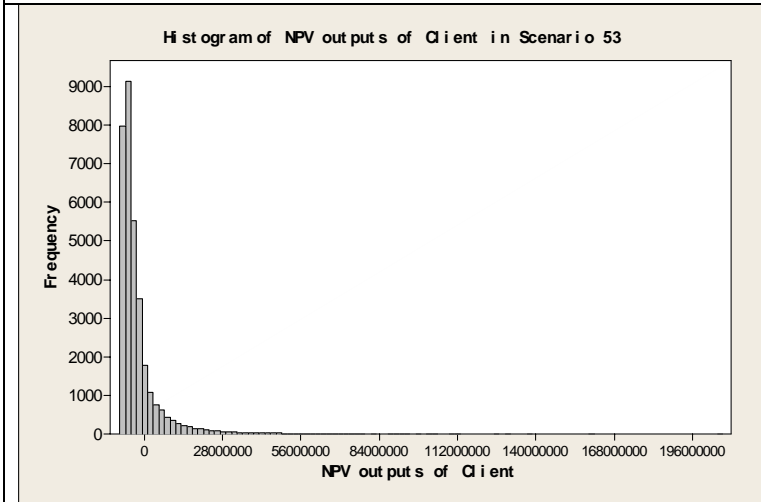
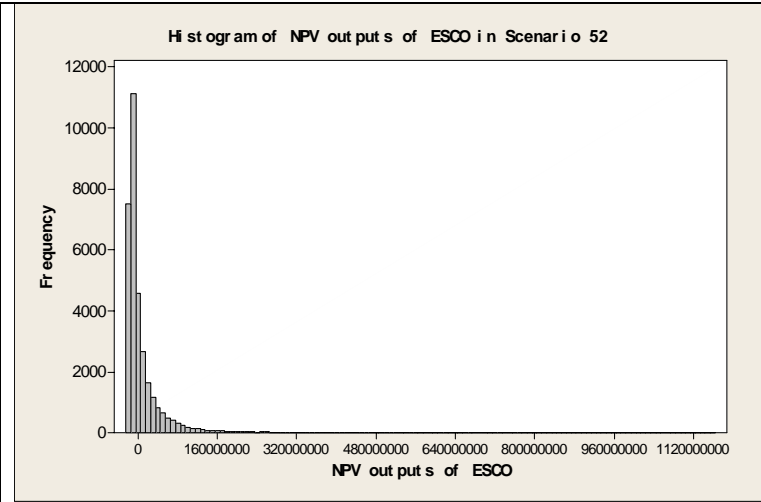
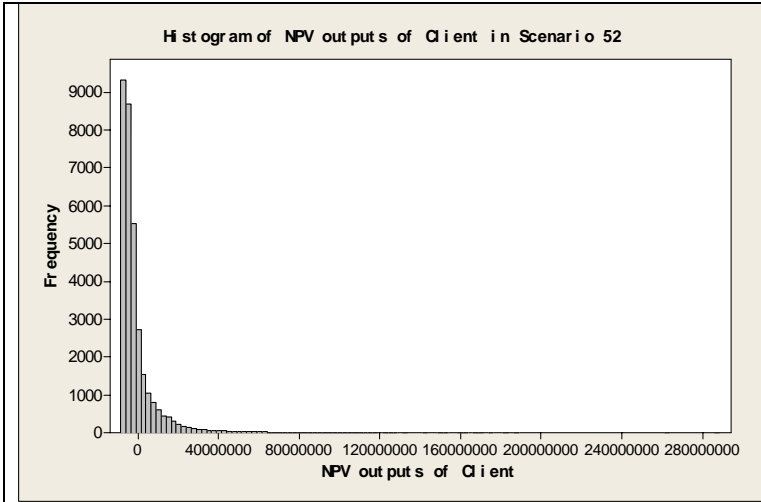


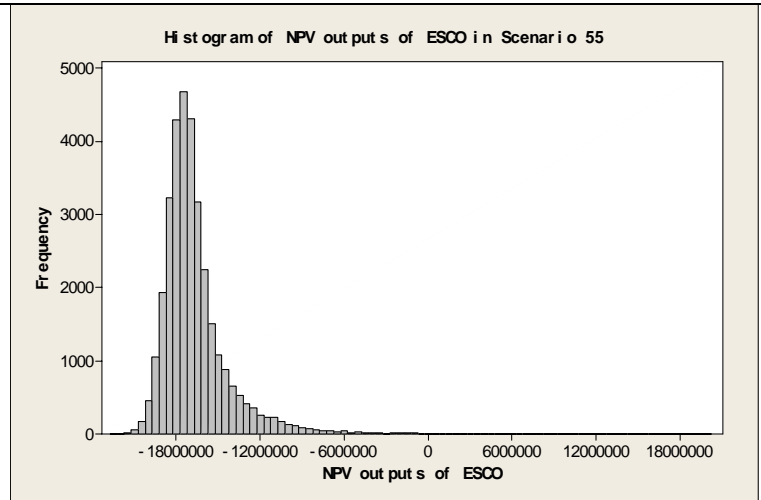
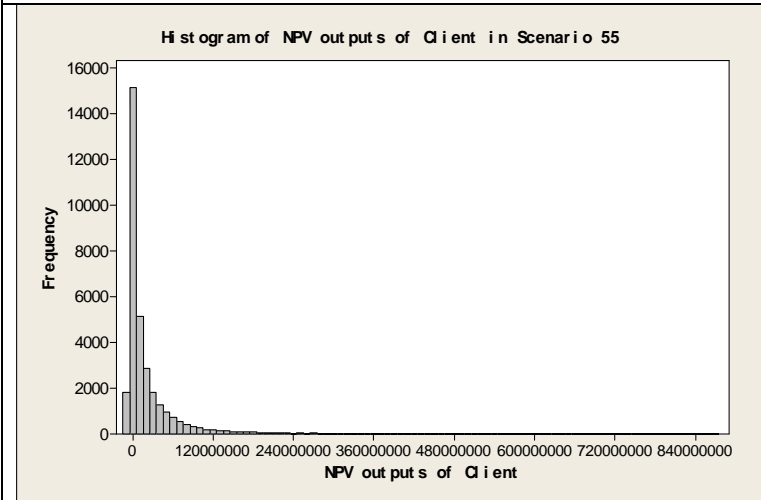
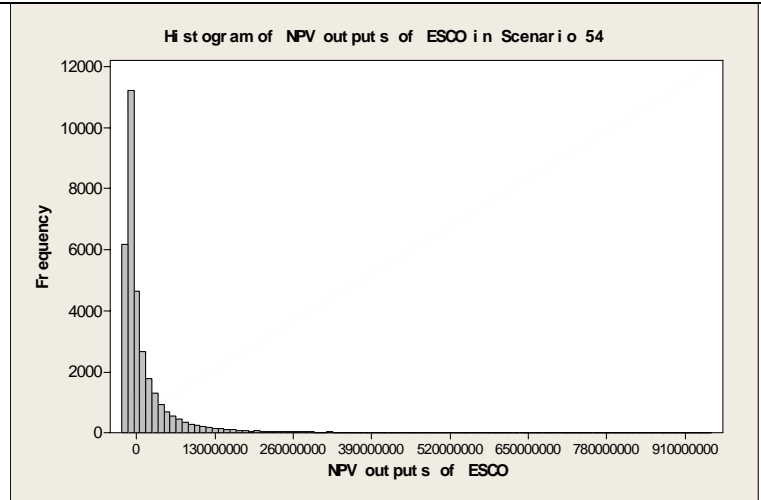
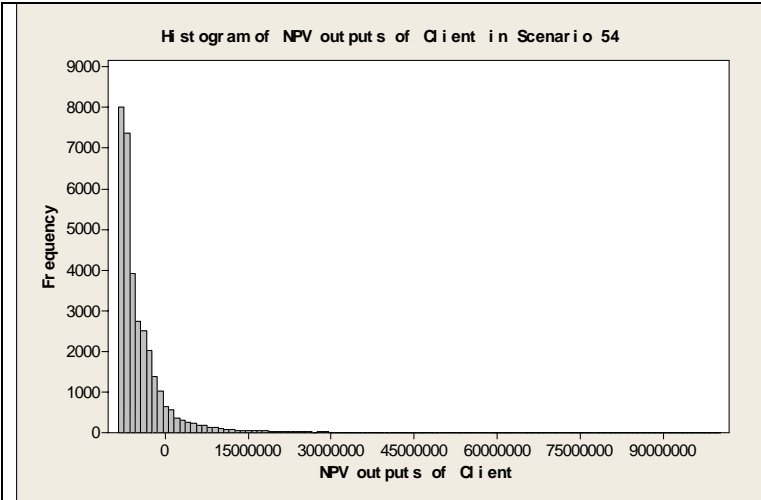


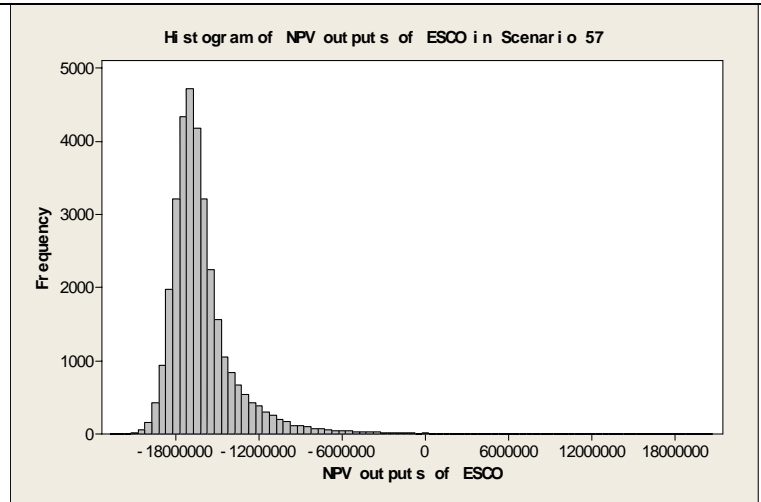
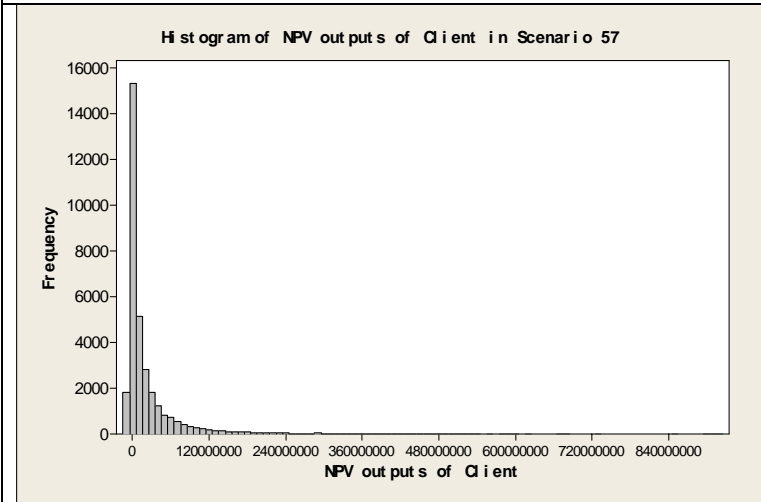
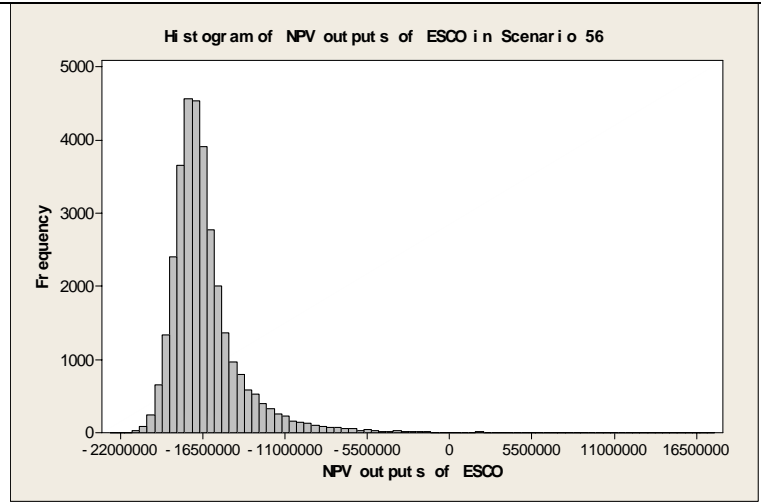
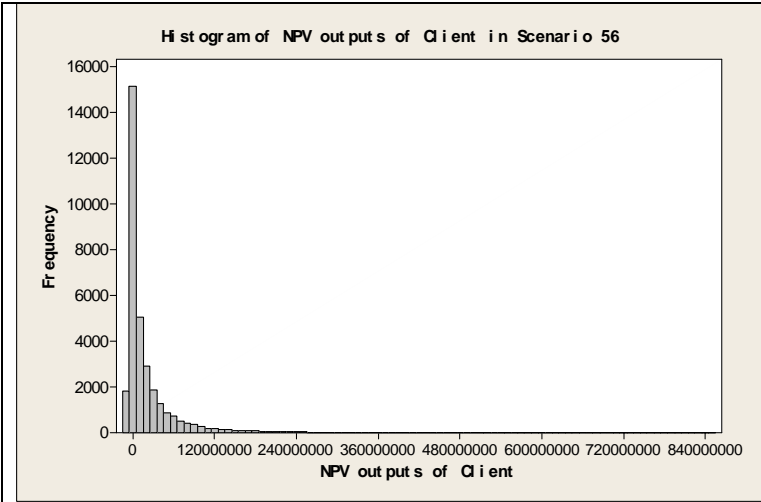


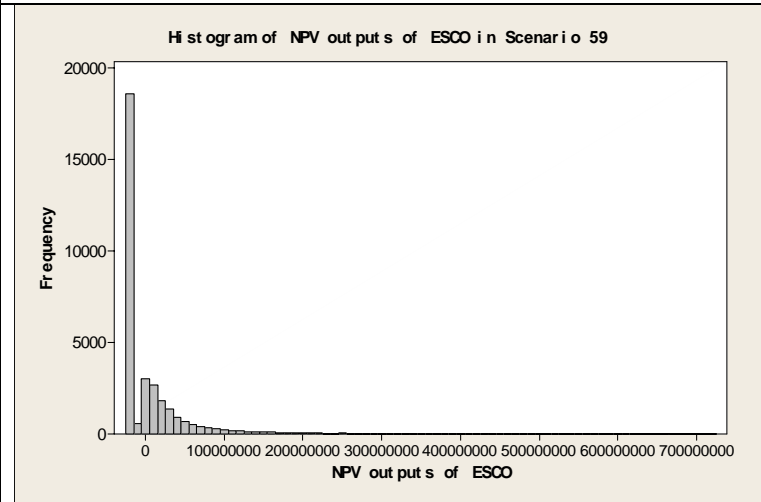
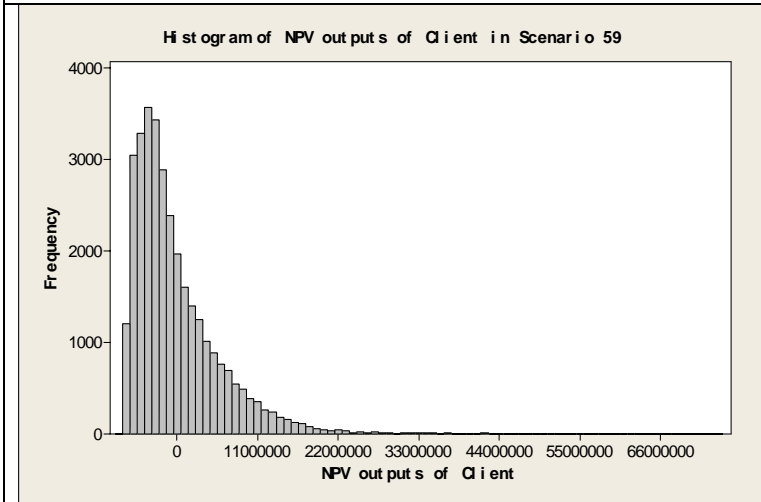
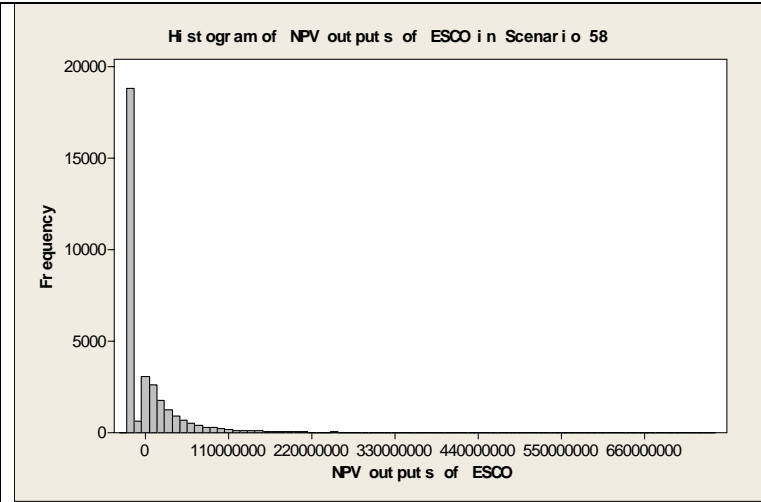
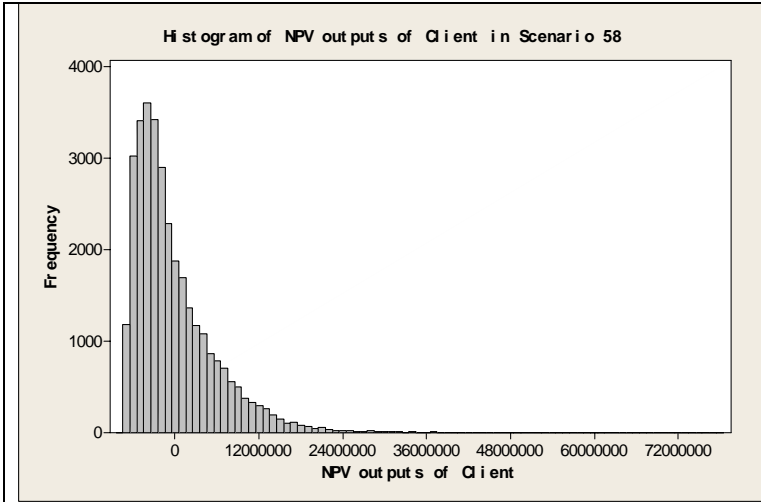


