LIFE CYCLE COSTING ANALYSIS OF INSULATION APPLICATIONS FOR EXISTING BUILDINGS IN TURKEY

by

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ABSTRACT

LIFE CYCLE COSTING ANALYSIS OF INSULATION APPLICATIONS FOR EXISTING BUILDINGS IN TURKEY

The energy efficiencies of existing buildings can be improved by upgrading the building envelope through insulation application on outer walls and ceilings. The objective of this study is to perform life cycle costing analysis (LCCA) of insulation applications for existing building in Turkey. The insulation applications include stone wool application on the ceiling at a thickness of 15 cm and expanded polystyrene (EPS) application on the outer walls at varying thicknesses. LCCA is performed on a representative building. Annual energy requirement of the insulated building is compared with the uninsulated one. The annual energy requirements are determined according to the Turkish Standard 825, Thermal Insulation Requirements for Buildings. A life cycle cost evaluation for the insulation applications is provided. Net savings (NS), internal rate of return (IRR), savings-to-investments ratio (SIR) and payback period (PBP) are calculated for different combinations of discount rate and escalation rate. Cash flow diagrams are provided for each insulation application to facilitate evaluation of each option. The study provides the optimized insulation thickness for each region in Turkey.

ÖZET

TÜRKİYEDEKİ MEVCUT BİNALARDA YALITIM UYGULAMALARININ YAŞAM DÖNEMİ MALİYET ANALİZİ

Mevcut binaların enerji verimliliği binanın tavanına ve dış duvarlarına yalıtım uygulaması yapılarak bina kabuğunun iyileştirilmesi ile geliştirilebilir. Bu tezdeki amaç Türkiye'deki mevcut binalardaki yalıtım uygulamalarının yaşam dönemi maliyet analizini yapmaktır. Yalıtım uygulamaları tavana 15 cm kalınlığında taş yünü uygulaması ve dış duvarlara değişen kalınlıklarda genleşmiş polistiren uygulamalarını içermektedir. Yaşam dönemi maliyet analizi temsili bir bina üzerinde uygulanmıştır. Yalıtımlı binanın yıllık enerji ihtiyacı yalıtımsız binanın yıllık enerji ihtiyacı ile karşılaştırılmıştır. Yıllık enerji ihtiyacı Türk Standardı 825, Binalarda Isı Yalıtım Kuralları'na göre hesaplanmıştır. Yalıtım uygulamaları için bir yaşam dönemi maliyet analizi yapılmıştır. Net kazançlar (NK), iç getiri oranı (İGO), kazanç-yatırım oranı (KYO) ve geri ödeme süresi (GÖS), iskonto oranı ve enerji fiyatı artış oranının çeşitli kombinasyonları için hesaplanmıştır. Her bir yalıtım uygulaması için nakit akış diyagramı elde edilerek seçenekler değerlendirilmiştir. Bu çalışmada Türkiye'nin her bir bölgesi için optimize edilmiş yalıtım kalınlıkları elde edilmiştir.

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LIST OF ACRONYMS / ABBREVIATIONS

ANAO	Australian National Audit Office
AAMCoG	Australian Asset Management Collaborative Group
DOD	The United States Department of Defense
EPS	Expanded Polystyrene
GLR	Gain/Loss Ratio
IGDAS	Istanbul Gas Distribution Industry & Trade Incorporated Company
IRR	Internal Rate of Return
LCC	Life Cycle Costing
LCCA	Life Cycle Costing Analysis
LPG	Liquefied Petroleum Gas
NPV	Net Present Value
NS	Net Savings
PBP	Payback Period
PWF	Present Worth Factor
R&D	Research & Development
SHL	Specific Heat Loss
SIR	Savings-to-Investment Ratio
TAM	Total Asset Management
TL	Turkish Lira
TS	Turkish Standard
TSI	Turkish Standards Institution
TOE	Tons of Oil Equivalent
VAT	Value Added Tax

1. INTRODUCTION

1.1. Background

The literature shows that it is possible to get extensive benefits with the adoption of life cycle costing analysis (Brady *et al*., 1999; Dowlatshahi, 2001). Life-cycle cost (LCC) optimization attempts have been made in various areas. In the manufacturing industry, it was seen that decisions related to the design and engineering costs affect the manufacturing costs significantly (Monden and Hamada, 1991). LCC has also been applied in construction. Examples include application in deteriorating bridges (Kong and Frangopol, 2003) and application in seismic design optimization (Liu and Neghabat, 1972; Kang and Wen, 2000; Ang and Lee, 2001).

In this study, the LCC analysis is applied on insulation applications. A representative building approach is used in order to determine the optimum insulation thicknesses for each region in Turkey. The insulation application is applied on existing residential buildings in Turkey. The cost of insulation application and the future savings due to decreasing heating energy costs are considered in the analysis. Finally, optimization is made to minimize the life-cycle costs.

1.2. Statement of Problem

The following statement is included in the Energy Performance Regulations for Buildings (Ministry of Public Works and Settlement, 2008):

"For the existing buildings and for the buildings in construction that have not taken occupancy permits, Energy Performance Certificate is going to be a must in ten years after Energy Efficiency Law is published".

The Energy Efficiency Law was published in 02.05.2007 (Ministry of Energy and Natural Sources, 2007), which means that the last date to get the Energy Performance Certificate is 02.05.2017. The Energy Performance Certificate is going to contribute to the

value of residential building as it summarizes the energy efficiency of the building. So, many building owners are going to apply insulation on their existing buildings in order to get better scores on the Energy Performance Certificate and increase the property value of their buildings. It is logical to expect a radical increase in the number of insulation applications at existing buildings in Turkey in the next years.

1.3. Aim and Objectives

The aim in this study is to apply Life Cycle Costing Analysis (LCCA) on insulation applications for existing buildings in Turkey. The objective of the study is to evaluate each insulation application option as an investment alternative and to find optimized insulation application for each region in Turkey.

The research findings can help a wide range of individuals who are thinking of applying insulation materials on their existing buildings. It gives them a general understanding of the consequences of insulation applications and an ability to evaluate an insulation application as an investment option. Also, the research findings can help questioning the minimum requirements on the Turkish Standard 825, whether or not they are at the desired levels.

The research aims to apply LCCA on insulation applications for existing buildings in Turkey. The following steps are taken in order to achieve this aim:

- To calculate annual heating energy requirement of a representative uninsulated and insulated building with varying insulation thicknesses.
- To determine annual heating energy savings for each insulation application option.
- To determine the cost of each insulation application option.
- To generate cash flow diagrams with appropriate assumptions.
- To calculate net savings (NS), internal rate of return (IRR), savings-to-investments ratio (SIR) and payback period (PBP) for each insulation application option.
- To find the optimized insulation application option for each region in Turkey.

1.4. Related Work

LCC has been applied various areas. In order to optimize life-cycle cost of deteriorating bridges, Kong and Frangopol (2003) presented a reliability-based methodology. Their objective was to apply the minimum maintenance cost strategy in a specific service life satisfying the given constraints. The constraints can provide satisfactory lifetime safety and serviceability levels for deteriorating bridges (Estes and Frangapol, 2001).

In seismic design optimization, Liu and Neghabat (1972) had a mathematical approach to determine the optimal design intensity of earthquakes for structures. The objective was to optimize total construction cost of the structure plus the expected cost of earthquake damage throughout the entire service life of the structure. Kang and Wen (2000) proposed a methodology to minimize expected life cycle cost and applied the methodology to seismic design of steel moment frame buildings. Ang and Lee (2001) made cost analysis in terms of the Park-Ang damage index on reinforced concrete buildings constructed in Mexico.

In terms of building insulation, various studies were performed, including determination of optimum insulation thickness for the coldest cities in Turkey (Çomaklı and Yüksel, 2003), determination of optimum insulation thickness for 16 cities from four climate zones of Turkey (Bolattürk, 2006), determination of optimum insulation thickness for cities with different degree days (DD) regions in Turkey (Sisman *et al*., 2007), determination of optimum insulation thickness in Turkey for each region and for changing glazing areas (Özkan and Onan, 2011) and determination of optimum insulation thickness in Denizli (Dombaycı *et al.*, 2006).

1.5. Research Methodology

LCCA is used in order to evaluate the insulation options on an existing representative building. The representative building is a five storey building with a width of 20 m, a length of 25 m, and a height of 15 m. The annual heating energy requirement of the uninsulated representative building is calculated according to TS 825 (TSI, 2008) for

all regions. Then, annual heating energy requirements are calculated for the insulated building. In the insulated building, stone wool insulation at a thickness of 15 cm exists in the ceilings and expanded polystyrene (EPS) insulation exists on the outer walls with varying thicknesses.

The annual savings are determined by calculating the decreases in the annual heating energy requirements. The decrease is equal to the difference between the annual heating energy requirements of the uninsulated and the insulated ones. Then, the cost of each insulation application is determined by taking offers from various companies and their average is taken in order to find the cost of each insulation application option.

The cost of insulation and the annual energy savings are used to generate the cash flow diagram. Annual savings in the future are calculated by assuming an average annual increase in energy prices, which is the escalation rate. Knowing how much energy is saved annually (kWh/year), the average energy price calculated in the corresponding year (TL/kWh) is multiplied by the saved energy amount to determine the annual savings.

LCCA considers all the costs that are incurred during the entire life of the items. It also considers the time value of money. In this study, the initial costs arising from the cost of insulation applications and the operational savings gained by decreasing the annual heating energy requirements are considered in LCCA. The analysis includes calculation of net savings (NS), internal rate of return (IRR), savings-to-investments ratio (SIR) and payback period (PBP). The optimized option is determined according to the net savings of the investments during the analyzed period, which is 20 years.

1.6. Significance of the Study

The results of this research may offer remarkable advantages to people or institutions to understand the investment value of insulation applications for existing buildings in Turkey. A good understanding of the investment value of the insulation applications would provide:

- An ability to understand the time value of money,

- An awareness of the LCC approach, which considers all the costs during the entire life of an item rather than considering just the initial cost,
- An ability to compare insulation investments with other investment alternatives,
- An awareness of the profitability of the insulation investments,
- An awareness of the importance of energy related investments for our country,
- Knowledge on optimized insulation thickness for each region in Turkey.

1.7. Definition of Terms

Life-Cycle Cost is defined by TAM (2004) as the total costs throughout the life of the asset including planning, design, acquisition and support costs and any other costs directly related to owning or using the asset.

Discounting is defined as converting the future values of cost and benefits to present. The discounted cost is the value when costs are discounted by the discount rate. The discount rate is the indicated rate that is used in the in the discounting process (ANAO, 2001).

Luehrman (1998) defined the net present value (NPV) as the difference between the value and cost of the operating assets in present. The corporation can increase its value by making the investment that has a positive NPV. If the NPV of the investment is negative, it is better for the corporation not to make the investment.

Internal rate of return (IRR), which was firstly used in private industry, represents the discount rate that makes the discounted costs and benefits equal. The IRR does not provide an acceptable decision criterion. However, it is very useful when budgets are constrained or when uncertainty exists in the discount rate (Pavement Division Interim Technical Bulletin, 1998).

Disposal cost is the cost of getting rid of the asset at the end of the life-cycle. It may have a net remaining value or it might have the cost of transferring or destroying the assets. Most of the time, the disposal cost of the assets that are compared is assumed to be equal to zero. However, it could be a positive or a negative value (Ellis, 2007).

1.8. Structure of the Thesis

The remainder of this study is described in four chapters. Chapter 2 reviews the energy consumption and the life cycle costing approach, including the elements of life cycle costing, calculations, measures, applications and evaluations of life cycle costing. Chapter 3 describes the research methodology in detail. Chapter 4 includes research findings as a result of the methodology applied and the discussion. The final chapter is the conclusion part, which includes the summary of the study and the recommendations.

2. ENERGY AND LIFE CYCLE COSTING ANALYSIS

2.1. Energy Consumption

Energy is an important factor for the social and economic development of societies. Energy saving has been an important part of national energy strategies since the energy crises of 1973. This is extremely important for Turkey due to the fact that most of the energy that is used in Turkey is imported. As a result of the increases in population and urbanization, energy consumption is rapidly increasing. The estimated population of Turkey in 2020 is over 100 million and energy consumption in Turkey has increased by an average of 4.4% in recent years (Bolattürk, 2006).

The followings are the primary energy resources that are produced in Turkey:

- Hard coal,
- Lignite,
- Asphaltite,
- Petroleum,
- Natural Gas,
- Hydroelectric energy,
- Geothermal energy.