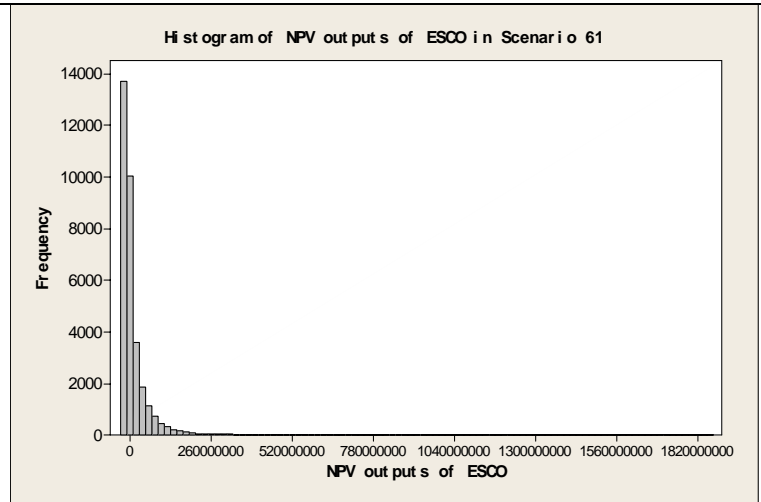
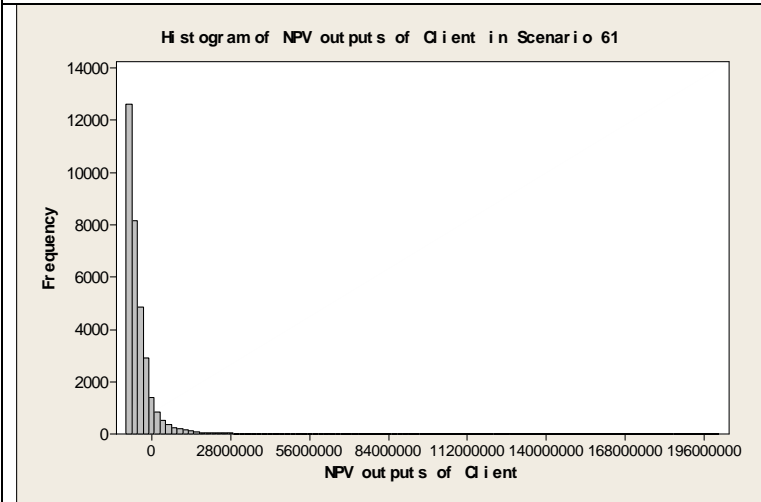
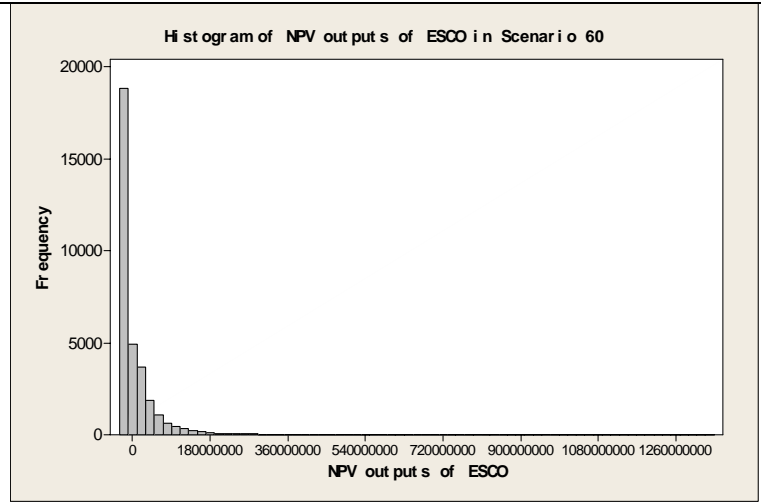
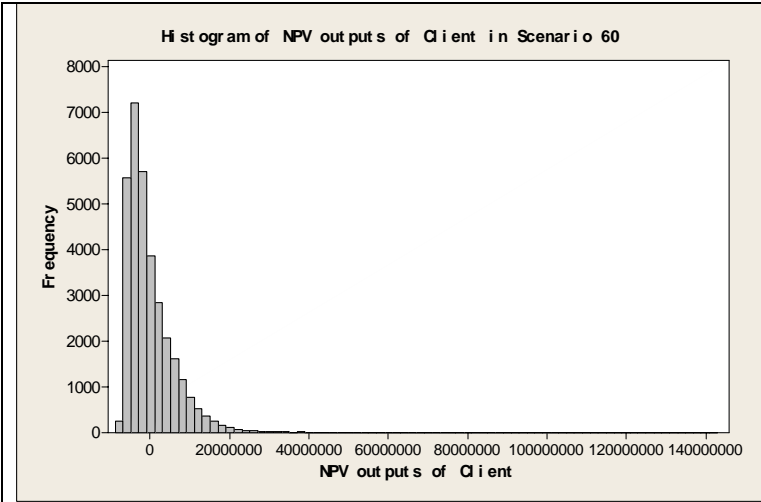


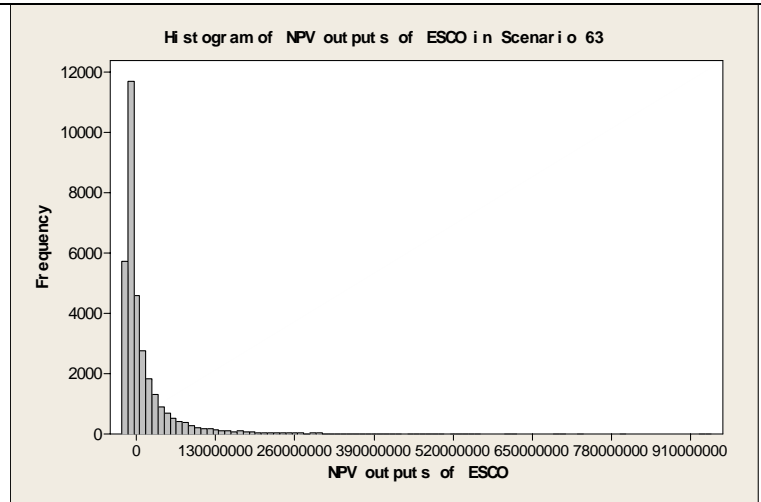
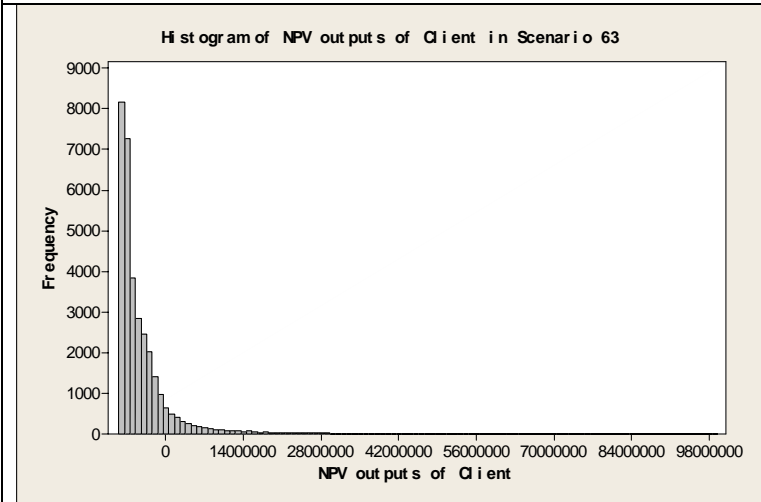
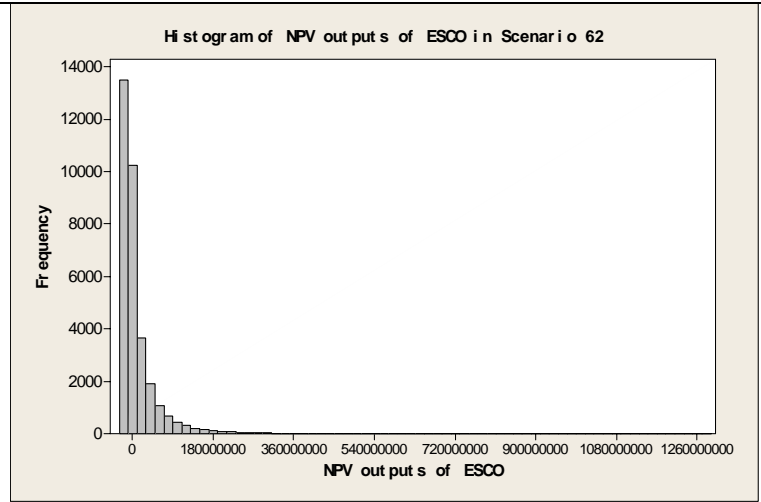
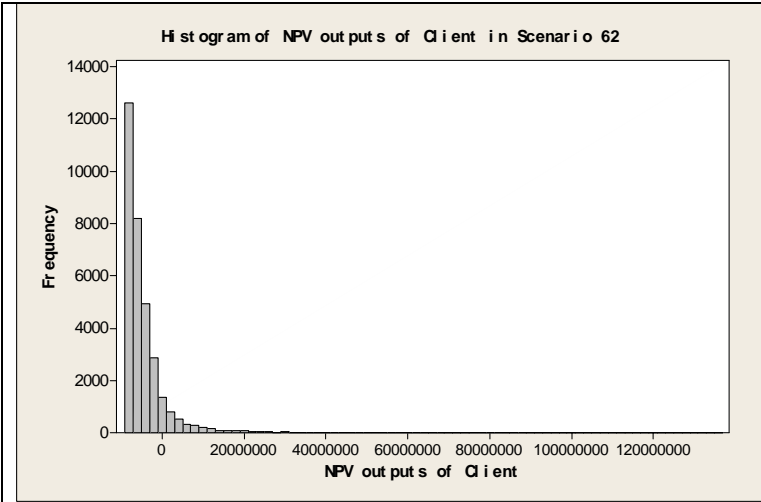


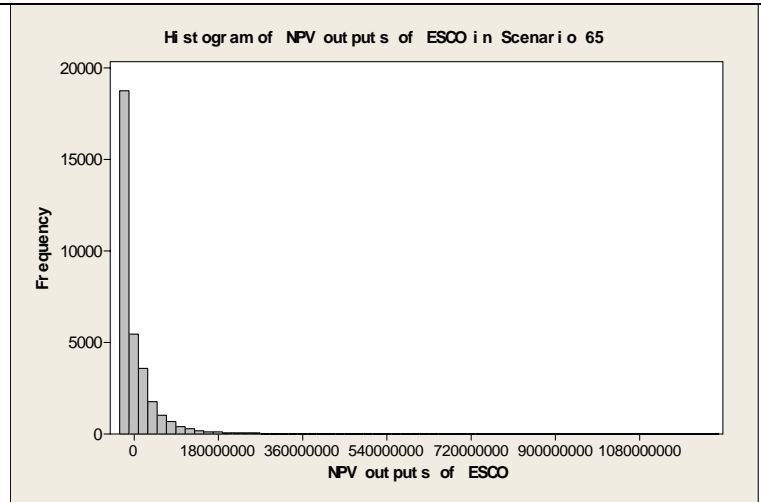
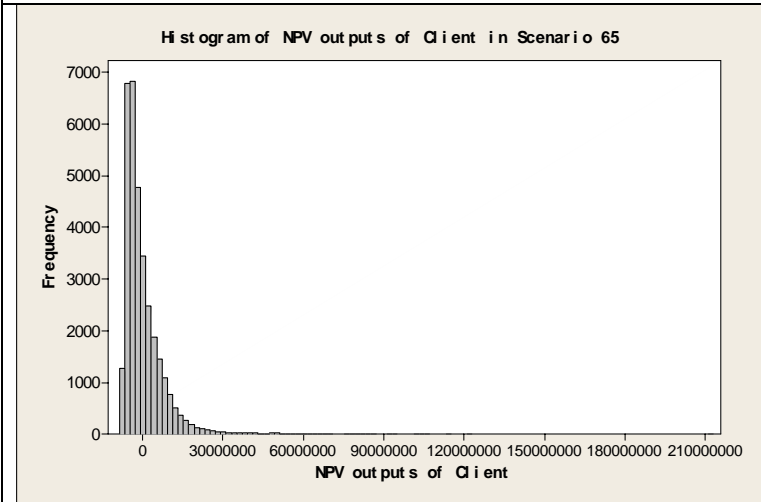
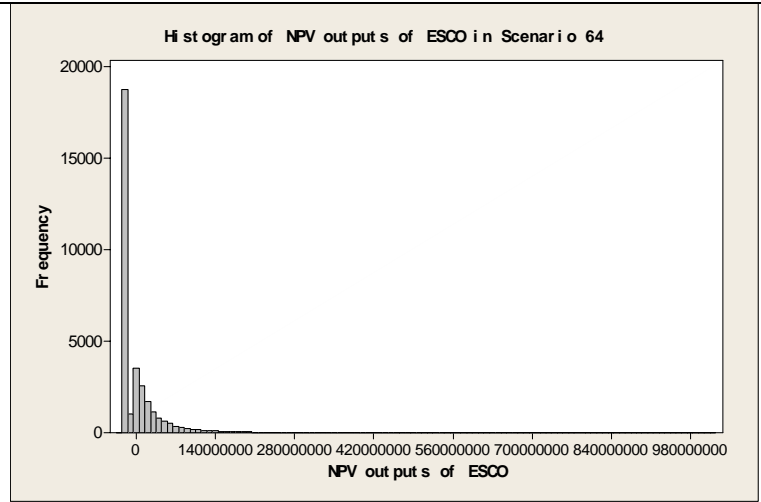
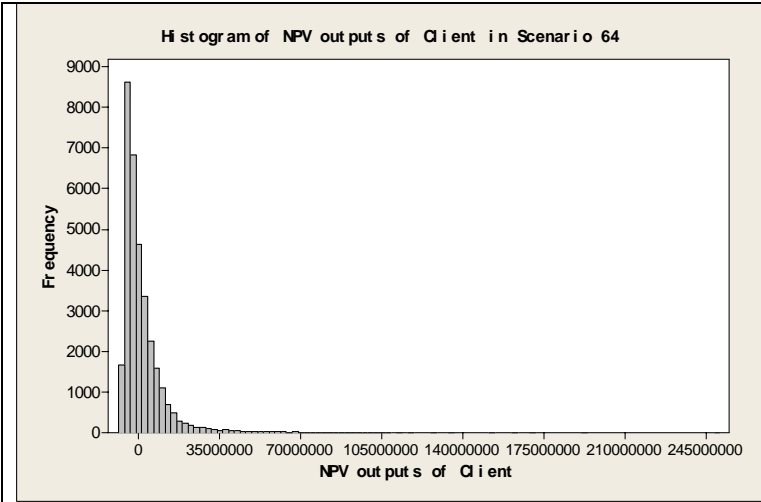


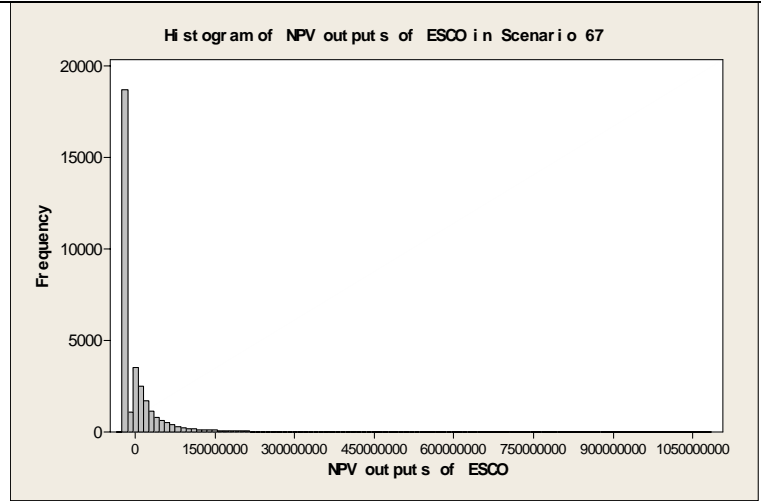
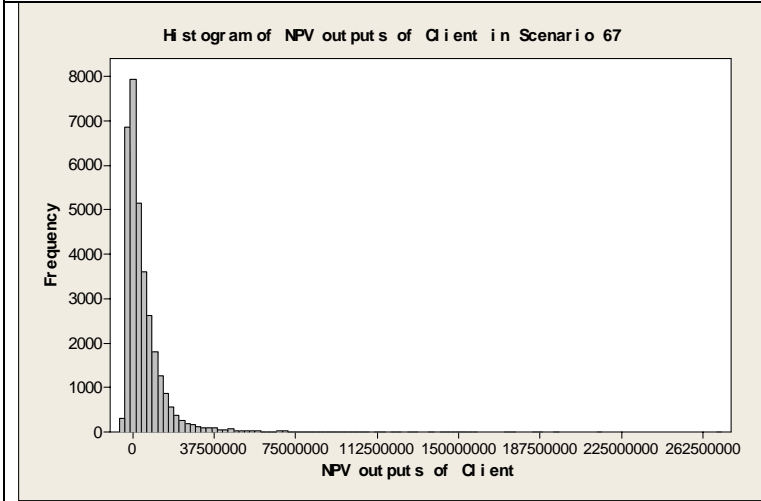
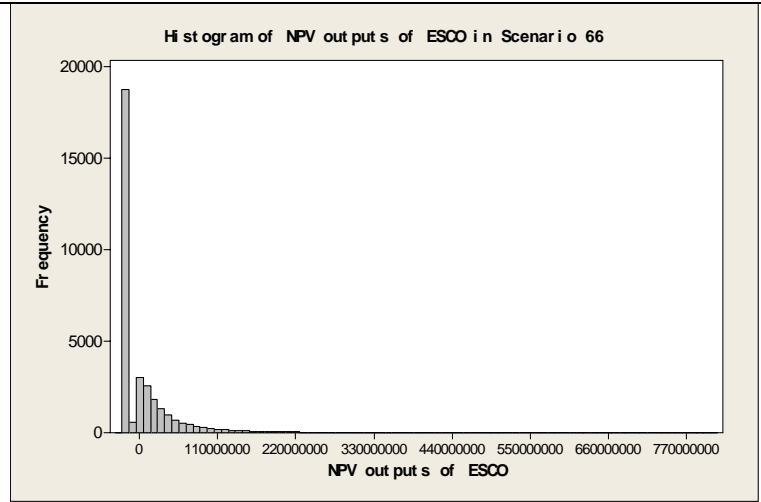
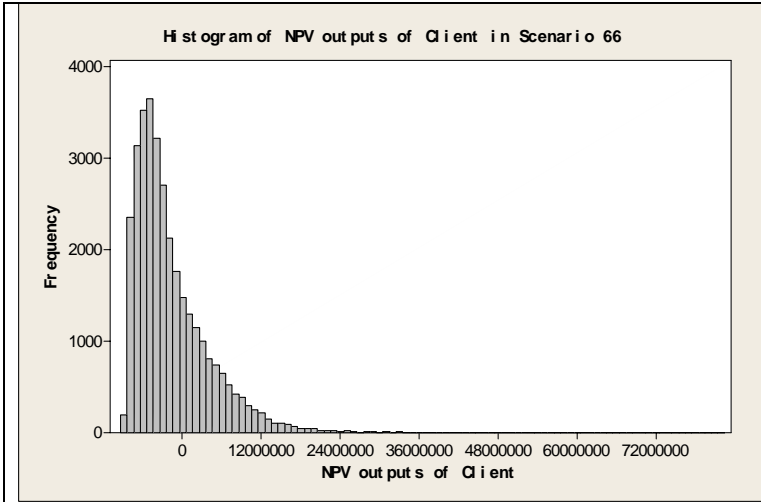


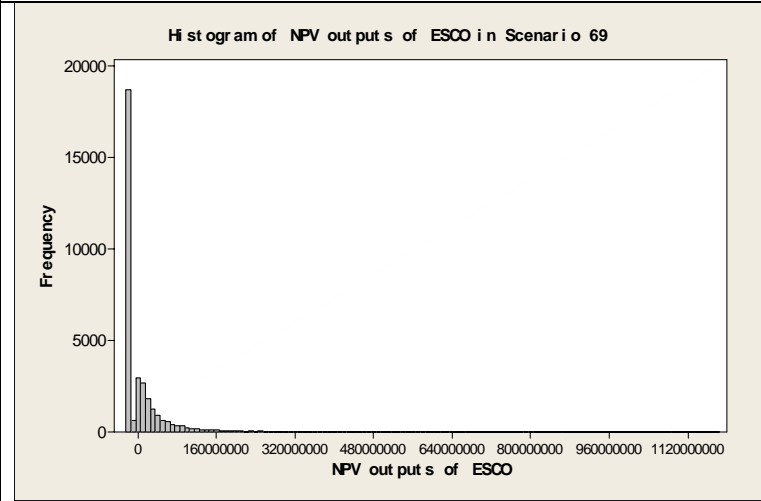
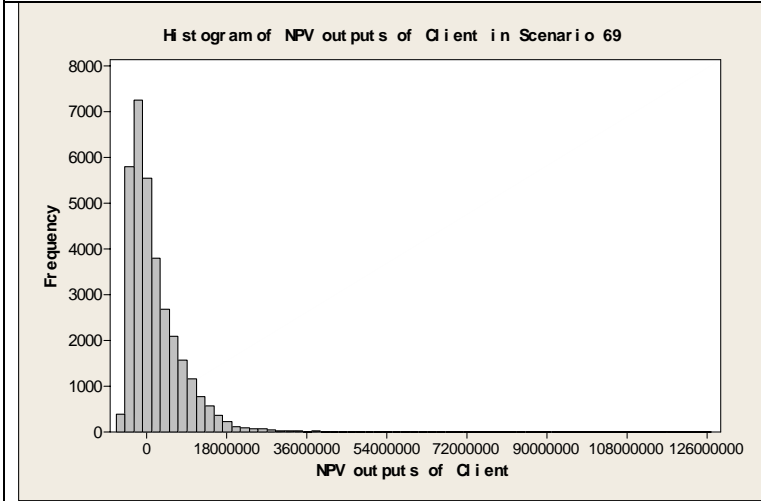
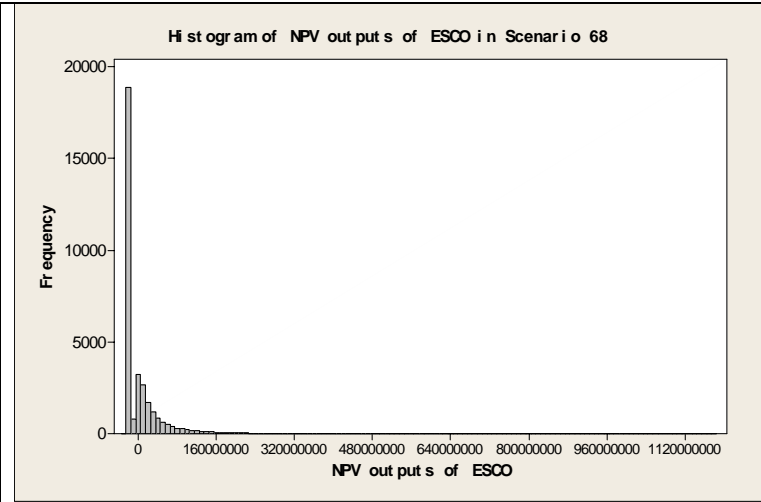
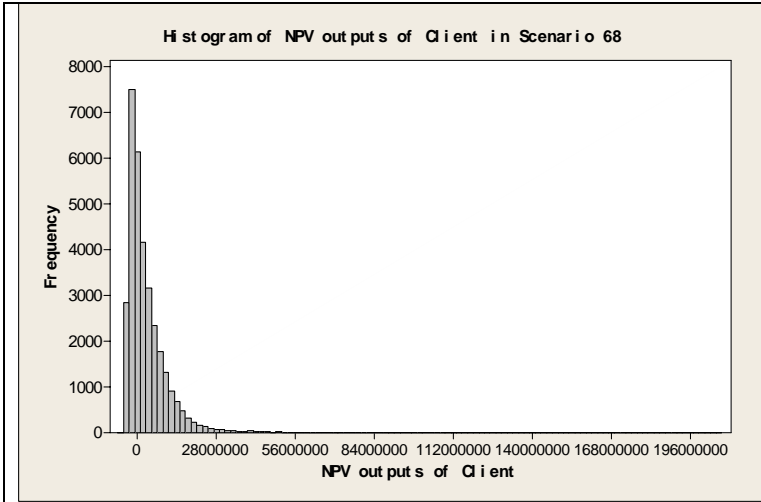


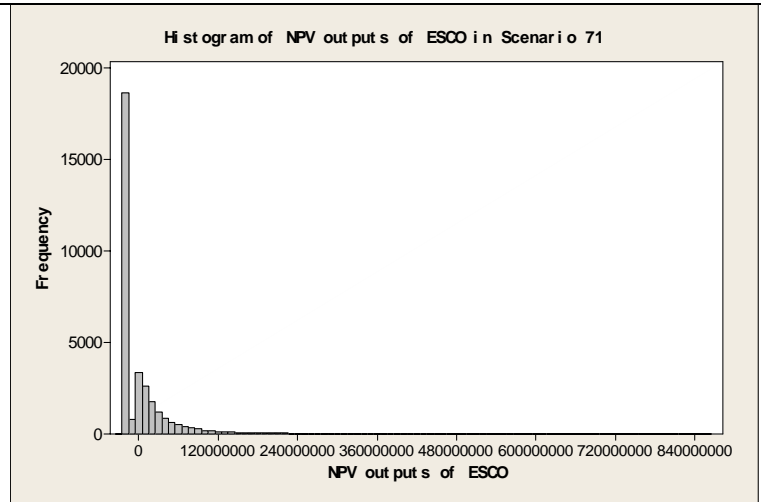
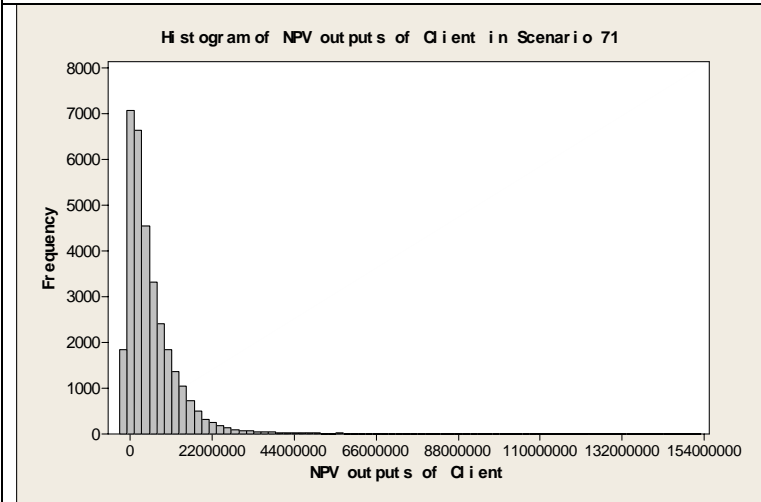
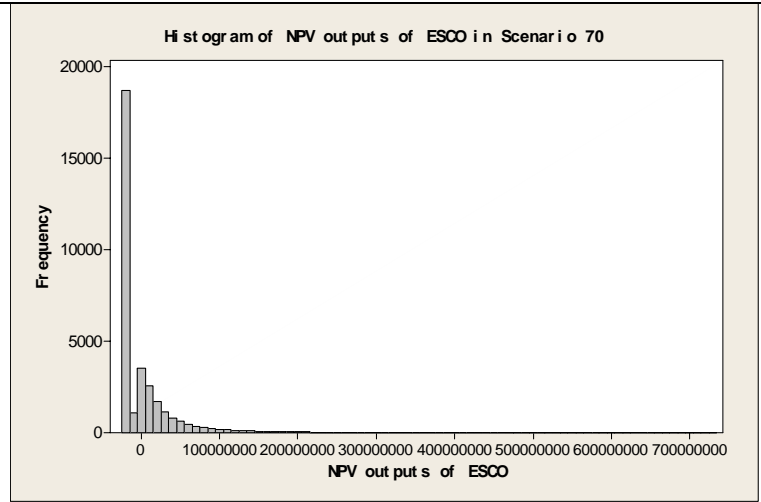
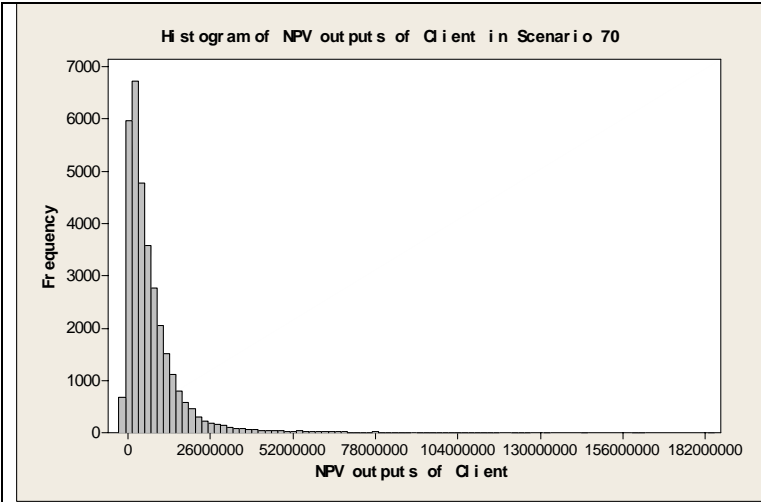


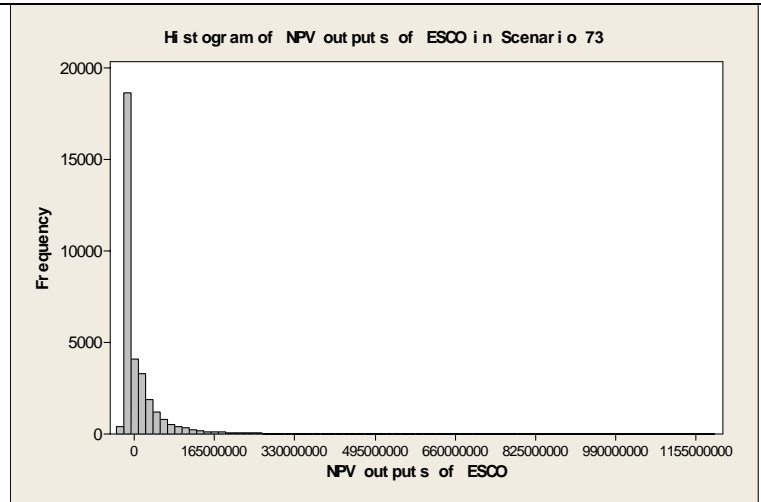
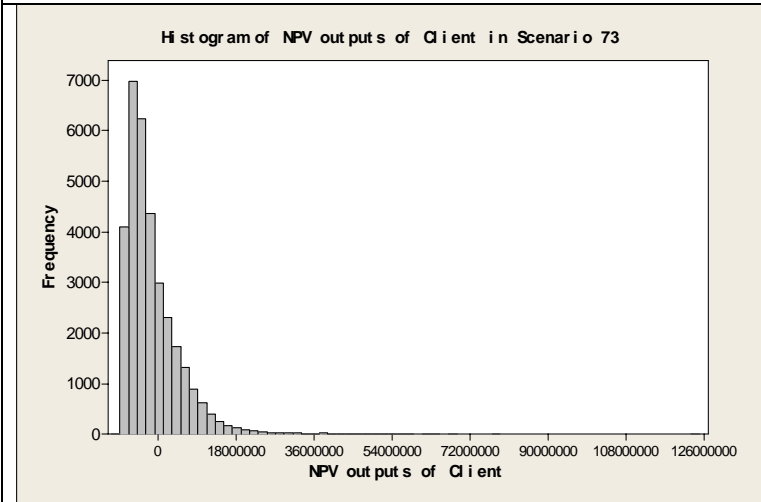
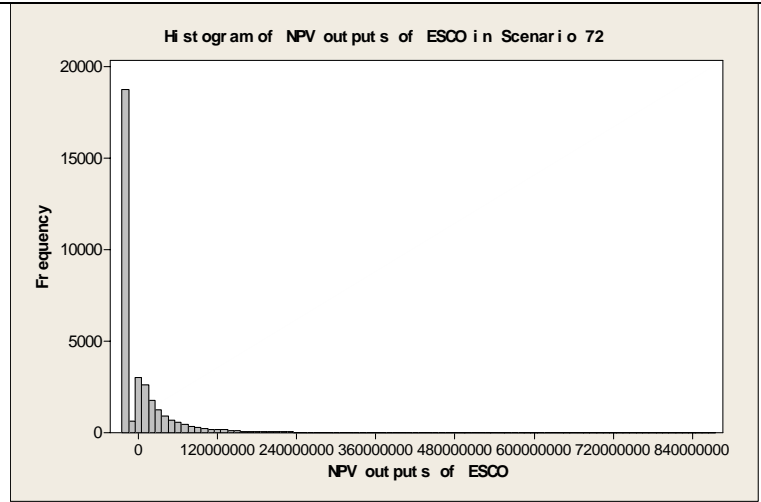
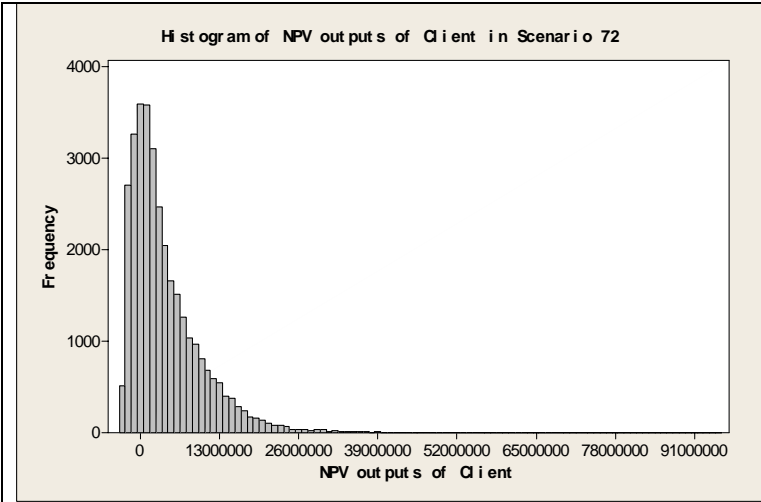