Turkey has to import 52% of the energy from abroad in order to meet the needs due to the lack of indigenous energy resources (Bolattürk, 2006). The energy consumption is distributed among four main sectors:

- Industrial,
- Building (residential),
- Transportation,
- Agriculture.

The sectorial distribution of the general energy demand is shown in Table 2.1. It is clear that the residential sector is the largest energy consumer after the industrial sector.

Table 2.1. Sectorial Distribution of Energy Consumption (1,000 TOE) (Ministry of Energy and Natural Sources, 2014).

Years	Industry	Transportation	Buildings	Agriculture	Other	Total Energy Consumption	Transformation Sector	Primary Energy Supply
2002	24,782	11,405	18,463	3,030	1,806	59,486	-18,845	78,331
2003	27,777	12,395	19,634	3,086	2,098	64,990	-18,836	83,826
2004	28,789	13,775	20,952	3,314	2,174	69,004	-18,814	87,818
2005	28,084	13,849	22,923	3,359	3,296	71,510	-19,564	91,074
2006	30,996	14,994	23,677	3,610	4,163	77,440	-22,201	99,642
2007	32,466	17,284	24,623	3,945	4,430	82,748	-24,879	107,627
2008	26,906	15,996	28,323	5,174	3,244	79,642	-26,779	106,421
2009	25,966	15,916	29,466	5,073	4,153	80,574	-25,565	106,138
2010	30,703	15,165	28,944	5,095	3,459	83,367	-25,894	109,260
2011	30,830	15,950	29,974	5,756	4,442	86,952	-27,528	114,480
2012	30,382	20,767	31,517	1,952	4,390	89,008	-31,086	146,930

Most of the energy that we consume is obtained from fossil fuels. Due to the scarcity of the resources available, we have to save energy. Also, the fuels used as energy resources give rise to significant environmental pollution. One of the ways of saving energy is to reduce the energy consumption in buildings. Heat loss can be reduced by a number of ways. One of the ways is the application of optimum insulation thickness to external walls. Çomaklı and Yüksel (2003) cited that wall and roof insulation can produce energy savings up to 77%.

2.2. Life Cycle Costing Concept

A number of economic criteria have been used by engineers in order to make decisions between alternative designs or investments. LCC is one of the methods that enables evaluation and considers all relevant costs of a system over a specified period of time. The differences in the timing of these costs are adjusted by the LCC procedure. It takes escalation rates and discount effects into account to reflect "time value of money" (Hughes, 1981).

The definition of LCC can be done in various ways as follows:

"The LCC of an item is the sum of all funds expended in support of the item from its conception and fabrication through its operation to the end of its useful life (Woodward, 1997)".

"... the structured analysis of the entire set of costs which are associated with a project or asset, in order to evaluate the total cost of ownership of the asset (AAMCoG, 2008)."

LCCA is an economic decision-making tool that enables choosing the best alternative, based on long-run cost performance. An economic analysis is required in order to justify the required additional investment when design improvements increase the initial capital cost, but reduce future operating costs or extend the life of the building or system (Sekhar and Toon, 1998).

If it is possible to express all attributes and consequences of a decision for a structure, the optimum decision becomes the one that minimizes the LCC of the structure (Val, 2003). The costs that are parts of the analysis might occur during the whole useful life of the asset, or might occur just for a period in which the owner of the entity is performing the analysis. The life cycle of an arbitrary asset is composed of various phases that can be divided into stages as follows (AAMCoG, 2008):

- Acquisition,
- Operation & Maintenance,
- Renewal (if applicable),
- Disposal.

In LCCA, all the costs that occur during its life cycle are structured and analysed. These costs are called as “Life Cycle Costs” and might occur at different life cycle stages that are shown above. Life cycle costs are generated by all kinds of expenses related to activities performed. Some of the expenses are (AAMCoG, 2008):

- Initial capital costs,
- Operating costs,
- Maintenance costs,
- Risk exposure costs,
- Renewal costs,
- Disposal costs.

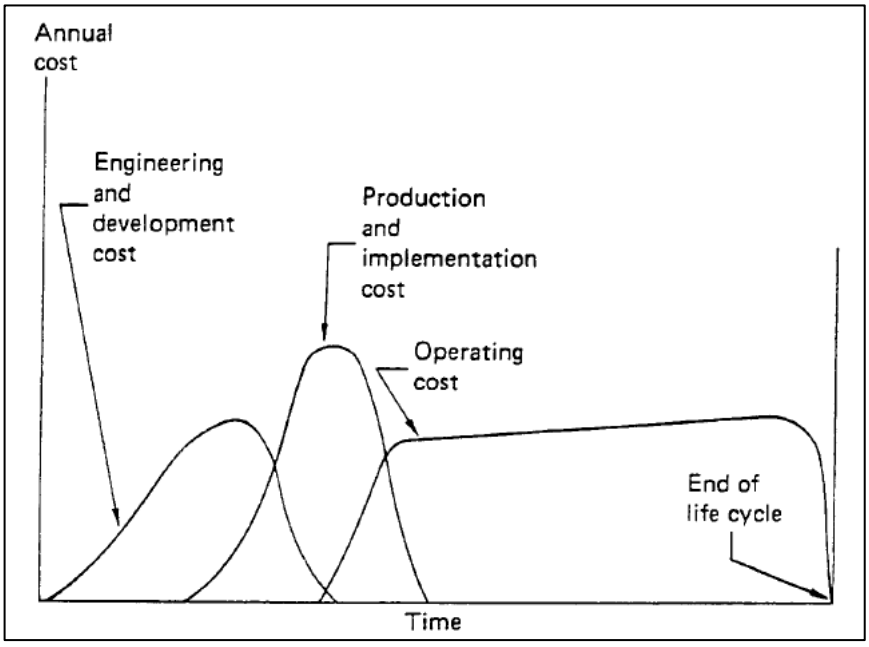


Figure 2.1. Stages of Life Cycle Costs (Woodward, 1997).

2.3. Elements of Life Cycle Costing

Woodward (1997) cited that the objectives of life cycle costing are as follows:

- To enable evaluation of investment options in a more effective way,
- To take all costs into consideration instead of just considering the initial capital costs,
- To support the effective management of completed projects and buildings,
- To make selection easier between alternatives.

There is no consensus on all elements and factors to be included in the LCC. The methodology has been used by the United States Department of Defense (DOD) in making purchase decisions since 1970. The number of elements used for life cycle cost analysis varies in the literature. Elements and factors used for life cycle cost analysis are shown in Table 2.2 (Hallaway, 1982).

Table 2.2. Elements and Factors in Life Cycle Cost Analysis (Hallaway, 1982).

	Ruffin, 1978 Home appliances	Lund, 1978 Home appliances	DOD 1970-73 Defense projects	DOE, 1980 Federal buildings	DOC, NBS Handbook 135, 1980
1	Purchase price	Acquisition Cost Purchase price Sales tax Transportation	Purchase price Delivery cost Testing cost	Investment costs less salvage	Investment costs less salvage
2	Installation cost	Installation cost	Installation cost		
3			Inventory management		
4			Training		
5	Operating costs Energy Supplies Maintenance Repair	Operating costs Energy Operator's time Repair and maintenance Routine maintenance Failure repair (excludes warranty)	Operating Labor Operating materials Preventive maintenance Corrective Maintenance	Energy costs Nonfuel operation and maintenance costs	Energy costs Nonfuel operation and maintenance costs
6	Expected life	Expected lifetime	Service life	Expected life	Expected life
7	Disposal or trade benefit	Disposal	Residual value	Replacement costs less salvage	Replacement costs
8	Discount factor (5% rate)	Discount factor	Discount factor (10% rate)	Discount factor (10% rate)	Discount factor (7% rate)
9	Dismantling	Contractual costs Rental or service contract			

The main idea behind life cycle costing approach is that it identifies all future costs and benefits and brings them back to present by making use of the discounting techniques. It can assess the economic worth of a project or a series of project options in this way. Woodward (1997) identified the following elements in order to achieve these objectives:

- Initial capital costs,
- Life of the asset,
- The discount rate,
- Operating and maintenance costs,
- Disposal cost,
- Uncertainty and sensitivity analysis.

2.3.1. Initial Capital Costs

The initial capital costs can be separated into three sub-categories as follows (Woodward, 1997):

- Purchase costs,
- Acquisition / finance costs,
- Installation / commissioning / training costs.

Purchase costs include valuation of items such as buildings, fees, land, equipment and furniture. The estimation of these costs can be made by obtaining offers from suppliers. Finance costs involve the cost effects of alternative sources. The other costs represent costs such as installation of a machine or training people (Woodward, 1997).

Consumers should consider the following questions and decide how they affect the initial cost (Hallaway, 1982):

- Is it possible for the consumer to transport and install the appliance, or will there be additional costs due to delivery and installation?
- Are there energy tax credits available?

- How much is the consumer's time worth in comparison to shop, deliver, and install the appliance?

2.3.2. Life of an Asset

The life of an asset is the time interval from the recognition of the need to the final disposal. The life of an asset is influenced by (ANAO, 2001):

- The failure of its key components,
- Its ability to continue to provide a required service.

Most of the assets come to the end of their useful life before becoming unserviceable. The effective life of an asset is determined by the technological developments and changes in user requirements.

Due to the exponential effect of life of an asset, the forecast life has a major influence on LCC analysis. Woodward (1997) stated that an asset's life expectancy is determined by five possible factors as follows:

- Functional life – It is the period for which there is a need for the asset;
- Physical life – It is the period for which the assed is expected to physically work until a comprehensive rehabilitation or a replacement is required;
- Technological life – It is the period for which a replacement is dictated due to technical obsolescence or due to the development of technologically better alternative;
- Economic life – It is the period for which replacement is dictated due to the existence of a lower cost alternative;
- Social and legal life – It is the period for which replacement is dictated due to legal requirements.

2.3.3. The Discount Rate

Costs and benefits can be added without taking timing effect into account if the method does not consider when they occur. However, if the effect of time is important, investment calculus needs to be applied. Discounting is one of the techniques. Discount rate is the factor that takes the time value of money into account. Gluch (2004) stated that the followings are the determinants of the discount rate:

- Inflation,
- Cost of capital,
- Investment opportunities,
- Personal consumption preferences.

Taking the discount rate as 0% means that there is no effect of timing. More importance is given to the near-present as the value of discount rate increases.

The conversion of future receipts and costs to an equivalent present value can be made with the following formula (ANAO, 2001):

$$\text{Present Value} = FV/(1+r)^n \qquad (2.1)$$

Where future value (FV) is the spent or received amount in the future, n is the number of years between the present and the future transactions, r is the discount rate.

Selection of a suitable discount rate is important in LCCA due to the fact that life cycle costs are discounted to the present value with the use of this variable. Selecting a high discount rate will favor alternatives with low capital costs, short life and high maintenance costs. A low discount rate will favor the alternatives with opposite properties (Woodward, 1997).

The appropriate discount rate value changes significantly for each organization. It is determined by the skill of the industrial accountant instead of arbitrary selection. It is easy to calculate the relevant discount rate in the case of estimating the rate of inflation. There

are many sophisticated techniques available from the financial management sub-discipline of accounting to assist with this particular problem (Woodward, 1997).

2.3.4. Operating and Maintenance Costs

The main idea of life cycle costing is to operate physical assets at minimum cost. So, it is essential to estimate operating and maintenance costs to minimize the total life cycle costing of the asset. Woodward (1997) claimed that the followings might be included in the operating costs of an asset:

- Direct labor,
- Direct materials,
- Direct expenses,
- Indirect labor,
- Indirect materials,
- Establishment costs.

These costs are estimated by observing the experience of similar assets. In most organizations, engineering departments are responsible for making these estimates of productive assets.

Energy cost can also be regarded as a part of operating cost. The following questions must be considered in order to estimate the annual energy cost (Hallaway, 1982):

- What is the local electric and gas rate?
- How long will the appliance be used?

Maintenance costs are composed of direct labour, fuel power, materials, equipment and purchased services. Maintenance costs can be categorised as follows (Woodward, 1997):

- Regular planned maintenance;
- Unplanned maintenance;

- Intermittent maintenance.