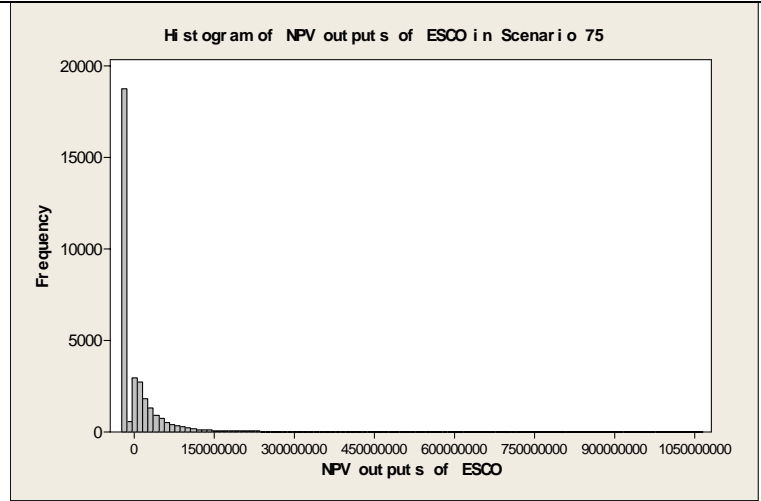
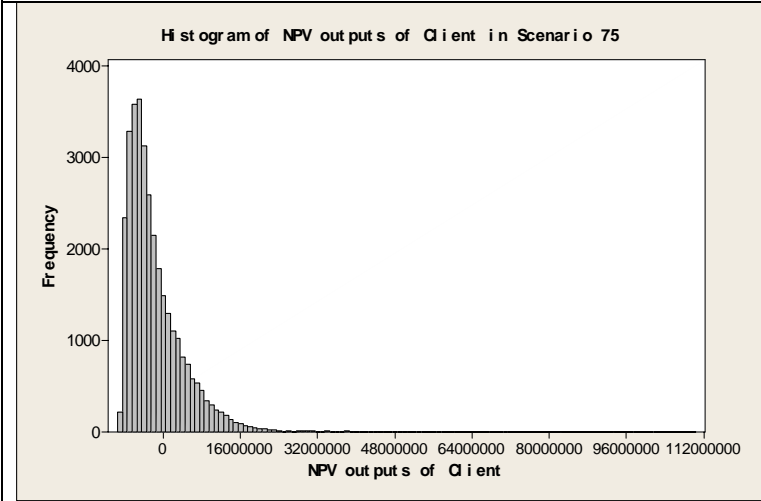
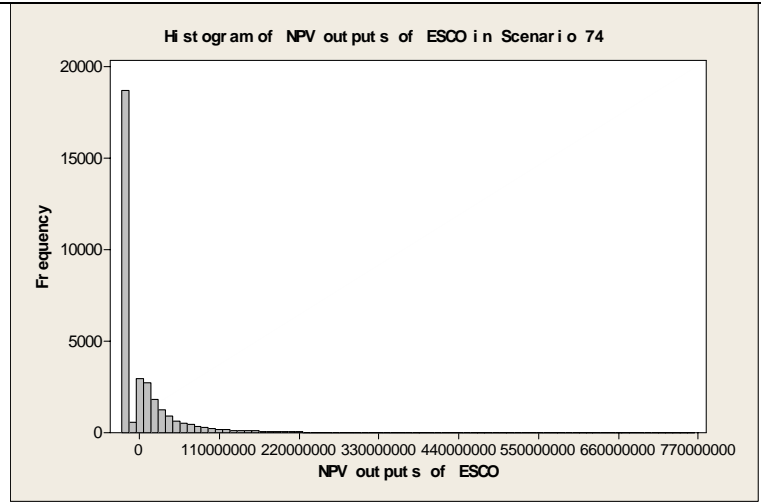
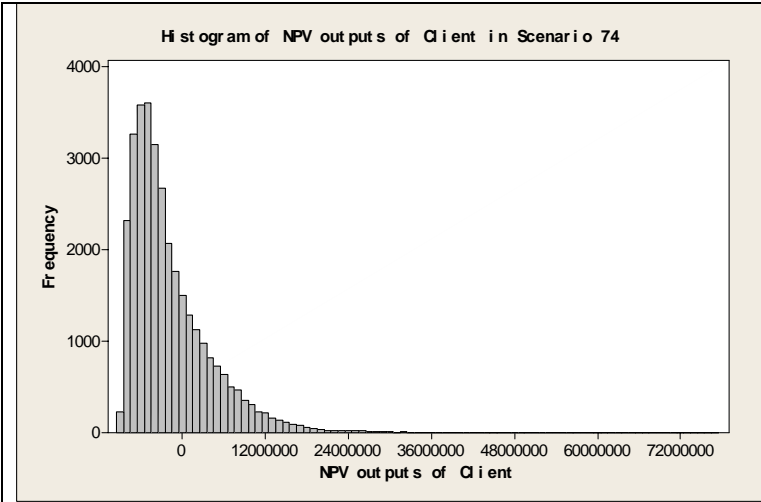


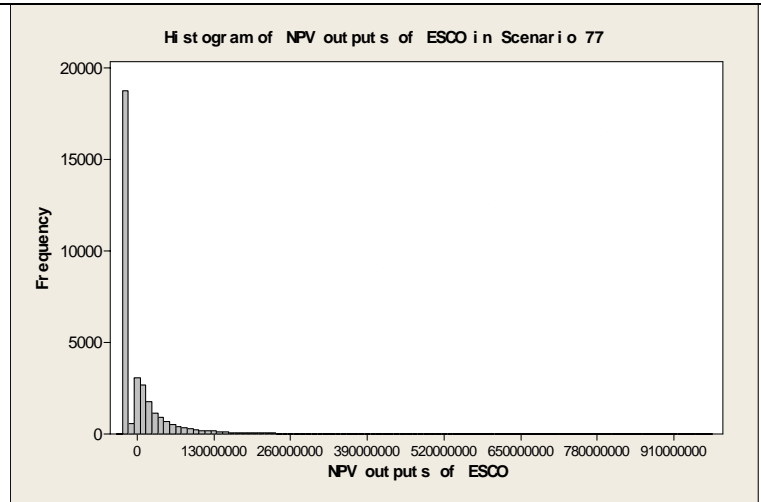
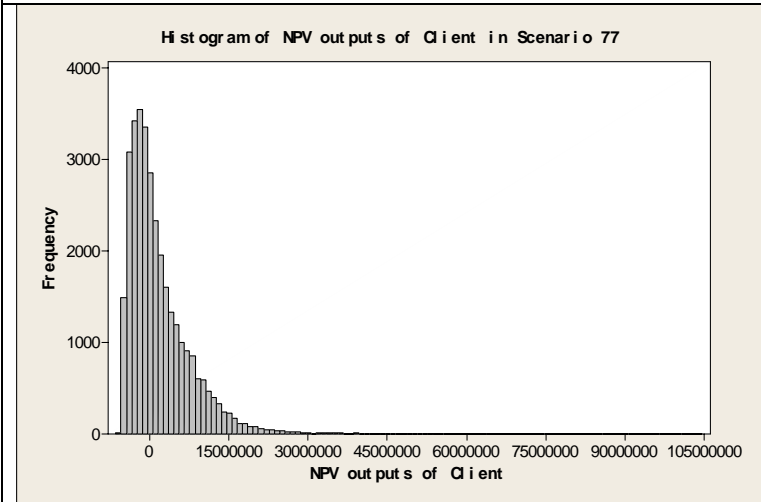
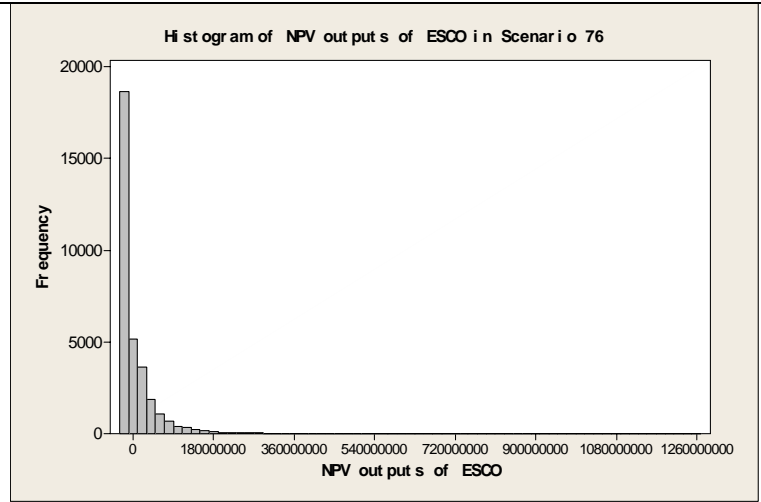
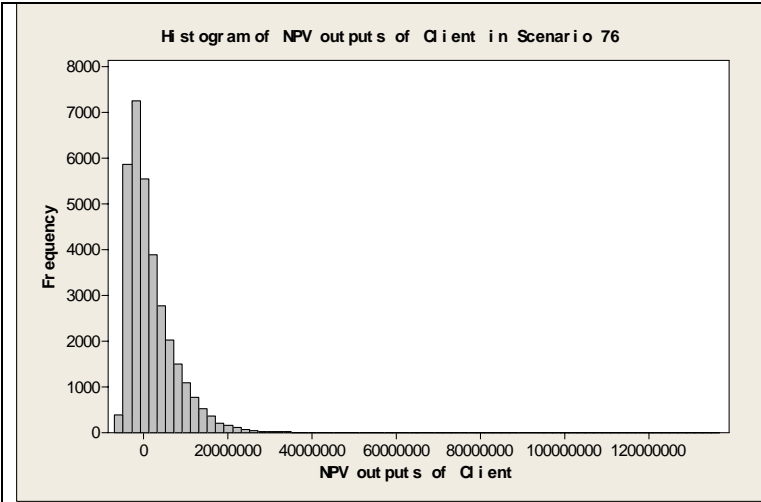


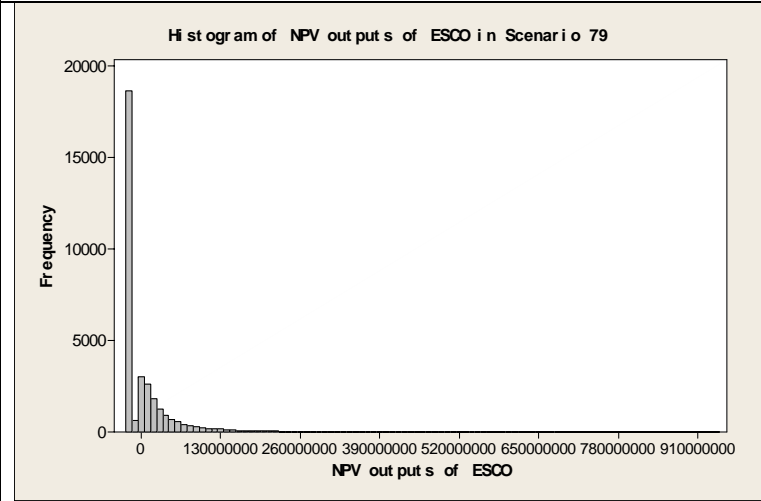
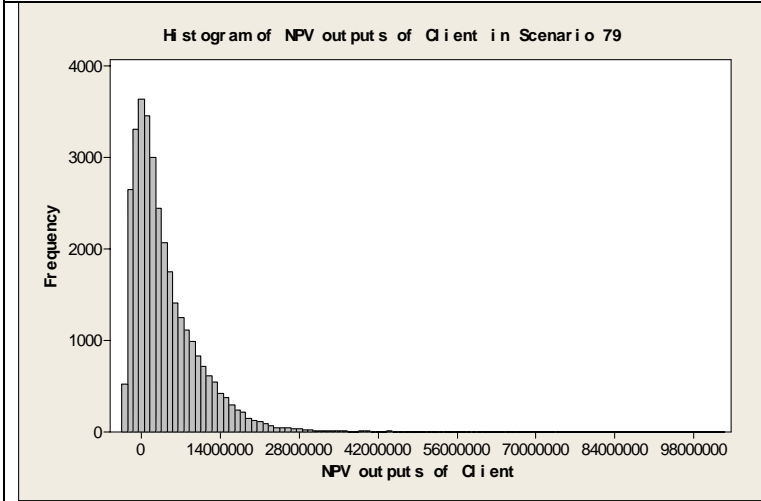
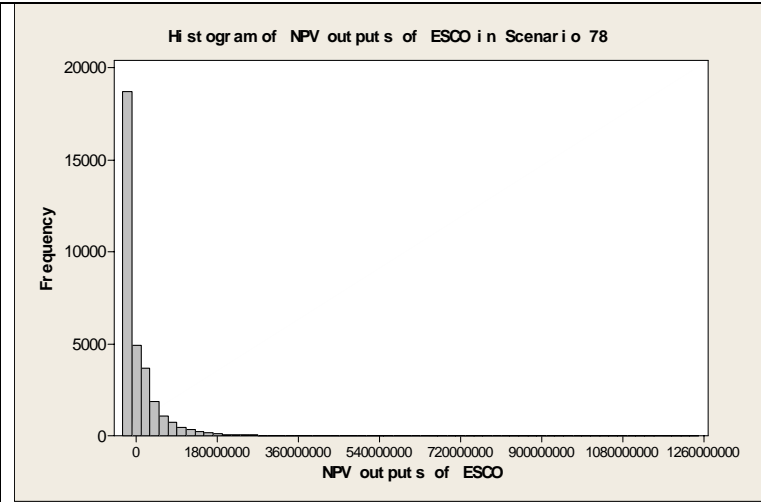
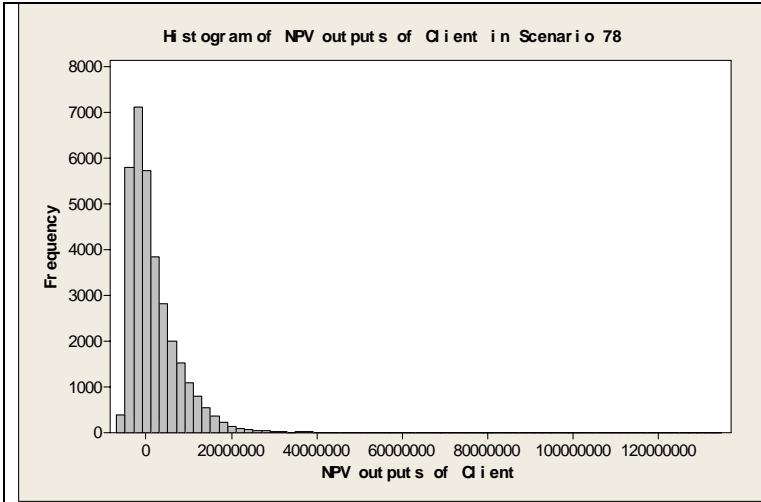


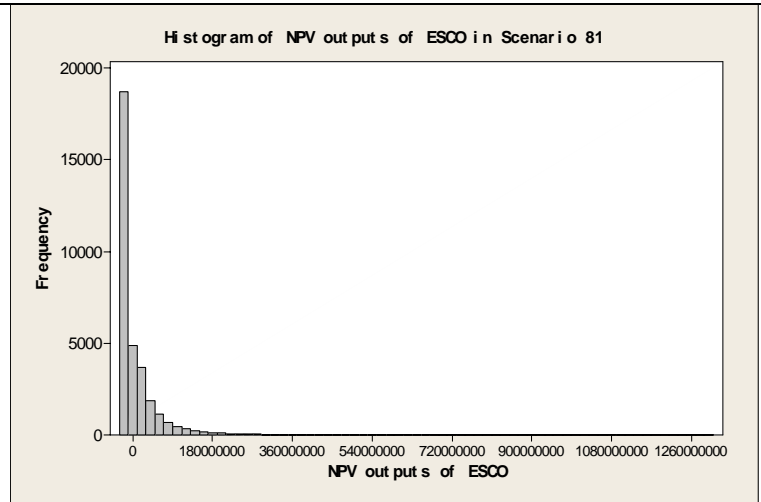
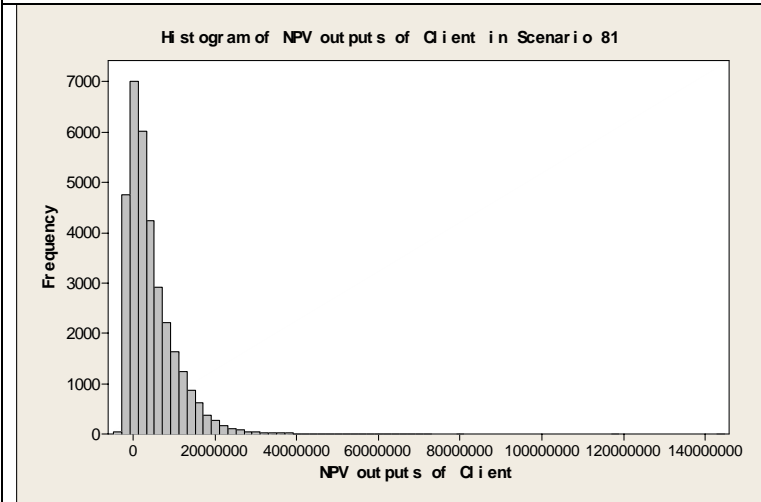
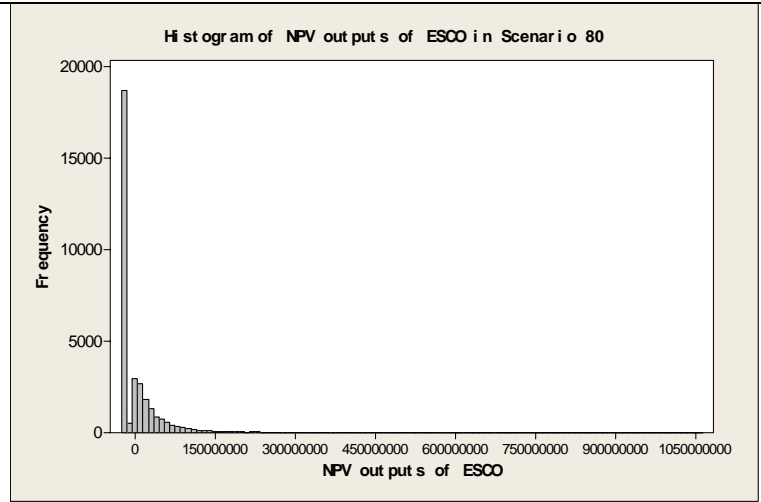
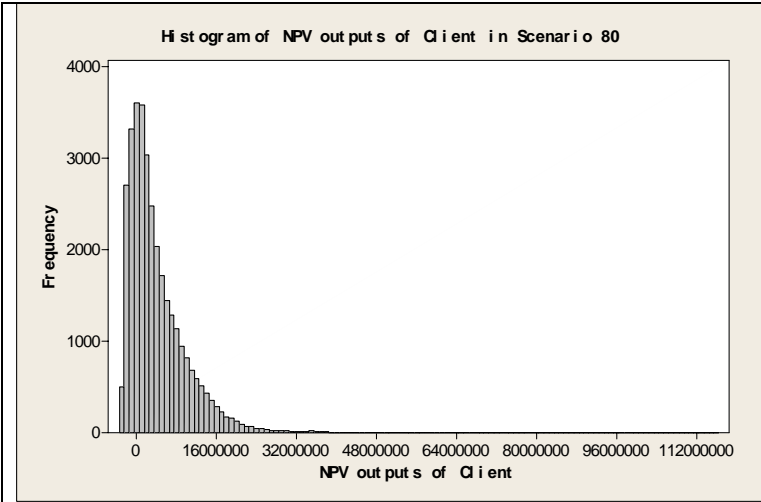


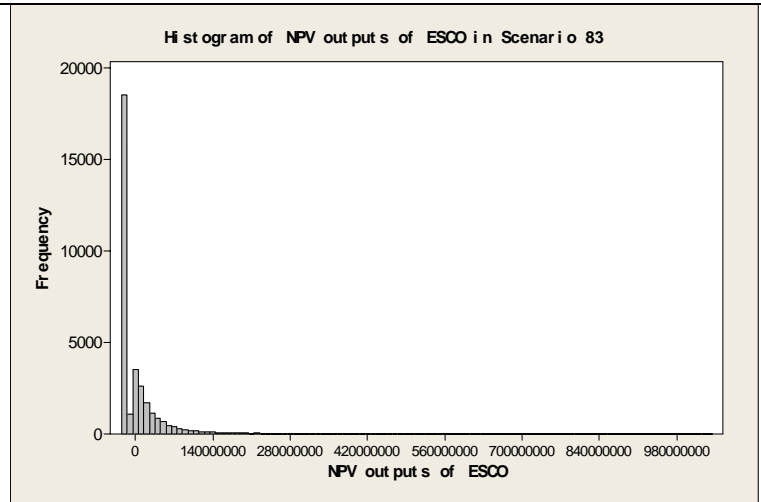
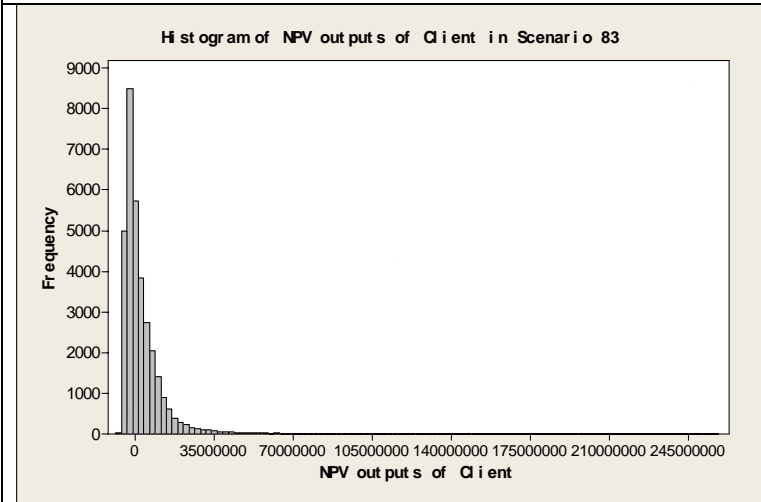
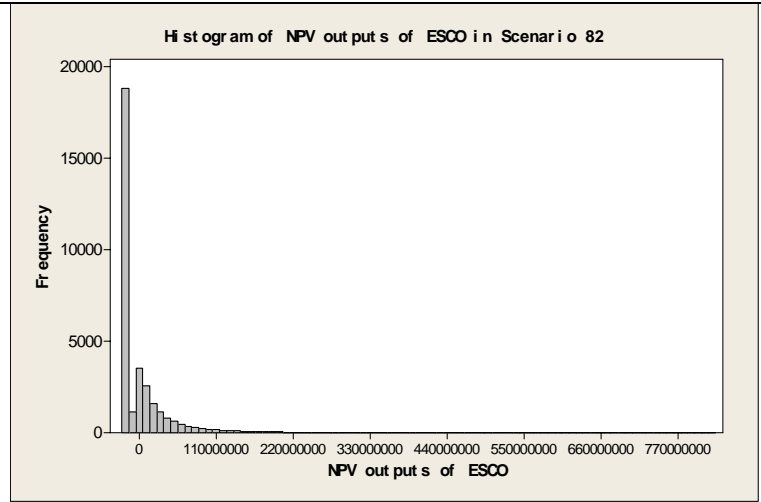
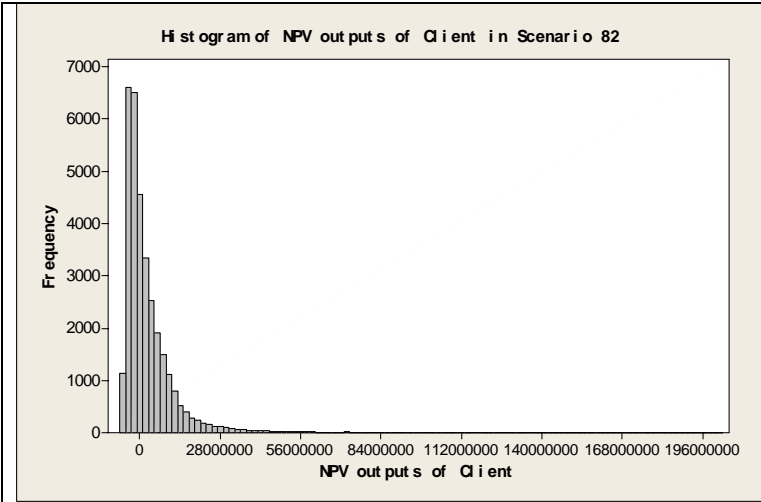


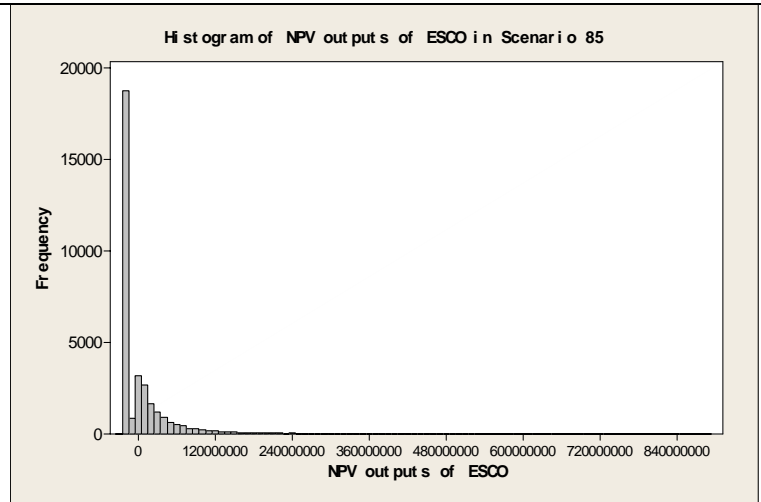
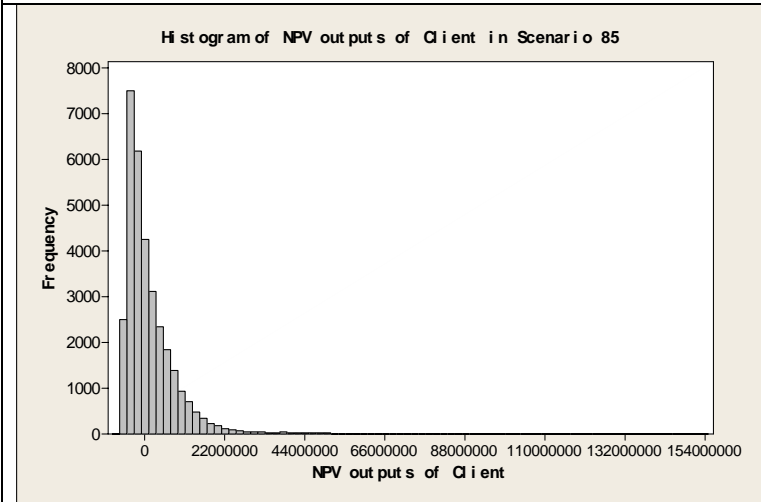
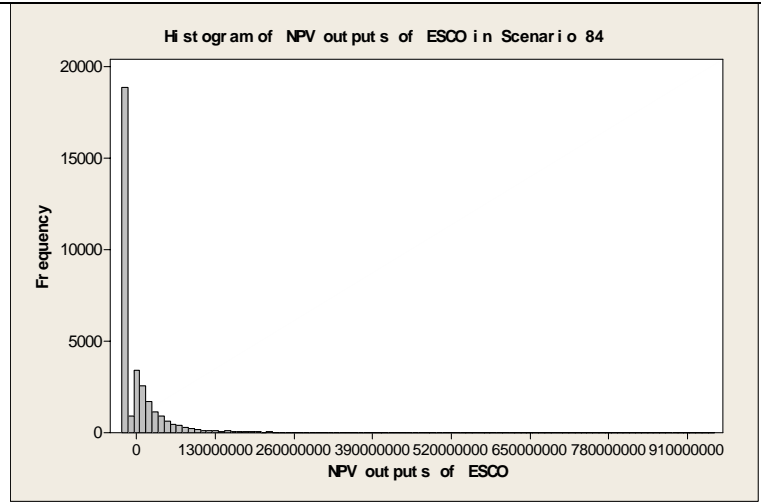
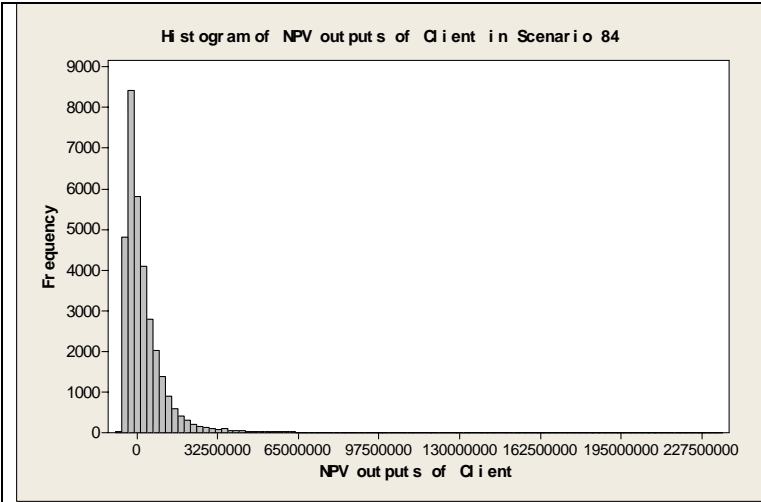


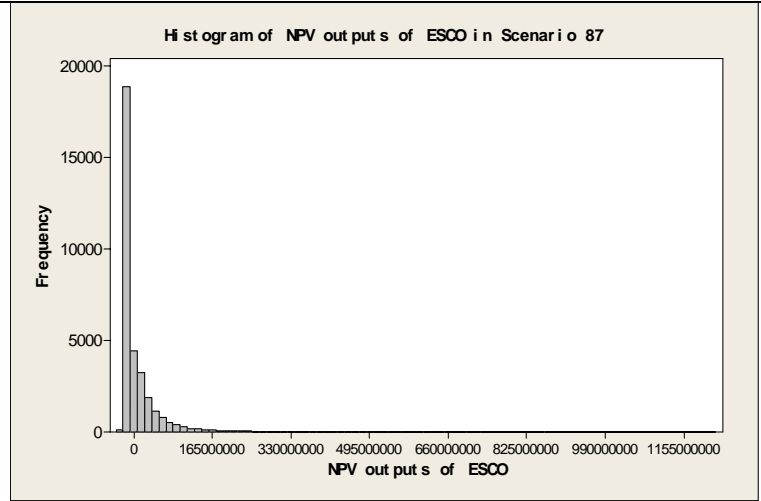
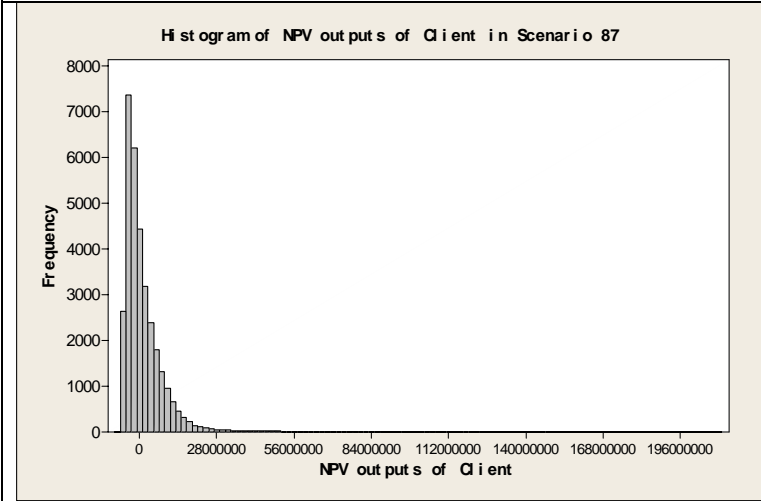
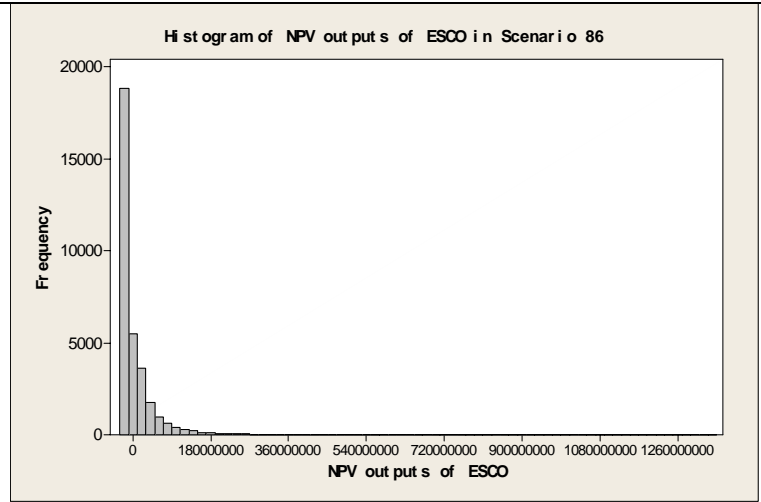
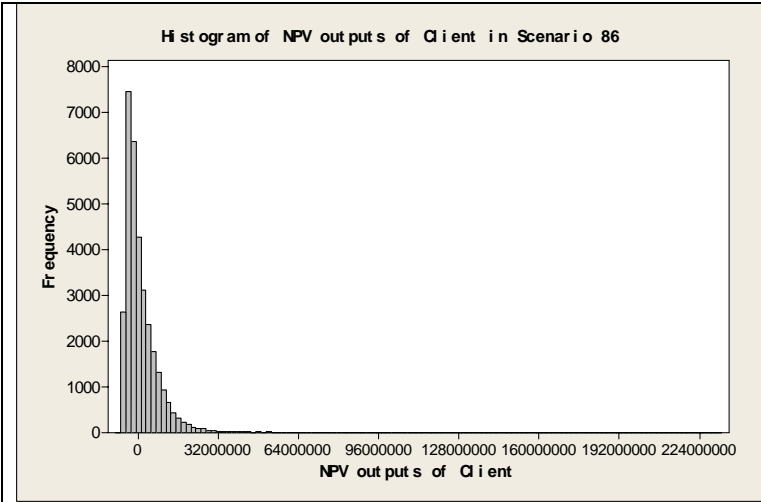