It is possible to reduce downtime costs with a regular, planned and preventive policy. However, resources are used as maintenance expenditure. On the other hand, the “run until it breaks” approach reduces maintenance costs but downtime losses increase. The relationship between them is shown in the Figure 2.2:

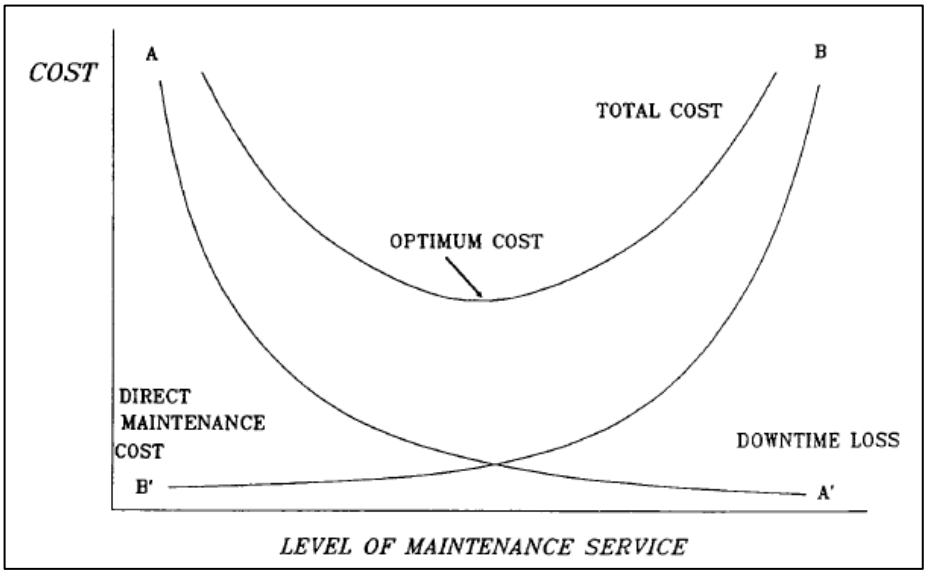


Figure 2.2. The Maintenance-Cost Relationship (Woodward, 1997).

If an asset has high downtime costs, a regular, planned maintenance policy is maintained. However, items with low downtime costs can be replaced when they become old. The key point is that optimum level of maintenance must be found in order to attain minimum total cost (Woodward, 1997).

2.3.5. Disposal Cost

This cost occurs in disposing of the asset at the end of its working life. The cost of demolition and selling value of the asset adjusted for taxes are included in the disposal costs. These costs are subtracted from the residual value of the asset (Woodward, 1997).

2.3.6. Uncertainty and Sensitivity Analysis

Assumptions and estimates made while collecting data have a strong effect on life cycle cost analysis. It is possible that the quality of these estimates can be improved with the usage of historical data and statistical method. However, existence of uncertainty associated with these estimates is undeniable (Woodward, 1997).

The sensitivity analysis is a technique to determine which input values can make a crucial difference to the outcome of the analysis. It calculates a range of outcomes in order to determine the lower and the upper bounds of the measures of economic evaluation. The followings are sufficient for performing sensitivity analysis (Fuller and Petersen, 1996):

- Vary uncertain input values,
- Recalculate the measures,
- Observe the changes and draw conclusions about the degree of uncertainty.

2.4. Cost Trade Offs

One of the main principles of a LCCA is the possibility to trade-off initial capital cost against subsequent revenue savings. This could be seen clearly in Figure 2.3:

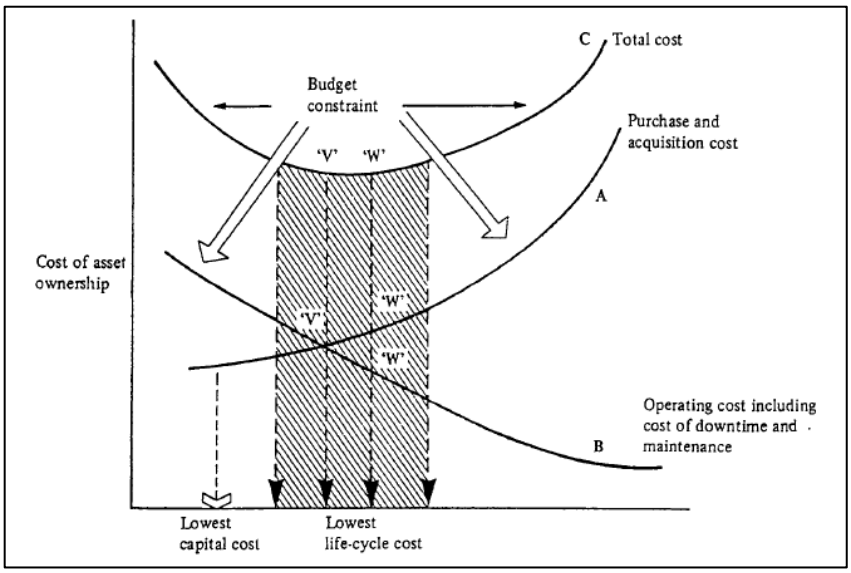


Figure 2.3. Cost Trade-Offs in Asset Ownership (Woodward, 1997).

As could be understood from Figure 2.3, an increase in capital expenditure, represented by curve A, results in reduced maintenance costs, represented by curve B. The optimum life cycle cost of asset ownership is reached when the total cost, represented by curve C, is at a minimum. It is also shown that the alternative with lowest capital cost has a very high life cycle cost (LCC) (Woodward, 1997).

A budget constraint is also located in the figure. The thick arrows represent budget constraint for capital and maintenance costs. The thin arrows represent budget constraint for the asset life cycle cost as a whole.

Some specific examples of trade-offs are shown as follows (Woodward, 1997):

- Allocate more resources to the R & D stage in order to reduce maintenance costs by increasing reliability and maintainability,
- Increase the efficiency of the machine (higher development / capital costs) in order to reduce scrap,
- Spend more on automation (higher initial costs) so that the manning costs decrease,
- Choose expensive machines having longer lives.

2.5. Calculation of Life Cycle Costs

The simple formula stated below can be used to express the life-cycle costs of an asset (ANAO, 2001):

LCC	=	Capital costs	+	Life-time operating costs
			+	Life-time maintenance costs
			+	Disposal costs
			-	Residual value

The LCC methodology discounts future amounts to present value base year amounts. The rate of inflation does not exist in the computations. However, energy price escalation rates which are related to the rate of inflation are included in the discounting procedure. Thus, initial investment costs, future replacement costs, operation and

maintenance costs, and salvage and resale values are included in LCC and combined into a single cost-effectiveness measure in order to facilitate comparison of alternate projects (Hughes, 1981).

The general formulation for the life cycle costing present value model is as follows (Fuller and Petersen, 1996):

$$LCC = \sum_{t=0}^{N} \frac{C_t}{(1+d)^t} \quad (2.2)$$

Where LCC is the total life cycle cost in present value, C_t is the sum of all the costs occurring in year t, N is the number of years and d is the discount rate used to take future cash flows back to present value.

2.6. Measures of Life Cycle Costing

2.6.1. Net Savings

Present value of investment costs are subtracted from the present value of savings in the operation phase to find the net savings. It provides measuring the cost effectiveness of the benefits to be achieved from the investments. It is cost effective when net saving value is greater than zero (Davis Langdon Management Consulting, 2007).

The following formula can be applied to calculate net savings using individual cost differences (Fuller and Petersen, 1996):

$$NS_{A:BC} = \sum_{t=0}^{N} \frac{S_t}{(1+d)^t} - \sum_{t=0}^{N} \frac{\Delta I_t}{(1+d)^t} \quad (2.3)$$

Where $NS_{A:BC}$ is the net savings of alternative (A), relative to base case (BC), S_t is the savings in operational costs associated with the alternative in year t, ΔI_t is the additional investment costs associated with the alternative in year t, t is the year of occurrence (0 is the base date), d is the discount rate and N is the number of years in the study period.

2.6.2. Internal Rate of Return

Hazen (2009) stated that the internal rate of return (IRR) is a widely used tool that can be a valuable aid in project acceptance and selection when used appropriately. Azar and Noueihed (2014) cited that the internal rate of the project must be compared with the hurdle rate. The hurdle rate is the discount rate that measures the opportunity cost of funds adjusted for the risk. If the IRR value comes out to be higher than the hurdle rate the project must be accepted. It must be rejected otherwise.

The net present value (NPV) for a discount rate R, future net cash flows x_i, period i, and useful life of N is calculated as follows (Azar and Noueihed, 2014):

$$NPV = \sum_{i=0}^{N} \frac{x_i}{(1+R)^i} \tag{2.4}$$

Internal rate of return is the rate r, with $-1 < r < +\infty$, which makes the NPV zero:

$$0 = \sum_{i=0}^{N} \frac{x_i}{(1+r)^i} \tag{2.5}$$

2.6.3. Savings-to-Investment Ratio

Savings-to-investment ratio (SIR) is the ratio of the savings obtained from operation costs to the investment cost to construct the more efficient system. In general, a project having an SIR value greater than 1.0 is cost effective can be considered as an alternative (Hughes, 1981).

The following formula can be applied to calculate savings-to-investment ratio (Fuller and Petersen, 1996):

$$SIR_{A:BC} = \frac{\sum_{t=0}^{N} \frac{S_t}{(1+d)^t}}{\sum_{t=0}^{N} \frac{\Delta I_t}{(1+d)^t}} \tag{2.6}$$

Where $SIR_{A:BC}$ is the ratio of present value of savings to present value of investment costs for the alternative relative to the base case, S_t is the savings in operational costs for the alternative in year t, ΔI_t is the additional investment costs associated with the alternative in year t, t is the year of occurrence, d is the discount rate and N is the number of years in study period.

2.6.4. Payback Period

Hughes (1981) stated that payback period (PBP) is the amount of time required for the cumulative savings to be equal to the initial investment costs. Two versions of payback period exist in the literature. The "discounted payback" takes the time value of money into account as the "simple payback" does not.

The following formula can be applied to calculate the discounted payback period (Fuller and Petersen, 1996):

$$\sum_{t=1}^{y} \frac{(S_t - \Delta I_t)}{(1+d)^t} \geq \Delta I_0 \qquad (2.7)$$

Where y is the minimum time that satisfy the condition that cash inflows offset investment costs, S_t is the savings in operational costs for the alternative in year t, ΔI_0 is the initial investment costs associated with the alternative, ΔI_t is the additional investment costs associated with the alternative in year t, t is the year of occurrence and d is the discount rate.

2.7. Analysis and Interpretation of the Results

The LCC process is based on a variety of assumptions about the current and future cash flows. Also, assumptions exist on a range of parameters such as the discount rate and the escalation factors. Each element has limited accuracy and a different impact on the outcome. So, the impact of changes in the values used for key data on the overall results must be explored. Such an investigation is known as sensitivity analysis (ANAO, 2001).

Sensitivity analysis involves repeating the calculations of the model with a number of alternative data values. The values are chosen in order to reflect the level of uncertainty for the data. For example, the cost of annual maintenance can range from $100,000 to $150,000 and is estimated at $125,000. Then, it is important to investigate the effects on the overall results by using the three values (ANAO, 2001).

2.8. Life Cycle Costing Applications in Construction

Life-Cycle Costing approach has been applied in construction many times. Some areas in which life-cycle costing analysis has been considered are deteriorating structures, seismic design optimization and insulation thickness optimization which is the topic in this study.

Kong and Frangopol (2003) introduced a reliability based methodology in order to achieve the optimized life-cycle cost of deteriorating bridges satisfying the given constraints in a specific service life. The objective was to minimize the present value of the cumulative maintenance cost in a given time. In order to assure objectivity in computations, a program called "Life-Cycle Analysis of Deteriorating Structures" was developed.

Çomaklı and Yüksel (2003) applied life-cycle costing approach in order to find the optimum insulation thickness for the coldest cities in Turkey. It was found that energy savings up to 12.113 $\$/m^2$ could be obtained in Erzurum with the application of optimum insulation thickness. The annual energy costs were calculated according to the Turkish Standard 825 (TSI, 1999). Present worth factor (PWF) of 6.39 was used in order to take future energy savings to the present. The optimum insulation thicknesses were determined as 10.48 cm, 10.73 cm and 8.51 cm for Erzurum, Kars and Erzincan, respectively.

Bolattürk (2006) applied life-cycle costing analysis to study the optimum insulation thickness for 16 cities from four climate zones of Turkey. He used various energy sources like coal, natural gas, fuel oil, liquefied petroleum gas (LPG) and electricity. The annual heating requirements of the building were calculated according to the TS 825 (TSI, 1999). He used a PWF of 6.72 in order to take future energy savings to the present. Optimum

insulation thicknesses varied between 2 cm and 17 cm and energy savings varied between 22% and 79%.

Sisman *et al*. (2007) studied the optimum insulation thickness for cities with different degree days (DD) regions in Turkey, namely, İzmir, Bursa, Eskişehir and Erzurum. The annual heating requirements of the buildings were calculated according to TS 825 (TSI, 1999). Optimum insulation thicknesses were determined for a lifetime of 10 years and annual interest rate and inflation rate of 17.79% and 9.32%, respectively. Optimum insulation thicknesses were calculated as 3.3 cm, 4.7 cm, 6.1 cm, and 8.0 cm for İzmir, Bursa, Eskişehir and Erzurum, respectively.