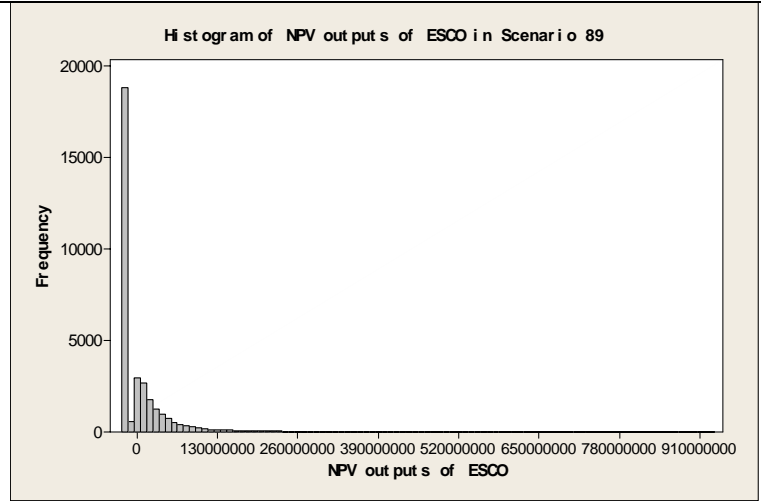
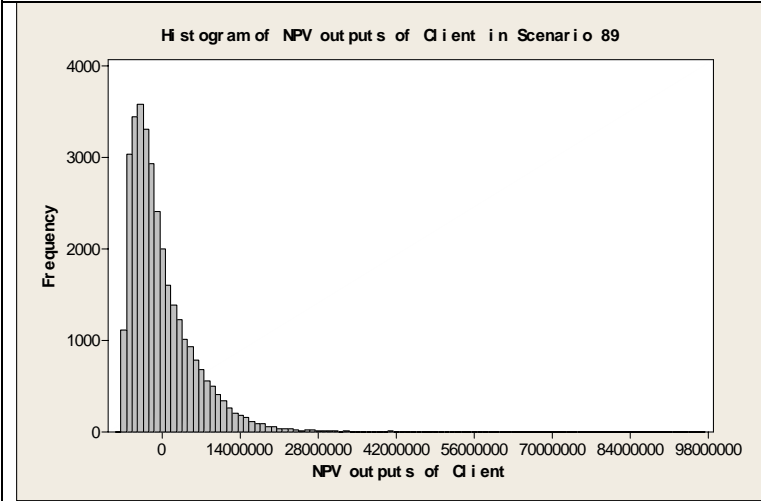
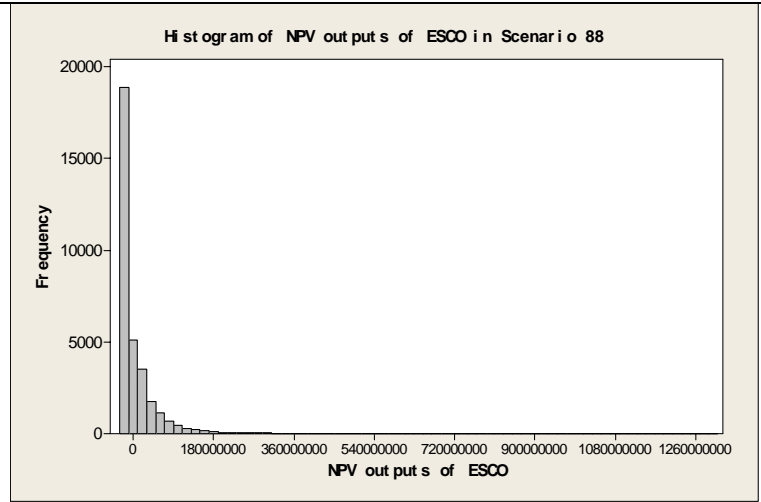
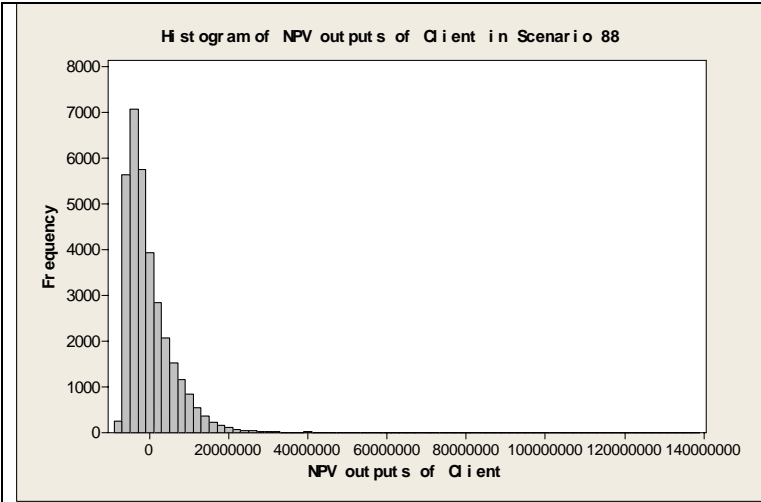


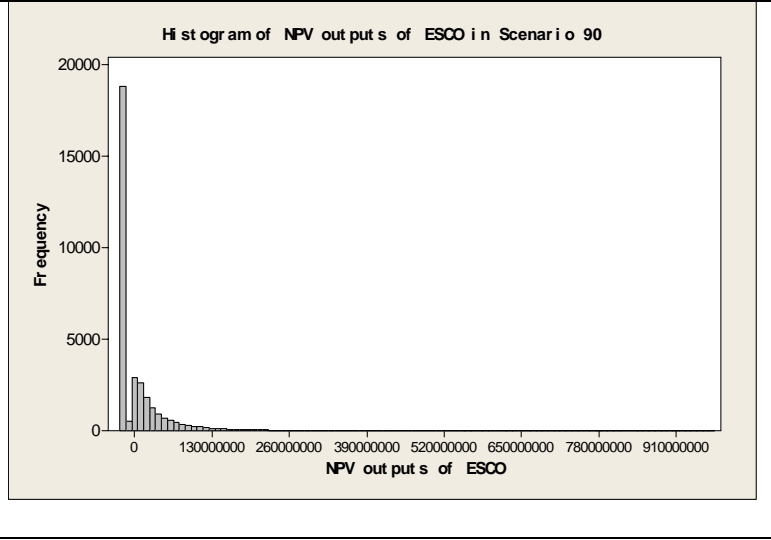
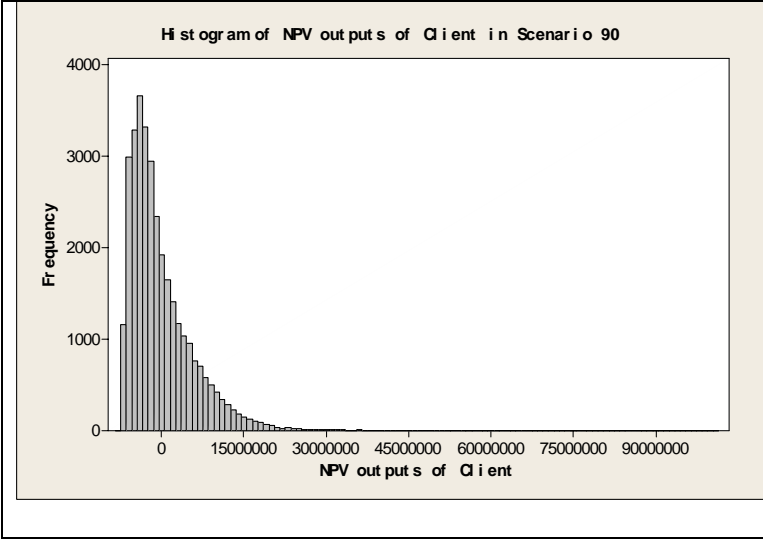












5. The control charts are drawn based on the “half-width of a Two-side CI/mean in %” for the client and the ESCO respectively. The charts are presented in Figure 31 and Figure 32. Also, the test results point out the outliers from the client’s control chart and the ESCO’s control chart.

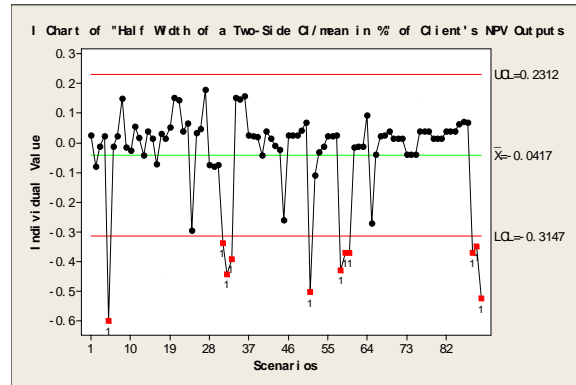


Figure 31 - Control chart of the “half-width of a Two-side CI/mean in %” of client’s NPV outputs

Figure 31 points out that the “half-width of a Two-side CI/mean in %” of client’s NPV outputs in the Scenarios 5, 31, 32, 33, 51, 58, 59, 60, 88, 89, and 90 are outliers in the control chart. The commonality between the scenarios 5, 31 and 32 is that the relationship between the price of sold energy and the price of purchased energy is 65% in these scenarios. The commonality between the scenarios 5, 51, 58, 59 and 60 is that the availability/yield of the system in these scenarios is 86% in these scenarios. The commonality between the scenarios 88, 89 and 90 is that the performance contract sharing rate is 90% in these scenarios.

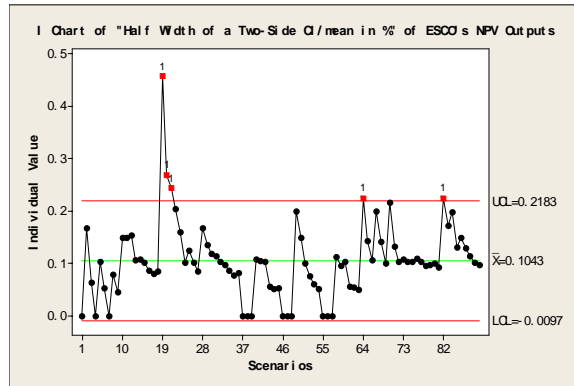


Figure 32 - Control chart for the “half-width of a Two-side CI/mean in %” of the ESCO’s NPV outputs

Figure 32 points out that the “half-width of a Two-side CI/mean in %” of the ESCO’s NPV outputs in the Scenarios 19, 20, 21, 64, and 82 are outliers in the control chart. The commonality between 19, 20 and 21 is that the relationship between the price of sold energy and the price of purchased energy is 60% in these scenarios. The commonality between 19, 64 and 82 is that the performance contract sharing rate is 80% in these scenarios.

The two control charts demonstrate that the “half-width of a Two-side CI/mean in %” for the NPV outputs of both client and ESCO are sensitive to the relationship between the price of sold energy and the price of purchased energy, although the two ratios are sensitive to the different levels of the relationship. It is interesting to note that there is no overlap between the outliers in the control chart “half-width of a Two-side CI/mean in %” of the ESCO’s NPV outputs and the control chart “half-width of a Two-side CI/mean in %” of the client’s NPV outputs.

CHAPTER V.

VALIDATION OF THE METHODOLOGY

Introduction

According to Kelton, validation is the process of ensuring that the model behaves in the same way as the real system (Kelton, Sadowski and Sturrock, 2003). There are many ways to validate a proposed method. Sandeep compared the analytical results to the simulation estimates from Arena software to validate his supply chain network model (Sandeep, 2004). Pablo validated his proposed methodology by applying it in a real world example (Pablo, 1988). Abdullah applied statistical and economic criteria to test the validity and accuracy of his proposed regression models that were used to estimate growth rates of exogenous sectors (Abdullah, 1983).

In this chapter, the methods used to validate the methodology are explained. The following paragraphs describe these methods in more detail.

Validation via Running the Methodology in a Deterministic Environment

In Subchapter “Application of the Model in a Deterministic Environment”, a reference scenario was set by running the model in a deterministic environment. One purpose of the reference scenario is to demonstrate the advantages of the methodology in the probabilistic environment. The other purpose is to validate the model using deterministic values which look reasonable to be applied in an actual project.

Statistical Validation

In Subchapter “Simulation of General Inflation Rates” and “Simulation of Specific Commodity Cost/Volatility”, a hypothesis test was performed to determine whether or not the correlation coefficient of the simulated general inflation rates and the correlation coefficient of the historical general inflation rates were significantly different at a 95% confidence level. The result from the hypothesis test exhibited that the correlation coefficient of the simulated general inflation rates was not significantly different from the correlation coefficient of the historical general inflation rates. Similarly, a hypothesis test was performed to determine whether or not the correlation coefficient of the simulated specific commodity cost/volatility and the correlation coefficient of the historical specific commodity cost/volatility were significantly different at a 95% confidence level. The result from the hypothesis test exhibited that the correlation coefficient of the simulated specific commodity cost/volatility was not significantly different from the correlation coefficient of the historical specific commodity cost/volatility. Therefore, the simulations of the general inflation rates and specific commodity cost/volatility are validated via the statistical method.

Validation of the Methodology via Practical Views

The scheme of the model was shown to the representatives from Johnson Controls, Inc. By doing so, the model is validated via practical view. The objective of the practical views is to (1) confirm whether or not the inputs used in the model are concerned in an actual ESPC project, (2) whether or not the assumptions for some inputs

are reasonable, and (3) whether or not the proposed model is logical and realistically applicable.

The feedback from the representatives was very positive. Although an ESPC project was very complicated and a number of factors needed to be considered, the representatives believed the inputs used in the model would significantly influence the success rate of an ESPC project. The representatives also confirmed that the assumption that the unit penalty cost was equal to the unit cost of purchased energy was reasonable. Overall, the representatives believed the model would be very helpful for the application of ESPC in energy efficiency projects. However, due to the proprietary of clients' information, the representative could not disclose any information in an actual ESPC project. As a result, the model inputs cannot be validated by the data from an actual ESPC project.

CHAPTER VI.

CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH

This chapter presents major conclusions reached in Chapter IV and proposes extensions to this research.

Conclusions

The contribution from the research is that it proposes a methodology which is built on a system level and expands risk analysis beyond party views in an ESPC project. The proposed methodology helps a client and an ESCO seek possible win-win ESPC strategies. The main conclusions from the research are listed as follows:

- The system-level methodology developed an analysis protocol for the parties involved in an ESPC project depending on the inputs and outputs of a proposed energy system.

In an ESPC project, there is essentially only one physical system view, and normally two primary parties are required, a client who wants to upgrade its energy systems and an ESCO which is willing to provide energy related services. In addition, the inputs and outputs of the proposed energy system determine that other possible parties may be involved in the ESPC project. These parties may include a transportation

company, an installation company and a disposition company. Although they are the secondary parties in the ESPC project, their benefits and costs will influence the cash flows of the client and the ESCO. Therefore, there are numerous party views in the ESPC project. Demonstration of both system view and party views checks the validity of each other. That is to say, all facets of the system must be accounted for in the party views, and the “summation” of the party views must constitute the system view. This demonstration provides an analysis protocol for the parties involved in the ESPC project to help them understand the complicated interrelationship inside the primary parties, the relationships between the primary parties and the secondary parties, and the relationship between the system and all parties.

- The proposed methodology developed a procedure to empower the parties involved in the ESPC project with information regarding the inherent system-level and party-level risks.

The proposed methodology develops an analysis protocol which involves both a system view and party views. The model based on the proposed methodology takes both system-level and party-level risks in an ESPC project into consideration. For example, in the CHP project demonstration, the system-level risks are described by the demand/capacity and the availability/yield of the system, and the general inflation rate and specific commodity cost/volatility. The client-level risks are described by the unit cost of the energy that the client purchases from the utility, the relationship between the price of the energy sold back to the utility and the price of the energy purchased from the utility, and the loan term of the client. The ESCO-level risks are described by the unit penalty cost for not realizing the guaranteed energy value, the performance contract

sharing rate and the loan term of the ESCO. Based on expert opinions, subjective judgments and historical data, the characteristics of the risks are determined and they can be referred to as probabilistic variables and deterministic parameters. Since the long-term and multi-parties' nature of the ESPC project decides that it is operating in an uncertainty environment, incorporating these risks into the model provides the parties with additional information that can be beneficial for many purposes, including decision making and financial development.

- The proposed methodology developed a procedure to present graphical outputs of multiple scenarios in the ESPC project to help the involved parties understand the influence of the input parameters on their benefits and costs.

The inherent risks in an ESPC project are described by probabilistic inputs and deterministic inputs. Based on their characteristics, the probabilistic inputs are simulated and the deterministic inputs are referred to as discrete arrays. The number of the deterministic inputs and the number of the values in each discrete array determine that there are multiple scenarios. Hence, the proposed methodology is an integration of simulations associated with multiple scenarios.

The scenarios order the parties' perceptions of alternative future environments. The multiple scenarios explore the future options in a systematic way. They help the parties evaluate the relative risks of different strategies, and thus serve as a useful decision support in the energy project investment process. The outputs from each scenario are not an accurate picture of "tomorrow", but they may provide information to assist in making better decisions about the future. In the CHP project demonstration, based on the outputs from multiple scenarios, the graphs including 3D, 2D, and control

charts are developed. 3D and 2D graphs compare the positive NPVs for both client and ESCO across the scenarios. Control charts help model users find the outlying scenarios. With the help of graphical outputs, the proposed methodology is able to model and communicate the influence of different levels of the input parameters on the benefits and cost of the parties. Moreover, using the methodology enables the parties to develop sensitivity analyses and explore combinations of the input parameters that make the proposed energy system attractive.

Recommendations for Future Research

The research proposed a methodology to analyze the influence of the risk factors inherent in an ESPC project on the benefits and costs of the client and the ESCO. There is still more work that can be done to complement this research:

- The proposed methodology can be extended to include the scenarios in which the proposed energy system is owned by the ESCO or shared by both client and ESCO.

The ownership of the proposed energy system is very flexible in an actual ESPC project. It can be purchased by either a client or an ESCO or both. For example, the proposed energy system can be leased by both client and ESCO. As a result, they share the lease cost. The ownership of the proposed energy system determines the party who can enjoy the depreciation benefit. The proposed methodology assumed that it was the client who purchased the proposed energy system and enjoyed the depreciation benefit. In the future, the methodology can be extended to include the scenarios in which an

ESCO purchases the proposed energy system or shares the purchasing/leasing cost of the proposed energy system with the client.

- The proposed methodology can be integrated with a physical-based model.

The proposed methodology is focused on the economic analysis of an ESPC project. In the research, a CHP project was used as an example to explain how the proposed methodology worked. One of the assumptions used in the CHP project was that it was technically feasible. The energy output from the CHP system was calculated as the multiplication of the availability/yield of the system and the demand/capacity of the system. The energy savings calculations of an actual ESPC project will be much more complicated than those of the CHP project demonstration. For example, the International Performance Measurement and Verification Protocol (IPMVP) provides four Measurement and Verification (M&V) options to help clients and ESCOs determine the savings realized through energy efficiency projects (M&V Guidelines: Measurement and Verification for Federal Energy Projects, 2000). Of these four options, Option D is the most complex one and applies software to create a simulated model to examine entire facility savings. In the future, the proposed methodology can be integrated with such a model to make the risk analysis more detailed.

- More details can be included in the risk analysis.

The proposed methodology is an integration of multiple-scenario analysis and simulations. The number of multiple scenarios is determined by the number of discrete input variables and the number of the values in each discrete array. In the CHP project, due to the sparse information, only three values were applied in each discrete array for

demonstration purposes. In the future, the user may incorporate more information to formulate scenarios more carefully.

- Explore the possibility of incorporating the proposed methodology into other commercial software.

In this research, the proposed methodology was implemented in Excel. The reason that Excel was chosen is that Excel is a popular and user friendly tool for ESCOs when they do energy savings calculations. However, if other commercial software is available to the users, the possibility of incorporating this methodology into other commercial software programs should be considered.

REFERENCES

- Abdullah, A. (1983), Manpower projection model for economic planning in Saudi Arabia using the input-output technique, Oklahoma State University, PhD dissertation
- Agashichev, S. P. (2004), Analysis of integrated co-generative schemes including MSF, RO and power generating systems (present value of expenses and “levelised” cost of water), *Desalination*, Vol. 164, Iss. 3, pp 281-302
- Al-Mansour, F. & Kozuh, M. (2007), Risk analysis for CHP decision making within the conditions of an open electricity market, *Energy*, Vol. 32, pp 1905-1916
- Arny, M. (1996), The retail energy services company model for restructuring the electric utility industry, *The Electricity Journal*, Vol. 9, Iss.1, pp 80-88
- ASHRAE Guideline 14: Measurement of Energy and Demand Savings (2002)
- Axelsson, H., Harvey, S., Asblad, A. & Berntsson, T. (2003), Potential for greenhouse gas reduction in industry through increased heat recovery and/or integration of combined heat and power, *Applied Thermal Engineering*, Vol.23, pp 65-87
- Balachandra, P. & Shekar, Gl. L. (2001), Energy technology portfolio analysis: an example of lighting for residential sector, *Energy Conversion and Management*, Vol. 42, Iss.7, pp 813-832
- Bannai, M., Tomita, Y., Ishida, Y., Miyazaki, T., Akisawa, A. and Kashiwagi, T. (2007), Risk hedging against the fuel price fluctuation in energy service business, *Energy*, Vol. 32, Iss. 11, pp 2051-2060
- Berkeley lab tracks energy services growth (2007), *Consulting-Specifying Engineer*, <http://www.csemag.com/article/CA6454421.html>
- Bureau of Labor Statistics (2007a), <http://data.bls.gov/cgi-bin/surveymost?bls>
- Bureau of Labor Statistics (2007b), <http://data.bls.gov/cgi-bin/surveymost?bls>
- Bhattacharyya, S. C. & Thang, D. N. Q. (2004), Economic buy-back rates for electricity from cogeneration: case of sugar industry in Vietnam, *Energy*, Vol. 29, pp 1039-1051
- Bluth, W., Bradley, R., Bunn, D., Clarke, C., Wilson, T. & Yang, M. (2007), Investment risks under certain climate change policy, *Energy Policy*, Vol. 35, Iss. 11, pp 5766- 5773

Borison, A. & Hamm, G. (2005), Better power contracts: using flexibility to increase value, *The Electricity Journal*, Vol. 18, pp 62-69

Caputo, A. C. & Pelagagge, P. M. (2001), Waste-to-energy plant for paper industry sludges disposal: technical-economic study, *Journal of Hazardous Materials*, Vol.81, Iss.3, pp 265-283

Castro, M., Delgado, A., Argul, F. J., Colmenar, A., Yeves, F & Peire, J. (2005), Grid-connected PV buildings: analysis of future scenarios with an example of Southern Spain, *Solar Energy*, Vol. 79, pp 86-95

Coleman, M. & Provol, S. (2005), Wind power economics understanding economic risks in wind power projects in the USA, *Refocus*, Vol. 6, Iss. 4, pp 22-24

Colle, S., de Abreu, S. L., & Ruther, R. (2001), Uncertainty in economical analysis of solar water heating and photovoltaic systems, *Solar Energy*, Vol. 70, pp 131-142

DSIRE (2007), Database of State Incentives for Renewables & Efficiency, <http://www.dsireusa.org/library/includes/tabsrch.cfm?state=OR&type=Loan&back=fintab&Sector=S&CurrentPageID=7&EE=1&RE=1>

Derrick, A. (1998), Financing mechanisms for renewable energy, *Renewable Energy*, Vol. 15, pp 211-214

Dubin, J., Miedema, A., & Chandra, R. (1986), Price effects of energy-efficient technologies: A study of residential demand for heating and cooling, *RAND Journal of Economics*, Vol. 17, Iss.3, pp 310-325

EIA (2007), Energy Information Administration, http://www.eia.doe.gov/cneaf/electricity/epa/average_price_state.xls

Gaterell, M. R. & McEvoy, M. E. (2005), The impact of energy externalities on the cost effectiveness of energy efficiency measures applied to dwellings, *Energy and Buildings*, Vol. 37, Iss.10, pp 1017-1027

Goldman, C.A., Osborn, J.G., Hopper, N.C., & Singer, T.E. (2002), Market trends in the U.S. ESCO industry: results from the NAESCO database project, Lawrence Berkeley National Laboratory, Berkeley, CA

Goldman, C. A., Hopper, N. C., & Osborn, J. G. (2005), Review of U.S. ESCO industry market trends: An empirical analysis of project data, *Energy Policy*, Vol. 33, Iss.3, pp 387-405

Groover, J., & Kunzler, C. (2004), Upgrades funded by energy savings, *The American City & County*, Vol. 119, Iss.13, pp 38

Hansen, S. J. (1992), Performance contracting for energy and environmental systems, The Fairmont Press, pp 102

Hassett, K. A. & Metcalf, G. E. (1995), Energy tax credits and residential conservation investment: evidence from panel data, *Journal of Public Economics*, Vol. 57, pp 201-217

Helle, C. (1997) On energy efficiency-related product strategies – illustrated and analyzed using contracting approaches in Germany as an example, *Utilities Policy*, Vol. 6, Iss.1, pp 75-85

Historic campus teaches lesson in energy (2000), *Engineered Systems*, Vol. 17, Iss.10, pp 20

Honeywell inks contract with Fort Dix (2000), *Air Conditioning, Heating & Refrigeration News*, Vol. 209, Iss.9, pp 73

Howarth, R. B., & Andersson, B. (1993), Market barriers to energy efficiency, *Energy Economics*, Vol. 15, Iss.4, pp 262-272

IPMVP (2007), International Performance Measurement and Verification Protocol, <http://www.evo-world.org/>

Jackson, J. (2007), Ensuring emergency power for critical municipal services with natural gas-fired combined heat and power (CHP) systems: A cost-benefit analysis of a preemptive strategy, *Energy Policy*, Vol. 35, Iss.11, pp 5931-5937

Kapil, P. (2004), Feasibility and economic study of steam turbine bottoming cycle cogeneration system

Kelton, W. D., Sadowski, R. P. & Sturrock, D. T. (2003), Simulation with Arena, The McGraw-Hill Companies, 3rd Edition

Kosub, D. (2004), Security concern breaks up base's central utility system, *ENR: Engineering News-Record*, Vol. 252, Iss.1, pp 18-19

Krey, V., Martinsen, D., & Wagner, H. (2007), Effects of stochastic energy prices on long-term energy-economic scenarios, *Energy*, Vol. 32, Iss.12, pp 2340-2349

Kromer, S. (2007), Efficiency valuation: How to “plan, play and settle” energy efficiency projects, *Strategic Planning for Energy and the Environment*, Vol. 27, Iss.1, pp 69-78

Kroner, W., Stark-Martin, J. A., & Willemain, T. (1992), Rensselaer's West Bend Mutual Study: Using advanced office technology to increase productivity, *The Center for Architectural Research and Center for Services Research and Education*, Rensselaer, New York

- Laurent, A. (1998), Let contractors take the risks, *Government Executive*, Vol. 30, Iss.8, pp 64- 65
- Law, A. M. & Kelton, W. D. (2000), *Simulation Modeling and Analysis*, McGraw-Hill
- Lee, W. L., & Yik, F. W. H. (2004), Partnership in building Energy Performance Contracting, *Building Research & Information*, Vol. 32, Iss.3, pp 235-243
- Lutz, J. D., Liu, X., Lekov, A. B., Whitehead, C. D., & McMahon, J. E. (2000), A Monte Carlo approach to calculation of energy consumption for residential gas-fired water heaters, *ASHRAE Transactions*, Vol. 106, Part 2
- Mathew, P., Kromer, J. S., Sezgen, O., & Meyers, S. (2005), Actuarial pricing of energy efficiency projects: Lessons foul and fair, *Energy Policy*, Vol. 33, pp 1319-1328
- Mathew, P. A., Koehling, E., & Kumar, S. (2006), Use of quantitative uncertainty analysis to support M&V decisions in ESPCs, *Energy Engineering*, Vol. 103, No. 2, pp 25- 39
- McMahon, J. E., & Liu, X. (2000), Variability of consumer impacts from energy efficiency standards, *Proceedings of the Second International Conference on Energy Efficiency in Household Appliances and Lighting*, Vol. 108, Iss.13
- M&V Guidelines: Measurement and Verification for Federal Energy Projects (2000), U. S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Version 2.2
- Mills, E. (2003a), The insurance and risk management industries: New players in the delivery of energy-efficient and renewable energy products and services, *Energy Policy*, Vol. 31, pp 1257-1272
- Mills, E. (2003b), Risk transfer via energy-savings insurance, *Energy Policy*, Vol. 31, pp 273-281
- Mills, E., Kromer, S., Weiss, G., & Mathew, P. A. (2006), From volatility to value: Analyzing and managing financial and performance risk in energy savings projects, *Energy Policy*, Vol. 34, pp 188-199
- Moran, D. & Sherrington, C. (2007), An economic assessment of windfarm power generation in Scotland including externalities, *Energy Policy*, Vol. 35, Iss.5, pp 2811-2825
- Musser, P. (2003), Utility-affiliated ESCOs: Is the honeymoon over? *Transmission & Distribution World*, Vol. 55, Iss.1, pp 46- 48
- Noresco signs energy contracts (1999), *Utility Business*, Vol. 2, Iss.2, pp73

- OIAC (2003), Oklahoma Industrial Assessment Center Energy Audit Report 650
- Painuly, J. P., Park, H., Lee, M. K., & Noh, J. (2003), Promoting energy efficiency financing and ESCOs in developing countries: Mechanisms and barriers, *Journal of Cleaner Production*, Vol. 11, Iss.6, pp 659-665
- Pearce, J. M., & Miller, L. (2006), Energy service companies as a component of a comprehensive university sustainability strategy, *International Journal of Sustainability in Higher Education*, Vol. 7, Iss.1, pp 16- 33
- Performance contract results in savings (1997), *American School & University*, Vol. 69, Iss.8, pp 69
- Performance contract helps county fund several energy-cutting retrofits (1998), *Air Conditioning, Heating & Refrigeration News*, Vol. 203, Iss.9, pp 3- 4
- Performance contract saves energy costs (1998), *American School & University*, Vol. 70, Iss.9, pp 66
- Phoa, W. (1999), Conditional Monte Carlo simulation, *Journal of Investing*, Vol. 8, Iss.3, pp 80-88
- Pollack-Johnson, B. & Liberatore, M. J. (2005), Project planning under uncertainty using scenario analysis, *Project Management Journal*, Vol. 36, Iss.1, pp 15-26
- Pye, M & McKane, A. (2000), Making a stronger case for industrial energy efficiency by quantifying non-energy benefits, *Resources, Conservation and Recycling*, Vol. 28, pp 171-183
- Reddy, A T., & Claridge, D E. (2000), Uncertainty of ‘Measured’ energy savings from statistical baseline models, *HVAC&R Research*, Vol.6, No.1, pp 3-20
- Rickard, S., Hardy, B., Von Neida, B., & Mihlmester, P. (1998), Investment risk in whole building energy efficiency upgrade projects. *Proceedings of the ACEEE 1998 Summer Study on Energy Efficiency in Building*, Vol. 4, pp 307-318
- Sadeghi, M. & Hosseini, H. M. (2006), Energy supply planning in Iran by using fuzzy linear programming approach (regarding uncertainties of investment costs, *Energy Policy*, Vol. 34, Iss.9, pp 993-1003
- Sandeep, S. (2004), Analytical performance modeling of supply chain networks, Oklahoma State University, Master Thesis
- School upgrade saves money (2006), *Air Conditioning, Heating & Refrigeration News*, Vol. 228, Iss.5, pp 6- 7

- Sheel, A. (1995), Monte Carlo simulations and scenario analysis – Decision-making tools for hoteliers, *Cornell Hotel and Restaurant Administration Quarterly*, Vol. 36, Iss.5, pp 18-26
- Siemens to help university save on energy costs (2005), *Air Conditioning, Heating & Refrigeration News*, Vol. 225, Iss.12, pp 6
- Skaer, M. (2005), “Big Boys” help owners save on energy, *Air Conditioning, Heating & Refrigeration News*, September 26, Vol. 226, Iss.4, pp 20- 22
- Sorrell, S. (2007), The economics of energy service contracts, *Energy Policy*, Vol. 35, pp 507-521
- Sundberg, G. & Karlsson, B. G. (2000), Interaction effects in optimizing a municipal energy system, *Energy*, Vol. 25, pp 877-891
- Sundberg, G. (2001), Ranking factors of an investment in cogeneration: Sensitivity analysis ranking the technical and economical factors. *International Journal of Energy Research*, Vol. 25, pp 223-238
- Sundberg, G. & Sjodin, J. (2003), Project financing consequences on cogeneration: industrial plant and municipal utility co-operation in Sweden, *Energy Policy*, Vol. 31, pp 491-503
- Taal, M., Bulatov, I., Klemes, J., & Stehlik, P. (2003), Cost estimation and energy price forecasts for economic evaluation of retrofit projects, *Applied Thermal Engineering*, Vol. 23, pp 1819-1835
- Tegtmeier, L. A. (2006), Cost cutting beyond labor, *Overhaul & Maintenance*, Vol. 12, Iss.3, pp 24
- Tharoor, M. (2000), Minimizing risks with performance contracting projects – A customer checklist, *Strategic Planning for Energy and the Environment*, Vol. 20, No. 1, pp 73-79
- Thompson, P. B. (1997), Evaluating energy efficiency investments: Accounting for risk in the discounting process, *Energy Policy*, Vol. 25, pp 989-996
- Top-ranked schools give performance contract top marks (2001), *Engineering Systems*, Vol. 18, Iss.3, pp 28
- U.S. DOE (1992), Energy performance contracting for public and Indian housing – A guide for participants, United States Department of Energy and Department of Housing and Urban Development, Washington, DC, <http://eber.edu.ornl.gov/ESPC.html>