Özkan and Onan (2011) studied the optimum insulation thickness in Turkey for each region and for changing glazing areas. The annual heating requirements of the buildings were calculated according to TS 825 (TSI, 2008). Optimum insulation thicknesses were determined for a lifetime of 10 years and annual interest rate and inflation rate of 19.375% and 9.67%, respectively.

Ucar and Balo (2010) studied the optimum insulation thickness in Turkey for four regions. Calculations were done for five different energy types and four different insulation materials. Optimum insulation thicknesses were determined for a lifetime of 10 years and annual interest rate and inflation rate of 4% and 5%, respectively.

Dombaycı *et al.* (2006) studied the optimum insulation thickness in Denizli for five different energy sources, namely, coal, natural gas, LPG, fuel oil and electricity; and for two insulation materials, namely, expanded polystyrene and rock wool. It was concluded that a life cycle saving of 14.09 $\$/m^2$ and a payback period of 1.43 years can be achieved with the application of the optimum insulation thickness. The annual heating requirements of the buildings were calculated according to TS 825 (TSI, 1999). PWF of 6.71 was used in order to take future energy savings to the present. Optimum insulation thicknesses were determined for a lifetime of 10 years and annual interest rate and inflation rate of 8% and 0%, respectively.

Sundaram and Bhaskaran (2014) studied the optimum insulation thickness of walls in hot regions of India. Only cooling energy was considered as the heating energy is zero in these regions. Electricity was used as the only energy source. Three different insulation materials were considered in the study, namely, expanded polystyrene (EPS), foamed polyurethane and foamed PVC. Optimum insulation thicknesses were determined for a lifetime of 20 years and annual discount rate and energy price rate of 5% and 5%, respectively.

Daouas (2011) calculated the optimum insulation thickness of walls in Tunisian buildings. Both the cooling and heating energies were considered in optimization. Electricity and natural gas were considered as energy sources for cooling and heating, respectively. Optimum insulation thicknesses were determined for a lifetime of 30 years and discount rate and inflation rate of 8% and 5%, respectively. The optimum insulation thicknesses varied between 10.1 and 11.7 cm.

Mishra *et al.* (2012) studied the optimum insulation thickness in India for different types of building walls. Extruded polystyrene and expanded polystyrene were used as insulation materials. Only heating energy was considered in the analysis. Optimum insulation thicknesses were determined for a lifetime of 10 years and annual interest rate and inflation rate of 8% and 10%, respectively. The optimum insulation thicknesses varied between 5.2 and 7.4 cm.

Yu *et al.* (2009) studied the optimum insulation thickness for four cities in China. Both the heating and cooling energies were considered in the study. Expanded polystyrene, extruded polystyrene, foamed polyurethane, perlite and foamed polyvinyl chloride were used as insulation materials. Optimum insulation thicknesses were determined for a lifetime of 20 years and annual discount rate and inflation rate of 5% and 1%, respectively. The optimum insulations varied between 5.3 and 23.6 cm.

Given this background, it is seen that the previous studies have mostly concentrated on the application of LCCA to determine the optimum insulation thickness. The optimum thicknesses have been determined by assuming the lifetime, the discount rate and the escalation rate. The same assumptions are made in this study to determine the optimized

thicknesses. However, a representative building approach is used. It means that the heating energy requirements are calculated for a representative building with specified properties. Also, in this study, optimized thicknesses are determined for an existing building and the limit values regarding the minimum insulation thicknesses for existing buildings in TS 825 are questioned.

3. METHODOLOGY

In this study, the life cycle costing analysis (LCCA) is applied on a representative building with specified properties. The annual heating energy requirements are calculated for the uninsulated and the insulated building in order to find the annual energy savings gained by the insulation application.

3.1. Representative Building

The LCCA is applied on insulation applications for a representative five-storey existing building in Turkey. The uninsulated building has a length of 25 m, a width of 20 m and each floor has a height of 3 m. Net height of each floor is 2.6 m. Gross volume (V_{gross}) of the building is 7500 m^3.

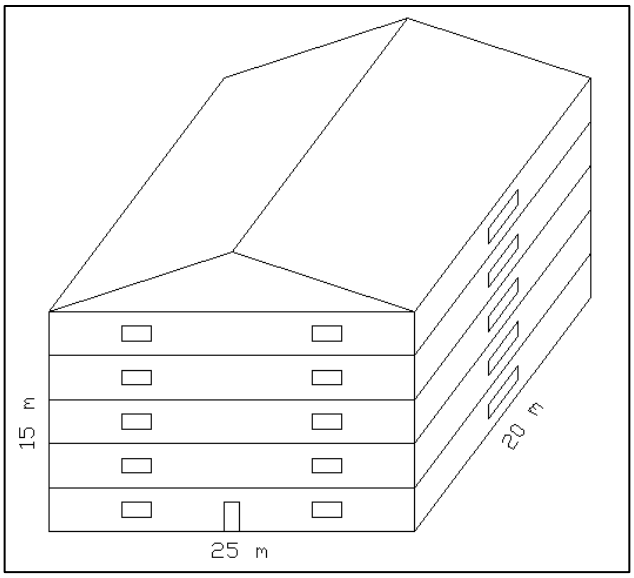


Figure 3.1. Representative Existing Building.

The total area of the windows and doors in the building are 130 m^2 and 5 m^2, respectively. For each direction, the area of the windows is as follows:

- A_{south} = 50 m^2
- A_{north} = 20 m^2

- A_{east} = 40 m^2
- A_{west} = 20 m^2.

It is assumed that natural ventilation is used for air-conditioning and natural gas is used to heat the building. The efficiency of the heating system is assumed to be 90%.

Annual heating energy requirement of the representative building is calculated using TS 825 (TSI, 2008). The heating energy requirement is calculated for the uninsulated building and the insulated building. In TS 825, Turkey is divided into 4 regions and calculations are done for each region separately. Also, for the insulated building, the annual heating energy requirement is calculated for each insulation thickness and as a result, annual energy savings (kWh/year) for each insulation application is determined.

The LCCA is done for insulation applications for the representative existing building in Turkey. The initial, or the capital cost is the cost of insulation application. It is obtained by taking offers from companies and taking the average of them. The operational cost is the annual heating energy requirement of the building. After insulation application, the annual heating energy requirement will decrease. As a result, annual savings will occur due to the decreases in the operational costs.

In this study, the LCCA is done considering the initial costs of the insulations and the annual savings due to the decreases in the operational costs. Annual savings occur over a certain period, which is assumed as 20 years. After determining the savings for each year, the cash flow diagram is drawn. The savings are discounted back to present with an appropriate discount rate in order to find net savings (NS), internal rate of return (IRR), savings-to-investment ratio (SIR) and payback period (PBP).

3.2. Energy Efficiency of the Representative Building

The representative building is an existing, uninsulated building. The constructional elements of the surfaces of the uninsulated building are detailed in Table 3.1:

Table 3.1 Building Elements of Surfaces in Uninsulated Building.

Surface Losing Heat	**Building Elements**	**Area**
Outer, Infilled Wall	Inner plaster (2cm) + Brick (19cm) + Outer Plaster (3cm)	680 m^2
Outer, Reinforced Concrete Wall	Inner plaster (2cm) + Reinforced Concrete (25cm) + Outer Plaster (3cm)	535 m^2
Ceiling with Roof	Inner plaster (2cm) + Reinforced Concrete (12cm)	500 m^2
Basement in Contact with Soil	Timber Flooring (1cm) + Screed (5cm) + Reinforced Concrete (15cm) + Lean Concrete (10cm) + Crushed Stone (20cm)	500 m^2
Outer Doors	-	5 m^2
Windows	-	130 m^2

Insulation is applied on the uninsulated building as detailed in Table 3.1. Stone wool having thickness of 15cm is applied on the ceiling and insulation material with various thicknesses is applied on the outer walls. The constructional elements of the surfaces of the insulated building are detailed in Table 3.2:

Table 3.2. Building Elements of Surfaces in Insulated Building.

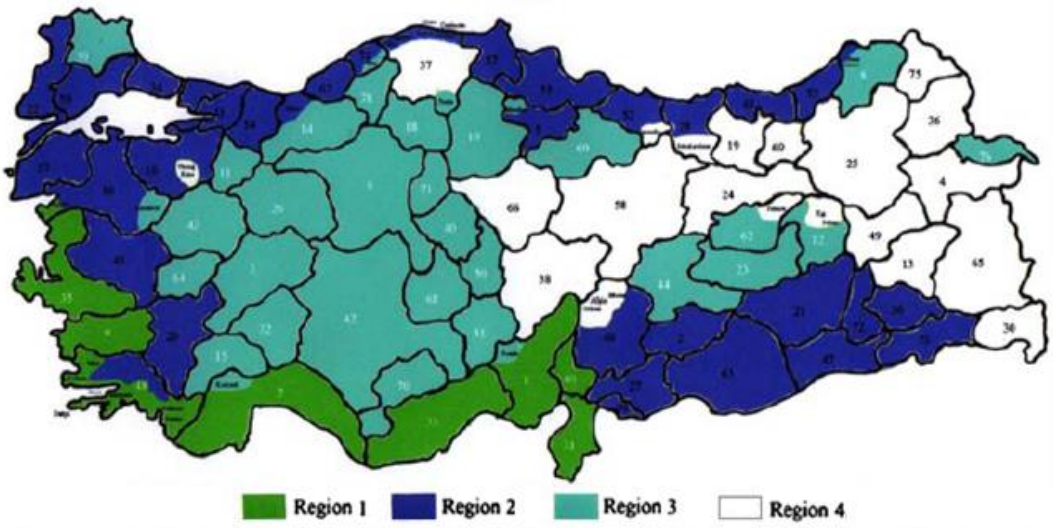
Surface Losing Heat	**Building Elements**	**Area**
Outer, Infilled Wall	Inner plaster (2cm) + Brick (19cm) + Outer Plaster (3cm) + **Insulation Material (x.cm)** + **Outer Plaster (0.8cm)**	680 m^2
Outer, Reinforced Concrete Wall	Inner plaster (2cm) + Reinforced Concrete (25cm) + Outer Plaster (3cm) + **Insulation Material (x.cm)** + **Outer Plaster (0.8cm)**	535 m^2
Ceiling with Roof	Inner plaster (2cm) + Reinforced Concrete (12cm) + **Stone Wool (15cm)**	500 m^2
Basement in Contact with Soil	Timber Flooring (1cm) + Screed (5cm) + Reinforced Concrete (15cm) + Lean Concrete (10cm) + Crushed Stone (20cm)	500 m^2
Outer Doors	-	5 m^2
Windows	-	130 m^2

The insulation material applied on the outer walls is expanded polystyrene (EPS) having thermal conductivity of 0.035 W/mK. The thickness of the EPS changes from 2 cm to 20 cm. The insulation material applied on the ceiling is stone wool having thermal conductivity of 0.035 W/mK. The thickness of the stone wool is kept constant (15 cm) for

all insulation applications. The only variable is the thickness of the EPS on the outer walls. The heating energy requirement calculations and the analysis are made for each thickness separately.

3.3. Thermal Insulation Requirements for Buildings (Turkish Standard 825)

TS 825 is the standard made by Turkish Standards Institute (TSI) to calculate the heating energies and to determine the maximum heating energies for buildings in Turkey. Insulation applications on new and existing buildings in Turkey have to satisfy the requirements stated in TS 825. In this study, the annual heating energy requirement is calculated according to Turkish Standard 825 (TSI, 2008). In TS 825, Turkey is divided into four regions according to the climate conditions as the average outdoor temperature values affect the heating energies. Regions of Turkey are shown in Figure 3.2:



01- ADANA	10- BALIKESİR	19- ÇORUM	28- GİRESUN	37- KASTAMONU	46- K.MARAŞ	55- SAMSUN	64- UŞAK	73- ŞIRNAK
02- ADIYAMAN	11- BİLECİK	20- DENİZLİ	29- GÜMÜŞHANE	38- KAYSERİ	47- MARDİN	56- SİİRT	65- VAN	74- BARTIN
03- AFYON	12- BİNGÖL	21- DİYARBAKIR	30- HAKKARİ	39- KIRKLARELİ	48- MUĞLA	57- SİNOP	66- YOZGAT	75- ARDAHAN
04- AĞRI	13- BİTLİS	22- EDİRNE	31- HATAY	40- KIRŞEHİR	49- MUŞ	58- SİVAS	67- ZONGULDAK	76- IĞDIR
05- AMASYA	14- BOLU	23- ELAZIĞ	32- ISPARTA	41- KOCAELİ	50- NEVŞEHİR	59- TEKİRDAĞ	68- AKSARAY	77- YALOVA
06- ANKARA	15- BURDUR	24- ERZİNCAN	33- İÇEL	42- KONYA	51- NİĞDE	60- TOKAT	69- BAYBURT	78- KARABÜK
07- ANTALYA	16- BURSA	25- ERZURUM	34- İSTANBUL	43- KÜTAHYA	52- ORDU	61- TRABZON	70- KARAMAN	79- KİLİS
08- ARTVİN	17- ÇANAKKALE	26- ESKİŞEHİR	35- İZMİR	44- MALATYA	53- RİZE	62- TUNCELİ	71- KIRIKKALE	80- OSMANİYE
09- AYDIN	18- ÇANKIRI	27- GAZİANTEP	36- KARS	45- MANİSA	54- SAKARYA	63- ŞANLIURFA	72- BATMAN	81- DÜZCE

Figure 3.2. Regions of Turkey According to TS 825 (TSI, 2008).