- U.S. DOE (2007), United States Department of Energy, <http://www1.eere.energy.gov/femp/financing/superespcs.html>
- U.S. GAO (2004), Capital Financing – partnerships and energy savings performance contracts raise budgeting and monitoring concerns, United States Government Accountability Office, GAO-05-55
- U.S. Master Tax Guide (2007), Cch Tax Law, pp 422
- U.S. NAS (1991), Policy implications of greenhouse warming – report of the mitigation panel, United States National Academy Press, Washington, DC
- Van Buskirk, R. (2006), Analysis of long-range clean energy investment scenarios for Eritrea, East Africa, *Energy Policy*, Vol. 34, Iss.14, pp 1807-1817
- Van Groenendaal, W. J. H. (1998), Estimating NPV variability for deterministic models, *European Journal of Operational Research*, Vol. 107, pp 202-213
- Vine, E. (2005), An international survey of the energy service company (ESCO) industry, *Energy Policy*, Vol. 33, Iss.5, pp 691-704
- Vine, E., Nakagami, H., & Murakoshi, C. (1999), The evolution of the U.S. Energy Service Company (ESCO) industry: from ESCO to super ESCO, *Energy*, Vol. 24, Iss.6, pp 479-492
- Weber, K. L., & Huckeby, M. A. (2005), Maintaining a viable energy savings performance contract, *Defense AR Journal*, Vol. 12, Iss.1, pp 78- 91
- Wei, Y., Liang, Q., Fan, Y., Okada, N. & Tsai, H. (2006), A scenario analysis of energy requirements and energy intensity for China's rapidly developing society in the year 2020, *Technological Forecasting and Social Change*, Vol. 73, Iss.4, pp 405-421
- Weisser, D. (2004), Costing electricity supply scenarios: A case study of promoting renewable energy technologies on Rodriguez, Mauritius, *Renewable Energy*, Vol. 29, Iss.8, pp 1319-1347
- Wickart, M. & Madlener, R. (2007), Optimal technology choice and investment timing: A stochastic model of industrial cogeneration vs. heat-only production, *Energy Economics*, Vo. 29, Iss.4, pp 934-952
- Wiser, R. H. (1997), Renewable energy finance and project ownership: The impact of alternative development structures on the cost of wind power, *Energy Policy*, Vol. 25, Iss.1, pp 15-27

Wiser, R. H. & Pickle, S. J. (1998), Financing investments in renewable energy: the impacts of policy design, *Renewable and Sustainable Energy Reviews*, Vol. 2, pp 361-386

Zhao, H., Kolarik, W., Turner, W. & Case, K. (2006), A win-win strategy to energy financing challenges – performance contracts, *Energy Engineering*, Vol. 103, No. 4, pp 53-80

Zobler, N., & Payne, M. (2003), Finding money for energy-efficient projects: A primer for public sector energy, facility, and financial managers, *Energy User News*, August 3rd

Zoppellari, R. (1990), Financing energy-saving projects: financial sources and investment evaluations, *Applied Energy*, Vol.36, pp 101-104

APPENDICES

Appendix A - Macro Code of Automating Recalculation and Recording the Outputs

Appendix A.1 - Macro code of automating recalculation and recording the outputs for
500 simulation runs

```
Sub Macro1()  
Dim i As Integer  
For i = 1 To 500  
Sheets ("sum").Select  
Range ("a2:h2").Select  
Application.CutCopyMode = False  
Selection.Copy  
Sheets ("summary").Select  
Cells (i, 1).Select  
Selection.Value = x  
ActiveCell.Offset(1, 0).Select  
Selection.PasteSpecial Paste:=xlPasteValuesAndNumberFormats, Operation:= _  
xlNone, SkipBlanks:=False, Transpose:=False  
Next i  
End Sub
```

Appendix A.2- Macro code of automating recalculation and recording the outputs for
5,000 simulation runs

```
Sub Macro1()  
Dim i As Integer  
For i = 1 To 5000  
Sheets("sum").Select  
Range("a2:h2").Select  
Application.CutCopyMode = False  
Selection.Copy  
Sheets("summary").Select  
Cells(i, 1).Select  
Selection.Value = x  
ActiveCell.Offset(1, 0).Select  
Selection.PasteSpecial Paste:=xlPasteValuesAndNumberFormats, Operation:= _  
xlNone, SkipBlanks:=False, Transpose:=False  
Next i  
End Sub
```

Appendix A.3- Macro code of automating recalculation and recording the output for
32,767 simulation runs

```
Sub Macro1()  
Dim i As Integer  
For i = 1 To 32767  
Sheets("sum").Select  
Range("a2:h2").Select  
Application.CutCopyMode = False  
Selection.Copy  
Sheets("summary").Select  
Cells(i, 1).Select  
Selection.Value = x  
ActiveCell.Offset(1, 0).Select  
Selection.PasteSpecial Paste:=xlPasteValuesAndNumberFormats, Operation:= _  
xlNone, SkipBlanks:=False, Transpose:=False  
Next i  
End Sub
```

Appendix B - Matlab Code of Drawing 3-D Plots to Find the Relationship between the “Positive NPVs for both Client and ESCO” and the Discrete Inputs

Appendix B.1- Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 1 to 9

```
x = [0.6 0.6 0.6 0.65 0.65 0.65 0.7 0.7 0.7];
y = [0.8 0.86 0.9 0.8 0.86 0.9 0.8 0.86 0.9];
z = [0.0018 0.0820 0.0891 0.0013 0.0954 0.0996 0.0015 0.1047 0.1096];
for i=1:length(x)
    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);
    hold on;
    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');
End
Set (gca, 'XLim', [0.55 0.75], 'Ylim', [0.7 1]);
Xlabel ('PR');
Ylabel ('AS');
Zlabel ('Positive NPVs for both client and ESCO');
Title ('Comparison of positive NPVs for both client and ESCO from Scenario 1 to 9');

Grid on;
```


Appendix B.2 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 10 to 18

```
x = [0.6 0.6 0.6 0.65 0.65 0.65 0.7 0.7 0.7];
y = [5 10 15 5 10 15 5 10 15];
z = [0.0663 0.1207 0.2084 0.0734 0.1301 0.2250 0.0799 0.1442 0.2374];

for i=1:length(x)
    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);
    hold on;
    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');
End

Set (gca, 'XLim', [0.55 0.75], 'Ylim', [4 16]);

Xlabel ('PR');

Ylabel ('Loan term of the client');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 10 to 18');

Grid on;
```

Appendix B.3 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 19 to 27

```
x = [0.6 0.6 0.6 0.65 0.65 0.65 0.7 0.7 0.7];
y = [0.8 0.85 0.9 0.8 0.85 0.9 0.8 0.85 0.9];
z = [0.2044 0.1459 0.1457 0.2225 0.1588 0.0937 0.2369 0.1748 0.1027];

for i=1:length(x)

    plot3 ([x(i) x(i)], [y(i) y(i)], [z(i) z(i)], 'y','LineWidth', 6);

    hold on;

    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');

End

set (gca, 'XLim', [0.55 0.75], 'Ylim', [0.75 0.95]);

Xlabel ('PR');

Ylabel ('PSR');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 19 to 27');

Grid on;
```

Appendix B.4 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 28 to 36

```
x = [0.6 0.6 0.6 0.65 0.65 0.65 0.7 0.7 0.7];
y = [5 10 15 5 10 15 5 10 15];
z = [0.0824 0.0840 0.0880 0.0926 0.0913 0.0927 0.1034 0.1058 0.1016];

for i=1:length(x)

    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);

    hold on;

    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');

End

Set (gca, 'XLim', [0.55 0.75], 'Ylim', [4 16]);

Xlabel ('PR');

Ylabel ('Loan term of the ESCO');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 28 to 36');

Grid on;
```

Appendix B.5 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 37 to 45

```
x = [0.8 0.8 0.8 0.86 0.86 0.86 0.9 0.9 0.9];
y = [5 10 15 5 10 15 5 10 15];
z = [0.0016 0.0021 0.0015 0.0728 0.1346 0.2242 0.0755 0.1423 0.2320];

for i=1:length(x)
    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);
    hold on;
    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');
End

Set (gca, 'XLim', [0.75 0.95], 'Ylim', [4 16]);

Xlabel ('AS');

Ylabel ('Loan term of the client');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 37 to 45');

Grid on;
```

Appendix B.6 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 46 to 54

```
x = [0.8 0.8 0.8 0.86 0.86 0.86 0.9 0.9 0.9];
y = [0.8 0.85 0.9 0.8 0.85 0.9 0.8 0.85 0.9];
z = [0.0017 0.0018 0.0015 0.2213 0.1593 0.0954 0.2294 0.1681 0.1019];

for i=1:length(x)

    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);

    hold on;

    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');

End

Set (gca, 'XLim', [0.75 0.95], 'Ylim', [0.75 0.95]);

Xlabel ('AS');

Ylabel ('PSR');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 46 to 54');

Grid on;
```

Appendix B.7 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 55 to 63

```
x = [0.8 0.8 0.8 0.86 0.86 0.86 0.9 0.9 0.9];
y = [5 10 15 5 10 15 5 10 15];
z = [0.0013 0.0017 0.0020 0.0919 0.0954 0.0919 0.0995 0.0973 0.1004];
for i=1:length(x)
    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);
    hold on;
    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');
End
Set (gca, 'XLim', [0.75 0.95], 'Ylim', [4 16]);
Xlabel ('AS');
Ylabel ('Loan term of the ESCO');
Zlabel ('Positive NPVs for both client and ESCO');
Title ('Comparison of positive NPVs for both client and ESCO from Scenario 55 to 63');
Grid on;
```

Appendix B.8 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 64 to 72

```
x = [5 5 5 10 10 10 15 15 15];
y = [0.8 0.85 0.9 0.8 0.85 0.9 0.8 0.85 0.9];
z = [0.1857 0.1315 0.0720 0.2813 0.2101 0.1339 0.3400 0.3210 0.2245];
for i=1:length(x)
    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);
    hold on;
    text (x(i), y(i), z(i), num2str(z(i)),'Color','r');
End
Set (gca, 'XLim', [4 16], 'Ylim', [0.75 0.95]);
Xlabel ('Loan term of the client');
Ylabel ('PSR');
Zlabel ('Positive NPVs for both client and ESCO');
Title ('Comparison of positive NPVs for both client and ESCO from Scenario 64 to 72');
Grid on;
```

Appendix B.9 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 73 to 81

```
x = [5 5 5 10 10 10 15 15 15];
y = [5 10 15 5 10 15 5 10 15];
z = [0.0735 0.0731 0.0706 0.1308 0.1330 0.1348 0.2283 0.2267 0.2279];

for i=1:length(x)

    plot3 ([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y', 'LineWidth', 6);

    hold on;

    text (x(i), y(i), z(i), num2str(z(i)), 'Color', 'r');

End

Set (gca, 'XLim', [4 16], 'Ylim', [4 16]);

Xlabel ('Loan term of the client');

Ylabel ('Loan term of the ESCO');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 73 to 81');

Grid on;
```


Appendix B.10 - Matlab code of drawing 3-D plots to find the relationship between the “Positive NPVs for both client and ESCO” and the discrete inputs in Scenario 82 to 90

```
x = [0.8 0.8 0.8 0.85 0.85 0.85 0.9 0.9 0.9];
y = [5 10 15 5 10 15 5 10 15];
z = [0.2169 0.2251 0.2225 0.1646 0.1560 0.1603 0.0947 0.0934 0.0954];

for i=1:length(x)

    plot3([x(i) x(i)], [y(i) y(i)], [0 z(i)], 'y','LineWidth', 6);

    hold on;

    text(x(i), y(i), z(i), num2str(z(i)),'Color','r');

End

Set (gca, 'XLim', [0.75 0.95], 'Ylim', [4 16]);

Xlabel ('PSR');

Ylabel ('Loan term of the ESCO');

Zlabel ('Positive NPVs for both client and ESCO');

Title ('Comparison of positive NPVs for both client and ESCO from Scenario 82 to 90');

Grid on;
```

Appendix C – Running Simulations in Multiple Excel Spreadsheets to Reach the Desired Stop Criteria

The maximum absolute value of "half width of a two-side CI/mean in %" from 32,767 simulation runs in a single Excel spreadsheet is 59.79% for Scenario 5, which is approximately six times the stop criteria of 10%. Scenario 5 is used as an example to illustrate how the desired stop criteria can be reached using multiple Excel spreadsheets. This procedure is demonstrated in the following paragraphs step by step.

In Step 1, similar to the Subchapter "Results of Scenarios after 32,767 Simulation Runs", run 32,767 simulations in a single Excel spreadsheet.

In Step 2, repeat the 32,767 simulation runs in 36 Excel spreadsheets. The total simulation runs will be 1,179,612.

In Step 3, calculate the mean and standard deviation of the 1,179,612 client's NPV output and 1,179,612 ESCO's NPV output, respectively.

In Step 4, based on the number of simulation runs (1,179,612), the mean and the standard deviation from the NPV outputs, the half width of a two-side confidence interval (CI) and the "half width of a two-side CI/mean in %" are calculated and presented in Table 24.

Table 24 - Simulation results of Scenario 5 from multiple Excel spreadsheets

SCENARIOS		Party	Mean	Standard Deviation	Half Width of a Two-Side Confidence Interval (CI)	Half Width of a Two-Side CI/Mean in %	% of Positive NPV	% of Positive NPV for Both Client and ESCO
sum	Client	\$ -160,025	\$ 6,131,242	\$ 11,064	-6.91%	35.50%	9.42%	
	ESCO	\$ 5,128,208	\$ 49,162,638	\$ 88,718	1.73%	35.64%		

In Step 5, compare the absolute value of "half width of a two-side CI/mean in %" with the stop criteria of 10%. The maximum absolute value of "half width of a two-side

CI/mean in %” from Scenario 5 is 6.91%, which is less than 10%; therefore, the desired stop criteria can be reached. Hence, the stop criteria of 10% can be met using Excel.

VITA

Haiyan Zhao

Candidate for the Degree of

Doctor of Philosophy

Thesis: EVALUATING ECONOMIC STRATEGIES FOR MULTI-PARTY
APPLICATION OF PERFORMANCE CONTRACTING

Major Field: Industrial Engineering

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Personal Data: Born in Liaocheng, Shandong Province, China, on July 15th, 1978, the daughter of Xiangrong Zhang and Guangling Zhao, and the wife of Naihui Song.

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Professional Memberships: Alpha Phi Mu

Name: Haiyan Zhao

Date of Degree: December, 2007

Institution: Oklahoma State University

Location: Stillwater, Oklahoma

Title of Study: EVALUATING ECONOMIC STRATEGIES FOR MULTI-PARTY
APPLICATION OF PERFORMANCE CONTRACTING

Pages in Study: 247

Candidate for the Degree of Doctor of Philosophy

Major Field: Industrial Engineering

Scope and Method of Study:

This subject matter is focused on the economic justification for energy management projects which involve both an energy client and an energy service company (ESCO) (and possibly other parties) in an Energy Savings Performance Contracting (ESPC) project. In this research, an analysis model is developed which includes multi-party involvement in justifying energy management projects that require expertise and capital beyond that found in the energy client. Examples include energy generation from waste heat, solar applications, and so on. The model is built on a system level and expands risk analysis beyond the simple party views. It is a multi-party model which seeks to find “win-win” solutions for all parties (or to expose shortcomings of projects where all parties cannot “win”). Such model application will help in justifying projects that might otherwise be discarded as too complex and too risky, or expose projects that will not produce demanded economic performance.

Findings and Conclusions:

The inputs of the model are referred to as being probabilistic and deterministic. The outputs of the model are the Net Present Values (NPV) of the client and the ESCO, respectively. The probabilistic inputs are either probability-distributed or simulated with the correlation coefficients from historical data. The deterministic inputs are referred to as either discrete arrays or single values. Multiple scenarios are generated in accordance with the number of the discrete arrays and the number of the values in each array. In each scenario, all probabilistic inputs are simulated, combined with the values randomly picked from the discrete arrays, and entered into the model. The output analysis is based on simulated NPVs for the primary parties (client and ESCO). The major contributions of the research include: (1) develop an analysis protocol for the parties involved in an ESPC project depending on the inputs and outputs of the proposed energy system, (2) develop a procedure to empower the parties involved in an ESPC project with information regarding the inherent risks, and (3) develop a procedure to present graphical outputs of multiple scenarios in an ESPC project to help the involved parties understand the influence of the significant inputs on the ESPC project.

ADVISER'S APPROVAL: Dr. William Kolarik