3.3.1. Calculation of Thermal Resistance

For single-layered construction components, thermal resistance (R) is calculated as follows:

$$R = \frac{d}{\lambda_h} \tag{3.1}$$

Where R is the thermal resistance (m^2.K/W), d is the thickness of the construction component (m) and λ_h is the thermal conductivity (W/m.K).

For multi-layered construction components having thicknesses (d_1, d_2….d_n) and thermal conductivities (λ_{h1}, λ_{h2}….λ_{hn}), thermal resistance (R) is calculated as follows:

$$R = \frac{d_1}{\lambda_{h1}} + \frac{d_2}{\lambda_{h2}} + \ldots\ldots + \frac{d_n}{\lambda_{hn}} \tag{3.2}$$

3.3.2. Calculation of Wall Conductance

The wall conductance (U) is calculated as follows:

$$U = \frac{1}{R_{in}+R+R_{out}} \tag{3.3}$$

Where R_{in} is the inside air film thermal resistance (m^2.K/W) and R_{out} is the outside air film thermal resistance (m^2.K/W).

3.3.3. Calculation of Annual Heating Energy Requirement

The annual heating energy requirement is calculated as follows:

$$Q_{year} = \Sigma Q_m \tag{3.4}$$

$$Q_m = [H.(\theta_{in}-\theta_{out})-\eta.(\phi_{in}+\phi_s)].t \tag{3.5}$$

Where Q_{year} is the annual heating energy requirement (Joule), Q_m is the monthly heating energy requirement (Joule), H is the specific heat loss of the building (W/K), θ_{in} is the monthly average indoor temperature (^oC), θ_{out} is the monthly average outdoor temperature (^oC), η is the average usage factor of heat gain, ϕ_{in} is the average interior heat gain (W), ϕ_s is the average solar energy gain (W) and t is the time (s).

After Q_{year} is found, it is divided with the efficiency of the heating system (η_b) to find the resultant energy requirement. In this study, the efficiency of the heating system is assumed as 90%.

The monthly average outdoor temperature values (^oC) are taken from Table 3.3 to use in heat loss calculations.

Table 3.3. Monthly Average Outdoor Temperature Values (^oC) (TSI, 2008).

Region / month	Region 1	Region 2	Region 3	Region 4
January	8.4	2.9	-0.3	-5.4
February	9.0	4.4	0.1	-4.7
March	11.6	7.3	4.1	0.3
April	15.8	12.8	10.1	7.9
May	21.2	18.0	14.4	12.8
June	26.3	22.5	18.5	17.3
July	28.7	24.9	21.7	21.4
August	27.6	24.3	21.2	21.1
September	23.5	19.9	17.2	16.5
October	18.5	14.1	11.6	10.3
November	13.0	8.5	5.6	3.1
December	9.3	3.8	1.3	-2.8

3.3.4. Calculation of Specific Heat Loss of a Building

Specific heat loss (SHL) of a building is equal to the sum of heat loss occurred in consequence of conduction and convection (H_{tr}) and heat loss occurred in consequence of ventilation (H_{ven}).

$$H = H_{tr} + H_{ven} \tag{3.6}$$

Heat loss occurred in consequence of conduction and convection (H_{tr}) is calculated as in the equation below:

$$\Sigma AU = U_{ew}A_{ew} + U_{gl}A_{gl} + U_{ed}A_{ed} + 0.8\ U_{ce}A_{ce} + 0.5\ U_{fl}A_{fl} \quad (3.7)$$

Where U_{ew} is the heat transfer coefficient of the external wall (W/m^2K), U_{gl} is the heat transfer coefficient of the glazing (W/m^2K), U_{ed} is the heat transfer coefficient of the external door (W/m^2K), U_{ce} is the heat transfer coefficient of the ceiling (W/m^2K), U_{fl} is the heat transfer coefficient of the floor (W/m^2K), A_{ew} is the area of the external wall (m^2), A_{gl} is the area of the glazing (m^2), A_{ed} is the area of the external door (m^2), A_{ce} is the area of ceiling (m^2) and A_{fl} is the area of floor (m^2).

Heat loss occurred in consequence of ventilation (H_{ven}) is calculated as follows:

$$H_{ven} = 0.264 \times n_a \times V_{gross} \quad (3.8)$$

Where n_a is the air changing ratio (h^{-1}), taken as 0.8 for natural ventilation and V_{gross} is the gross heated volume of the building (m^3).

3.3.5. Average Interior Heat Gain (ϕ_{in})

The monthly average interior heat gain (ϕ_{in}) includes the followings:

- Metabolic heat gains arising from the humans,
- Heat gains arising from the hot water system,
- Heat gains arising from the cooking operations,
- Heat gains arising from the lightening system,
- Heat gains arising from the various devices in the buildings.

The monthly average interior heat gain is calculated as follows:

In the residences, schools and normally equipped buildings;

$$\phi_{in} \leq 5 \text{ x } A_n \text{ (W)} \quad (3.9)$$

In buildings with high interior energy gains;

$$\phi_{in} \leq 10 \text{ x } A_n \text{ (W)} \quad (3.10)$$

Where A_n is the building usage area (m^2).

A_n is calculated as follows:

$$A_n = 0.32 \text{ x } V_{gross} \quad (3.11)$$

Where V_{gross} is the gross heated volume of the building (m^3).

3.3.6. Average Solar Energy Gain (ϕ_s)

The monthly average solar energy gain (ϕ_s) is calculated as follows:

$$\phi_{s,j} = \sum_k r_j . g_j . I_{j,k} . A_{gl,k} \quad (3.12)$$

Where r is the monthly average shading factor of the transparent surfaces, g is the solar energy permeation factor of the transparent elements, I is the monthly average solar radiation intensity and $A_{gl,k}$ is the total glazing area in direction k.

In this study, r is taken as 0.8 because the building is considered to be detached.

The monthly average solar radiation intensity values are given in Table 3.4:

Table 3.4. Values of Average Monthly Solar Radiation Intensity (W/m^2) (TSI, 2008).

Solar radiation	January	February	March	April	May	June	July	August	September	October	November	December
I_{south}	72	84	87	90	92	95	93	93	89	82	67	64
I_{north}	26	37	52	66	79	83	81	73	57	40	27	22
$I_{east/west}$	43	57	77	90	114	122	118	106	81	59	41	37

Solar energy permeation factor (g) is calculated as follows:

$$g_j = F_w \, . \, g_{\perp} \tag{3.13}$$

Where F_w is the correction factor for windows, which is 0.8 and $g_{\perp}$ is the solar energy permeation factor measured under laboratory conditions for the rays striking the surface vertically, taken as 0.75 for colourless glass.

3.3.7. Average Usage Factor of Heat Gain (η)

Monthly average usage factor of heat gain is calculated as follows:

$$\eta = 1 - e^{(-1/GLR)} \tag{3.14}$$

Where GLR is the gain/loss ratio, which is calculated as follows:

$$GLR = (\phi_{in} + \phi_s) / H\,(\theta_{in} - \theta_{out}) \tag{3.15}$$

When GLR is inserted in Equation 3.14, η becomes:

$$\eta = 1 - e^{\left(\frac{H(\theta_{out}-\theta_{in})}{(\phi_{in}+\phi_s)}\right)} \tag{3.16}$$

Where θ_{in} is the monthly average indoor temperature (^oC), θ_{out} is the monthly average outdoor temperature (^oC), ϕ_{in} is the monthly average interior heat gain (W) and ϕ_s is the monthly average solar energy gain (W).

If GLR is equal to or more than 2.5, it is assumed that no heat loss occurs for that month.

3.4. The Results

In TS 825 (TSI, 2008), it is written that "*when substantial repair, amendment and additions are made to the whole or independent sections of the existing buildings, the limit heat transfer coefficient values should be observed in terms of providing the values equal*

or smaller than these for the section in which applications are made". The limit values are shown in Table 3.5:

Table 3.5. The Limit Values in TS 825 for Existing Buildings (TSI, 2008).

Region	U_{ew} (W/m^2K)	U_{ce} (W/m^2K)	U_{fl} (W/m^2K)	U_{gl} (W/m^2K)
Region 1	0.70	0.45	0.70	2.4
Region 2	0.60	0.40	0.60	2.4
Region 3	0.50	0.30	0.45	2.4
Region 4	0.40	0.25	0.40	2.4

In this study, applications are made to the ceiling and outer walls. The ceiling is insulated with stone wool having a thickness of 15 cm. The resultant conductance is 0.219. The value is less than the required value for all the regions as shown in the column U_{ce}.

The outer walls are insulated with expanded polystyrene (EPS) with various thicknesses. The resultant heat transfer coefficient values must be below the values stated in the column U_{ew}. The resultant heat transfer coefficient values are shown in the Table 3.6.

It is concluded that the minimum thickness of the insulation material (EPS) on the outer walls is:

- 4 cm in the Region 1,
- 5 cm in the Region 2,
- 6 cm in the Region 3,
- 8 cm in the Region 4.

Table 3.6. Heat Transfer Coefficient Values of Insulation Applications.

U_{ew} values (W/m^2K)		Region 1 U_{ew}'=0.70	Region 2 U_{ew}'=0.60	Region 3 U_{ew}'=0.50	Region 4 U_{ew}'=0.40
Insulation Thickness (cm)	None	3.24	3.24	3.24	3.24
	2	1.11	1.11	1.11	1.11
	3	0.84	0.84	0.84	0.84
	4	0.68	0.68	0.68	0.68
	5	0.57	0.57	0.57	0.57
	6	0.49	0.49	0.49	0.49
	7	0.43	0.43	0.43	0.43
	8	0.38	0.38	0.38	0.38
	9	0.34	0.34	0.34	0.34
	10	0.31	0.31	0.31	0.31
	11	0.29	0.29	0.29	0.29
	12	0.27	0.27	0.27	0.27
	13	0.25	0.25	0.25	0.25
	14	0.23	0.23	0.23	0.23
	15	0.22	0.22	0.22	0.22
	16	0.20	0.20	0.20	0.20
	17	0.19	0.19	0.19	0.19
	18	0.18	0.18	0.18	0.18
	19	0.17	0.17	0.17	0.17
	20	0.17	0.17	0.17	0.17

The shaded values in Table 3.4 indicate that these insulation thicknesses satisfy the minimum condition stated in TS 825 (TSI, 2008) and thus, they can be alternative insulation options. Thicknesses less than the minimum values are the non-shaded ones. These do not satisfy the minimum requirements and cannot be regarded as alternatives.

The calculations are done according to TS 825 (TSI, 2008). For the uninsulated and insulated buildings with various thicknesses, the annual energy requirements are summarized in Table 3.7:

Table 3.7. Annual Energy Requirements.

Annual Energy Requirements (kWh/year)		Region 1	Region 2	Region 3	Region 4
Insulation Thickness (cm)	None	160,409	300,178	413,385	536,711
	2	65,981	132,285	185,948	248,636
	3	58,874	119,090	168,031	225,617
	4	54,424	110,759	156,684	210,997
	5	51,377	105,016	148,845	200,877
	6	49,158	100,818	143,104	193,452
	7	47,472	97,614	138,717	187,771
	8	46,146	95,088	135,255	183,284
	9	45,077	93,046	132,453	179,649
	10	44,196	91,361	130,140	176,645
	11	43,458	89,947	128,197	173,266
	12	42,831	88,744	126,542	171,130
	13	42,291	87,707	125,116	169,287
	14	41,822	86,804	123,874	167,681
	15	41,410	86,011	122,783	166,270
	16	41,046	85,309	121,816	165,020
	17	40,722	84,683	120,954	163,904
	18	40,431	84,122	120,181	162,903
	19	40,168	83,616	119,483	161,999
	20	39,931	83,156	118,850	161,179

It is shown in Table 3.7 that a great amount of decreases in annual energy requirements occur as a result of insulation. The annual energy requirement values decrease about 60-70% with the application of insulation with the minimum allowable thicknesses. However, it is possible to decrease annual energy requirements even more by applying insulation materials with higher thicknesses. The graphical representation of annual energy requirements for each region is shown in Figure 3.3:

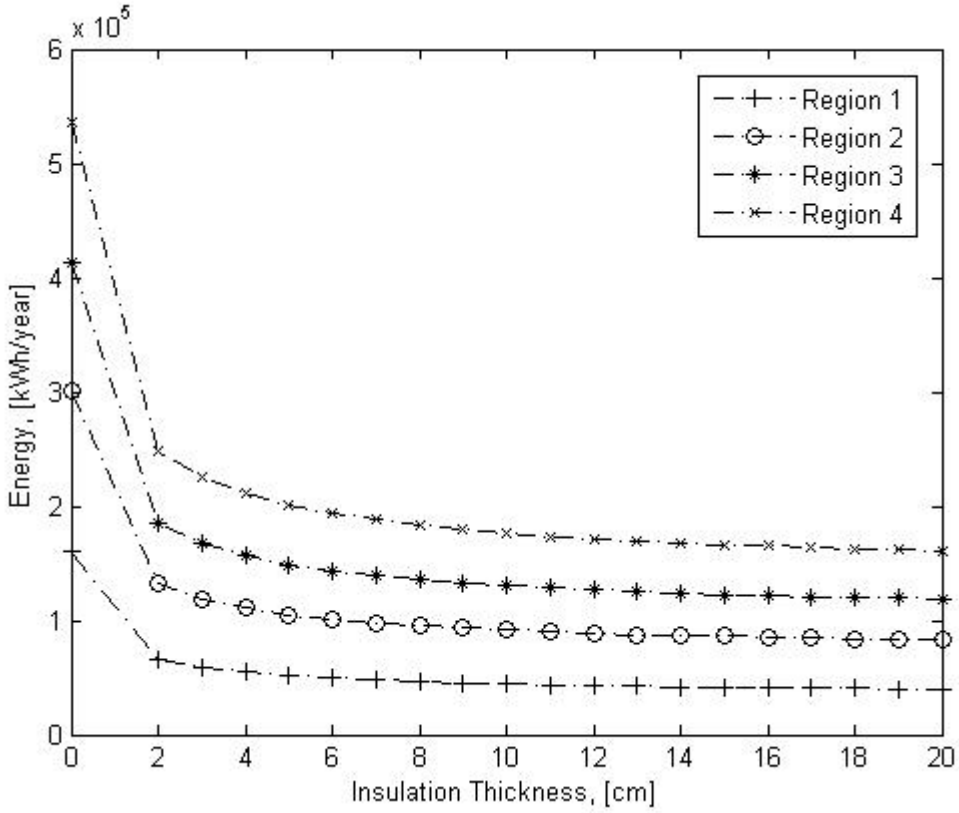


Figure 3.3. Annual Energy Requirements.

The annual energy savings as a result of insulation applications are shown in Table 3.8 and Figure 3.4. It can be seen that applying a thicker insulation material than the minimum possible thickness can increase the energy saving amount up to 15%.

Table 3.8. Annual Energy Savings.

Annual Energy Savings (kWh/year)		Region 1	Region 2	Region 3	Region 4
Insulation Thickness (cm)	None	0	0	0	0
	2	94,428	167,893	227,437	288,075
	3	101,535	181,088	245,354	311,094
	4	105,985	189,419	256,701	325,714
	5	109,032	195,162	264,540	335,834
	6	111,251	199,360	270,281	343,259
	7	112,937	202,564	274,668	348,940
	8	114,263	205,090	278,130	353,427
	9	115,332	207,132	280,932	357,062
	10	116,213	208,817	283,245	360,066
	11	116,951	210,231	285,188	363,445
	12	117,578	211,434	286,843	365,581
	13	118,118	212,471	288,269	367,424
	14	118,587	213,374	289,511	369,030
	15	118,999	214,167	290,602	370,441
	16	119,363	214,869	291,569	371,691
	17	119,687	215,495	292,431	372,807
	18	119,978	216,056	293,204	373,808
	19	120,241	216,562	293,902	374,712
	20	120,478	217,022	294,535	375,532

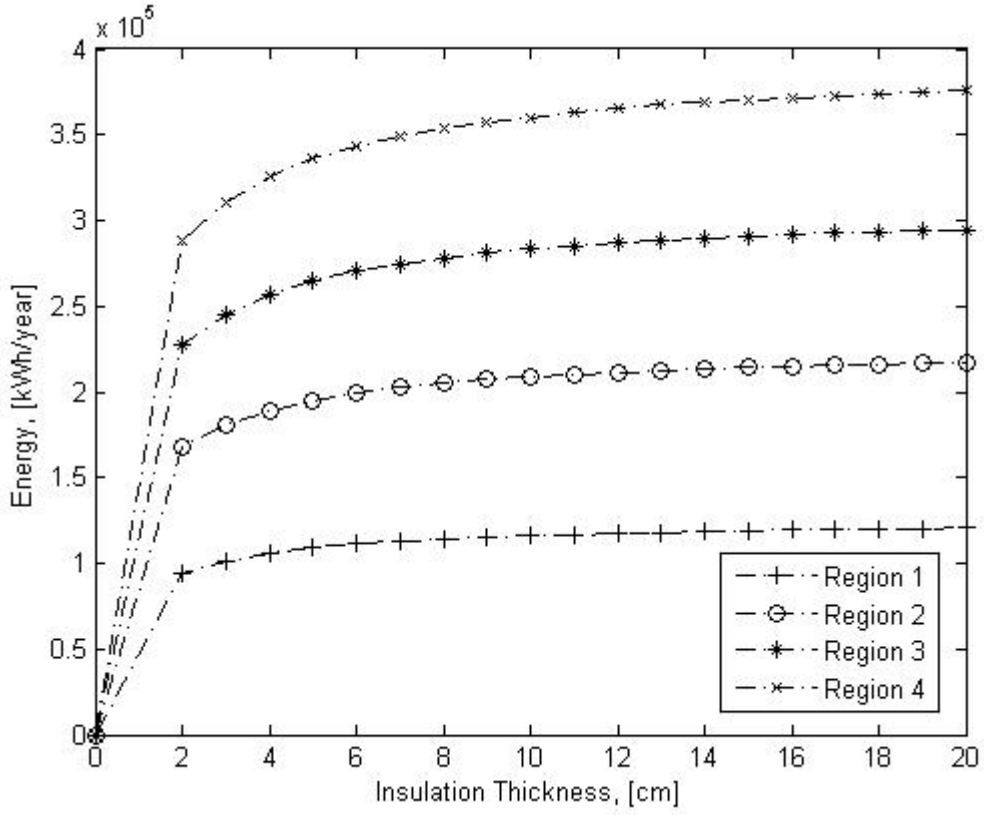


Figure 3.4. Annual Energy Savings.

3.5. Economic Evaluations

The LCC approach considers the total costs of items during the entire life. It considers initial costs, operation and maintenance costs, renewal costs and disposal costs. Regarding this approach, insulation application has an initial cost and operational savings. The initial cost is the sum of material and application cost. It occurs only one time when the insulation is first applied.

The operational savings occur as a result of the decrease in annual energy requirements of the building. The operational savings occur each year until the end of its life. These costs and savings must be analyzed in order to understand the investment value of insulation applications.

3.5.1. Cost of Insulation

The cost of insulation is determined by taking offers from two companies. The offers are taken in the same format so that they can be compared and their averages can be taken in order to determine the cost of insulation. The offers from two companies are shown in Table 3.9 and Table 3.10:

Table 3.9. Offer from Company A.

EPS Insulation Thickness	Material Cost (TL/m^2)	Auxiliary Items Cost (TL/m^2)	Application Cost (TL/m^2)	Total Unit Cost (TL/m^2)
2 cm	2.00	7.74	20.00	29.74
3 cm	3.50	7.74	20.00	31.24
4 cm	5.00	7.74	20.00	32.74
5 cm	6.50	8.00	20.00	34.50
6 cm	8.00	8.00	20.00	36.00
7 cm	9.50	8.04	20.00	37.54
8 cm	11.00	8.04	20.00	39.04
9 cm	12.50	8.08	20.00	40.58
10 cm	14.00	8.08	20.00	42.08
11 cm	15.50	9.40	20.00	44.90
12 cm	17.00	9.40	20.00	46.40
13 cm	18.50	9.64	20.00	48.14
14 cm	20.00	9.64	20.00	49.64
15 cm	21.50	9.88	20.00	51.38
16 cm	23.00	9.88	20.00	52.88
17 cm	24.50	10.12	20.00	54.62
18 cm	26.00	10.12	20.00	56.12
19 cm	27.50	10.36	20.00	57.86
20 cm	29.00	10.36	20.00	59.36
Stone Wool Insulation Thickness	Material Cost (TL/m^2)	Auxiliary Items Cost (TL/m^2)	Application Cost (TL/m^2)	Total Unit Cost (TL/m^2)
15 cm	28.50	10.70	29.30	68.50

Table 3.10. Offer from Company B.

EPS Insulation Thickness	Material Cost (TL/m^2)	Auxiliary Items Cost (TL/m^2)	Application Cost (TL/m^2)	Total Unit Cost (TL/m^2)
2 cm	2.56	9.26	18.50	30.32
3 cm	3.84	9.26	18.50	31.60
4 cm	5.12	9.26	18.50	32.88
5 cm	6.40	9.40	18.50	34.30
6 cm	7.68	9.40	18.50	35.58
7 cm	8.96	9.64	19.00	37.60
8 cm	10.24	9.64	19.50	39.38
9 cm	11.52	9.90	19.50	40.92
10 cm	12.80	9.90	19.50	42.20
11 cm	14.52	9.90	20.00	44.42
12 cm	15.84	10.20	20.00	46.04
13 cm	17.16	10.20	20.00	47.36
14 cm	18.48	10.20	21.00	49.68
15 cm	19.80	10.50	21.00	51.30
16 cm	21.60	10.50	21.00	53.10
17 cm	22.61	10.50	22.00	55.11
18 cm	23.94	10.90	22.00	56.84
19 cm	25.27	10.90	23.00	59.17
20 cm	26.60	10.90	23.00	60.50
Stone Wool Insulation Thickness	Material Cost (TL/m^2)	Auxiliary Items Cost (TL/m^2)	Application Cost (TL/m^2)	Total Unit Cost (TL/m^2)
15 cm	36.50	12.20	21.00	69.70

The cost of insulation was found by taking the average of the two offers and adding the taxes, which is the value added tax (VAT).

Table 3.11. The Total Cost of Insulation Applications (VAT included).

EPS Insulation Thickness	Material Cost (TL/m^2)	Auxiliary Items Cost (TL/m^2)	Application Cost (TL/m^2)	Total Unit Cost (TL/m^2)	Total Cost (TL)
2 cm	2.69	10.03	22.72	35.44	43,054.01
3 cm	4.33	10.03	22.72	37.08	45,046.85
4 cm	5.97	10.03	22.72	38.72	47,039.70
5 cm	7.61	10.27	22.72	40.59	49,319.28
6 cm	9.25	10.27	22.72	42.23	51,312.12
7 cm	10.89	10.43	23.01	44.33	53,865.54
8 cm	12.53	10.43	23.31	46.27	56,216.81
9 cm	14.17	10.61	23.31	48.09	58,426.14
10 cm	15.81	10.61	23.31	49.73	60,418.99
11 cm	17.71	11.39	23.60	52.70	64,031.91
12 cm	19.38	11.57	23.60	54.54	66,268.48
13 cm	21.04	11.71	23.60	56.35	68,462.04
14 cm	22.70	11.71	24.19	58.60	71,200.41
15 cm	24.37	12.03	24.19	60.58	73,609.03
16 cm	26.31	12.03	24.19	62.53	75,974.63
17 cm	27.79	12.17	24.78	64.74	78,662.82
18 cm	29.46	12.40	24.78	66.65	80,978.24
19 cm	31.13	12.55	25.37	69.05	83,895.82
20 cm	32.80	12.55	25.37	70.72	85,924.51
Stone Wool Insulation Thickness	Material Cost (TL/m^2)	Auxiliary Items Cost (TL/m^2)	Application Cost (TL/m^2)	Total Unit Cost (TL/m^2)	Total Cost (TL)
15 cm	38.35	13.51	29.68	81.54	40,769.00

An insulation application option has the cost of the stone wool, which is applied on the ceiling at a thickness of 15 cm, and the cost of EPS, which is applied on the outer walls at varying thicknesses. So, the cost of an insulation application is found by summing the two.

3.5.2. Operational Savings

Operational savings occur as a result of the decrease in the annual energy requirements of the building. These savings continue until the end of building life. In this study, it is assumed that the savings will occur over 20 years. The economic analyses are done accordingly.

The most important factor that determines the annual operational savings is the cost of natural gas. Historical data is taken from the official site of IGDAS. The cost of natural gas in the past 5 years is summarized in Table 3.12:

Table 3.12. Natural Gas Prices for the Last 5 Years (IGDAS, 2014).

Date	Cost of Natural Gas (TL/kWh)
01.08.2010	0.058605
01.08.2011	0.059511
01.08.2012	0.078213
01.08.2013	0.086292
01.08.2014	0.087363

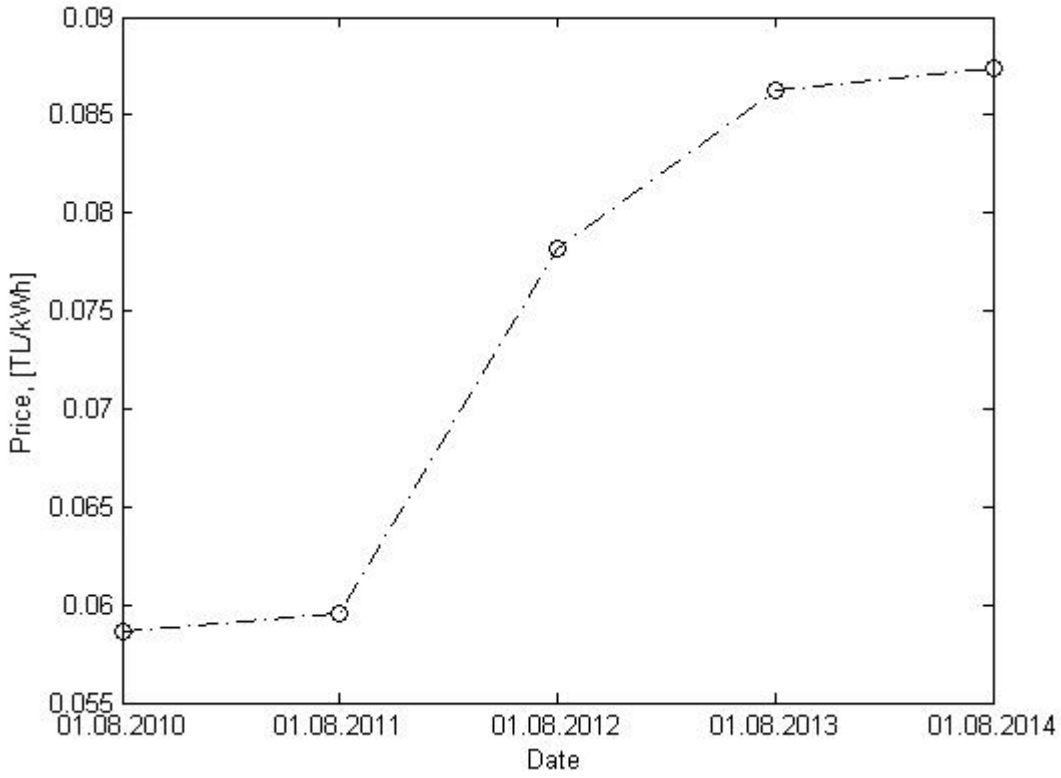


Figure 3.5. Cost of Natural Gas for the Last 5 Years.

It can be seen in Table 3.12 that the price of the natural gas has increased from 0.058605 TL/kWh to 0.087363 TL/kWh in 4 years. The increase is about 49%, which corresponds to an average increase of approximately 10.5% per year.

3.5.3. Cash Flow Diagram

Cash flow diagram is generated using the initial cost and the operational savings over 20 years. The initial cost is the cost of insulation, which is calculated by adding the cost of 15 cm stone wool insulation on the ceiling to the cost of EPS insulation at various thicknesses on the outer walls.

The operational savings are the savings resulted from the decrease in annual energy requirements of the building. An operational saving in one year is found by multiplying the annual energy saving amount (kWh), which is determined by the insulation thickness and

the region, with the average natural gas price in this year, which is the average of the natural gas prices (TL/kWh) in the beginning and in the end of the corresponding year.

The natural gas prices in the future are determined by the following formula:

$$\text{Energy Price (n)} = 0.087363 \text{ TL/kWh} \times (1+\text{VAT}) \times (1+ e)^n \quad (3.17)$$

Where Energy Price (n) is the natural gas price in the year n (TL/kWh), VAT is the value added tax, which is 18%, e is the escalation rate of natural gas price and n is the year. For example in 2017, n is equal to 2017-2014 = 3.

Here, the 0.087363 TL/kWh is the natural gas price in the base year, 2014. 2014 is considered as the beginning year, 0. “n” is an integer value varying between 0 and 20.

So, the operational saving in year “n” can be formulated as follows:

$$\text{Operational Saving (n)} = \text{Annual Energy Saving} \times \frac{\text{EnergyPrice(n}-1)+\text{EnergyPrice(n)}}{2} \quad (3.18)$$

4. RESEARCH FINDINGS AND DISCUSSION

4.1. Research Findings

The cash flow diagram is generated in order to find net savings (NS), internal rate of return (IRR), savings-to-investments ratio (SIR) and payback period (PBP) for each insulation option. Each insulation option includes 15 cm stone wool insulation on the ceilings and EPS insulation on the outer walls at varying thicknesses.

The minimum thickness of EPS that can be applied on the outer walls is:

- 4 cm in the Region 1,
- 5 cm in the Region 2,
- 6 cm in the Region 3,
- 8 cm in the Region 4.

So, the options with smaller EPS thicknesses are not considered as investment options.

The net savings (NS), internal rate of return (IRR), savings-to-investments ratio (SIR) and payback period (PBP) are calculated for all possible options in each region. Then, the option having the highest net savings value is considered as the optimized option.

There are two variables in the cash flow diagram. These are:

- The escalation rate,
- The discount rate.

Due to the changes of those rates, more than one value is assigned to each of them and optimized thicknesses are found for each combination. The values assigned to each of them are as follows:

- The discount rate: 7%, 9%, and 11%,
- The escalation rate: 7%, 8.5%, 10% and 12%.

The resultant combinations are shown in Table 4.1:

Table 4.1. Combinations of the Discount Rate and the Escalation Rate.

Combination No	Discount Rate	Escalation Rate
1	7%	7%
2	7%	8.5%
3	7%	10%
4	7%	12%
5	9%	7%
6	9%	8.5%
7	9%	10%
8	9%	12%
9	11%	7%
10	11%	8.5%
11	11%	10%
12	11%	12%

The insulation option with the highest net savings value is regarded as the optimum option. To illustrate, the net savings in the Region 3 are shown in Figure 4.1:

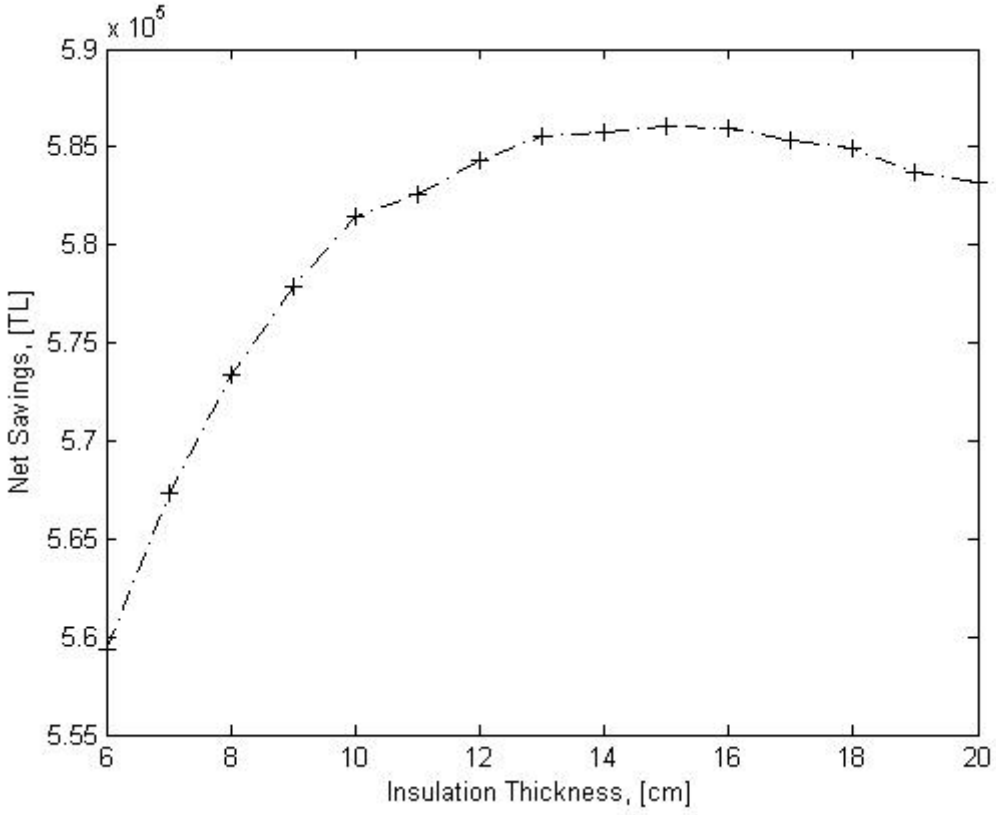


Figure 4.1. NS values in the Region 3 for Discount Rate 9%, Escalation Rate 10%.

The following tables show the optimum thicknesses for each combination:

Table 4.2. Optimized Insulation Thicknesses for Combination 1.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 9 cm	156,371 TL	19.19%	2.58	7-8 years
Region 2, 13 cm	361,587 TL	29.56%	4.31	4-5 years
Region 3, 15 cm	529,572 TL	36.90%	5.63	3-4 years
Region 4, 16 cm	706,893 TL	44.65%	7.06	2-3 years

Table 4.3. Optimized Insulation Thicknesses for Combination 2.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 10 cm	195,827 TL	20.54%	2.94	7-8 years
Region 2, 13 cm	433,799 TL	31.21%	4.97	4-5 years
Region 3, 16 cm	628,444 TL	38.08%	6.38	3-4 years
Region 4, 18 cm	833,626 TL	45.05%	7.85	2-3 years

Table 4.4. Optimized Insulation Thicknesses for Combination 3.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 10 cm	242,883 TL	22.10%	3.40	7-8 years
Region 2, 13 cm	519,831 TL	32.86%	5.76	4-5 years
Region 3, 16 cm	746,503 TL	39.79%	7.39	3-4 years
Region 4, 20 cm	985,142 TL	45.52%	8.78	2-3 years

Table 4.5. Optimized Insulation Thicknesses for Combination 4.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 10 cm	320,077 TL	24.17%	4.16	6-7 years
Region 2, 16 cm	662,143 TL	33.70%	6.67	4-5 years
Region 3, 18 cm	941,098 TL	40.95%	8.73	3-4 years
Region 4, 20 cm	1,234,586 TL	47.85%	10.74	2-3 years

Table 4.6. Optimized Insulation Thicknesses for Combination 5.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 8 cm	112,659 TL	19.41%	2.16	8-9 years
Region 2, 10 cm	281,940 TL	31.04%	3.79	4-5 years
Region 3, 13 cm	419,672 TL	38.10%	4.84	3-4 years
Region 4, 15 cm	565,291 TL	45.31%	5.94	2-3 years

Table 4.7. Optimized Insulation Thicknesses for Combination 6.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 9 cm	142,785 TL	20.75%	2.44	7-8 years
Region 2, 10 cm	336,935 TL	32.70%	4.33	4-5 years
Region 3, 13 cm	495,591 TL	39.82%	5.54	3-4 years
Region 4, 16 cm	663,108 TL	46.42%	6.68	2-3 years

Table 4.8. Optimized Insulation Thicknesses for Combination 7.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 10 cm	178,901 TL	22.10%	2.77	7-8 years
Region 2, 13 cm	402,852 TL	32.86%	4.69	4-5 years
Region 3, 15 cm	586,011 TL	40.32%	6.12	3-4 years
Region 4, 18 cm	779,179 TL	46.81%	7.40	2-3 years

Table 4.9. Optimized Insulation Thicknesses for Combination 8.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 10 cm	238,015 TL	24.17%	3.35	7-8 years
Region 2, 13 cm	510,931 TL	35.06%	5.68	4-5 years
Region 3, 16 cm	734,290 TL	42.06%	7.29	3-4 years
Region 4, 20 cm	969,412 TL	47.85%	8.65	2-3 years

Table 4.10. Optimized Insulation Thicknesses for Combination 9.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 7 cm	79,430 TL	19.63%	1.84	9-10 years
Region 2, 10 cm	220,652 TL	31.04%	3.18	4-5 years
Region 3, 10 cm	335,364 TL	40.03%	4.31	3-4 years
Region 4, 13 cm	457,062 TL	46.81%	5.18	2-3 years

Table 4.11. Optimized Insulation Thicknesses for Combination 10.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 7 cm	102,763 TL	21.19%	2.09	8-9 years
Region 2, 10 cm	263,793 TL	32.70%	3.61	4-5 years
Region 3, 13 cm	394,620 TL	39.82%	4.61	3-4 years
Region 4, 15 cm	533,098 TL	47.09%	5.66	2-3 years

Table 4.12. Optimized Insulation Thicknesses for Combination 11.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 8 cm	130,536 TL	22.53%	2.35	8-9 years
Region 2, 10 cm	314,610 TL	34.37%	4.11	4-5 years
Region 3, 13 cm	464,773 TL	41.53%	5.25	3-4 years
Region 4, 16 cm	623,371 TL	48.19%	6.34	2-3 years

Table 4.13. Optimized Insulation Thicknesses for Combination 12.

Option	Net Savings	IRR	SIR	Pay Back Period
Region 1, 10 cm	176,028 TL	24.17%	2.74	7-8 years
Region 2, 13 cm	397,600 TL	35.06%	4.64	4-5 years
Region 3, 15 cm	578,828 TL	42.60%	6.06	3-4 years
Region 4, 18 cm	769,939 TL	49.16%	7.32	2-3 years

The optimized insulation thicknesses for each region of Turkey and for each combination are summarized in Table 4.14:

Table 4.14. Optimum Insulation Thicknesses for All Combinations.

Combination No	Discount Rate	Escalation Rate	Region 1	Region 2	Region 3	Region 4
1	7%	7%	9 cm	13 cm	15 cm	16 cm
2	7%	8.5%	10 cm	13 cm	16 cm	18 cm
3	7%	10%	10 cm	13 cm	16 cm	20 cm
4	7%	12%	10 cm	16 cm	18 cm	20 cm
5	9%	7%	8 cm	10 cm	13 cm	15 cm
6	9%	8.5%	9 cm	10 cm	13 cm	16 cm
7	9%	10%	10 cm	13 cm	15 cm	18 cm
8	9%	12%	10 cm	13 cm	16 cm	20 cm
9	11%	7%	7 cm	10 cm	10 cm	13 cm
10	11%	8.5%	7 cm	10 cm	13 cm	15 cm
11	11%	10%	8 cm	10 cm	13 cm	16 cm
12	11%	12%	10 cm	13 cm	15 cm	18 cm

The optimum insulation thickness intervals for each region and the corresponding optimum U_{ew} value intervals are shown in Table 4.15:

Table 4.15. Corresponding U_{ew} Values for the Optimized Thicknesses.

Option	Optimized Thicknesses	Corresponding U_{ew} values (W/m^2K)
Region 1	7-10 cm	0.314 – 0.429
Region 2	10-16 cm	0.204 – 0.314
Region 3	10-18 cm	0.183 – 0.314
Region 4	13-20 cm	0.165 – 0.247

4.2. Discussion

LCC approach on finding the optimized insulation thicknesses in Turkey has been applied in various studies. Although the aim of the studies looks the same, there are differences in the methodology and assumptions.

The main difference between the previous studies mentioned above and this study is the methodology. In the previous mentioned studies, the optimum insulation thicknesses were determined by making the derivative of the total cost formula equal to zero. The insulation thickness value that makes the derivative of the total cost equal to zero was regarded as the optimized thickness. However, a representative existing building approach is used in this study. LCCA is applied for each insulation thickness and the thickness having the highest net savings value is regarded as the optimized thickness.

The annual heating energy requirements are calculated according to TS 825 in Turkey. However, the calculations change as the version of TS 825 changes. Bolattürk (2006), Sisman *et al.* (2007), Çomaklı and Yüksel (2003) and Dombaycı *et al.* (2006) calculated the optimum thicknesses according to TS 825 Version (1999). Özkan and Onan (2011) calculated the optimum thicknesses according to TS 825 Version (2008). In this study, the latest version to date, TS 825 Version (2008) is used for the annual heating energy requirements.

The lifetime of the LCCA has an effect on the results. The lifetime is the life of the insulation material. Bolattürk (2006), Sisman *et al.* (2007), Özkan and Onan (2011), Ucar and Balo (2010) and Mishra *et al.* (2012) assumed a lifetime of 10 years. Sundaram and Bhaskaran (2014) and Yu *et al.* (2009) assumed a lifetime of 20 years. Daouas (2011) assumed a lifetime of 30 years. The assumed lifetimes vary between 10 and 30 years. In this study, it is assumed as 20 years.

Escalation rate is the rate of increase in energy prices. It is a critical variable due to its exponential effect in LCCA. It was shown that the present value factor for a lifetime of 20 years changes significantly for varying energy price rates and discount rates (Söylemez, 2012). Escalation rate was assumed as 9.2%, 9.32% and 9.67% by Bolattürk (2006), Sisman *et al.* (2007) and Özkan and Onan (2011), respectively. Due to the fact that changes in this variable can affect the results significantly, more than one value is used in the calculations in this study. The assumed numbers are 7%, 8.5%, 10% and 12%.

Discount rate is the rate at which the future savings are discounted back to present. It is also a critical variable due to its exponential effect in LCCA. It was assumed as

17.79%, 17.79% and 19.375% by Bolattürk (2006), Sisman *et al.* (2007) and Özkan and Onan (2011), respectively. In this study, the discount rate values are assumed as 7%, 9% and 11%. These values are smaller than the values assumed by Bolattürk (2006), Sisman *et al.* (2007) and Özkan and Onan (2011). The difference can be explained by the hurdle rate. The hurdle rate is the discount rate that measures the opportunity cost of funds adjusted for the risk (Azar and Noueihed, 2014). The opportunity cost changes according to who the investor is. In case of companies that could invest in business, the opportunity cost could be high. However, in case of residents, the only option is considered as depositing their money in the banks, therefore in this study, the discount rate is taken as the interest rates the banks offer, because investors are the home owners.

Energy source is another parameter that is used in LCC approach for determining the optimum insulation thickness. Bolattürk (2006), Dombaycı *et al.* (2006) and Ucar and Balo (2010) used various energy sources like coal, natural gas, fuel oil, liquefied petroleum gas (LPG) and electricity. Sundaram and Bhaskaran (2014) used electricity as the energy source. Daouas (2011) used electricity and natural gas as the energy sources for cooling and heating, respectively. In this study, natural gas is used as the energy source as it is commonly used in Turkey.

Optimum insulation thicknesses are determined for various insulation materials. Ucar and Balo (2010) used extruded polystyrene, expanded polystyrene, nil siding and rock wool as insulation materials. Dombaycı *et al.* (2006) used two insulation materials, namely, expanded polystyrene and rock wool. Sundaram and Bhaskaran (2014) used three different insulation materials, namely, expanded polystyrene (EPS), foamed polyurethane and foamed PVC. Mishra *et al.* (2012) used extruded polystyrene and expanded polystyrene as the insulation materials. In this thesis, expanded polystyrene is the insulation material used in the analysis as it is the most frequently used material in insulation applications in Turkey.

5. CONCLUSION

5.1. Summary

The main purpose of this research is to perform LCCA for existing buildings in Turkey, considering the cost of insulation applications and the operational savings throughout the remaining life of the buildings.

Firstly, the annual heating energy requirement for the uninsulated building is determined according to TS 825 (TSI, 2008) for the four regions of Turkey. Specific heat loss (SHL) of the building is determined and heat gains are also considered in calculations. The annual heating energy requirement is found by adding monthly heating energy requirement for each month. The annual heating energy requirement is found in kJ and it is also converted into kWh.

The annual heating energy requirement is also found for the insulated building. The insulated building includes stone wool insulation on the ceilings at a thickness of 15 cm and expanded polystyrene (EPS) insulation on the outer walls at varying thicknesses. The annual heating energy requirement of the representative building is determined for each EPS thickness and for each region of Turkey. The annual energy savings as a result of the insulation applications are determined in order to find annual operational savings as a result of insulation applications.

After determining the annual operational savings for each insulation application and for each region, the cost of insulation applications is determined by taking offers from 2 companies. The average of these two is taken and the value added tax is included to find the cost of each insulation application.

Determining the initial cost, which is the cost of insulation application, and the annual operational savings provides enough information to generate the cash flow diagram. The analysis is done for a life cycle of 20 years. Net savings (NS), internal rate of return (IRR), savings-to-investment ratio (SIR) and payback period (PBP) are determined for 12

combinations of discount rate and escalation rate. Discount rate values are assumed as 7%, 9%, and 11%, and escalation rate values are considered as 7%, 8.5%, 10%, and 12%.

The optimized insulation thickness for each region is found for each combination of discount rate and escalation rate. The optimized thickness is determined as the one having the maximum net savings value. The optimized thickness intervals are found as follows:

- 7 - 10 cm for the Region 1,
- 10 - 16 cm for the Region 2,
- 10 - 18 cm for the Region 3,
- 13 - 20 cm for the Region 4.

Accordingly, the corresponding optimized U_{ew} values are found as follows:

- 0.314 – 0.429 W/m^{2}K for the Region 1,
- 0.204 – 0.314 W/m^{2}K for the Region 2,
- 0.183 – 0.314 W/m^{2}K for the Region 3,
- 0.165 – 0.247 W/m^{2}K for the Region 4.

Clearly, the optimized thicknesses and U_{ew} values are found to be different than the requirements in TS 825 (TSI, 2008). The optimized thicknesses are found to be almost twice of the TS 825 requirements which are 4 cm, 5 cm, 6 cm, and 8 cm for the first, second, third and fourth regions, respectively. The same could be stated for the U_{ew} values. The optimized U_{ew} values are almost half of the TS 825 requirements which are 0.70 W/m^{2}K, 0.60 W/m^{2}K, 0.50 W/m^{2}K, and 0.40 W/m^{2}K for the first, second, third and fourth regions, respectively. It means that the minimum requirements for existing buildings in TS 825 (TSI, 2008) are not at the optimum levels. It might be economically and environmentally better if the limiting U_{ew} values stated TS 825 (TSI, 2008) are lowered.

5.2. Recommendations

LCCA shows that there is a great difference between the limit heat transfer coefficients for external walls in TS 825 (TSI, 2008) and the optimized U_{ew} values for the existing buildings. The reason of such a difference can be explained with the fact that the minimum requirements for existing buildings in TS 825 is not hard to achieve. It is possible to come up with some recommendations for the government and the owners of the existing buildings.

Government should lower the limiting heat transfer coefficients in TS 825. It is shown in this study that it would be economically better to apply thicker insulation than the limiting values stated in TS 825 (TSI, 2008). Considering the environmental concerns, it is obvious that the thicker the insulation is, the cleaner the environment will be. So, it is going to be economically and environmentally better to lower the limiting heat transfer coefficients in TS 825.

Owners of the existing buildings should apply the optimum insulation thicknesses rather than the minimum insulation thickness that satisfies the conditions in TS 825 (TSI, 2008). The increasing initial costs make the owners of the buildings reluctant to apply thicker insulation. However, they should be aware of the future operational savings. Also, they must be aware of the fact that the minimum insulation thicknesses that satisfy the conditions in TS 825 (TSI, 2008) are not the optimum thicknesses and it is possible to get economically better outcomes with the application of optimum insulations.

APPENDIX A: SPECIFIC HEAT LOSS OF THE BUILDING

Table A.1. Specific Heat Loss of the Uninsulated Building.

1	2	3	4	5	6	7	8
Surface Losing Heat	Constructional Elements	Thickness d (m)	Thermal Conductivity λ_h (W/mK)	Thermal Resistance R (m^2K/W)	Conductance U (W/m^2K)	Area A (m^2)	Heat Loss A x U W/K
Wall surfaces (outer, infilled wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Brick (7.1.2.1)	0.19	0.50	0.38			
	Plaster (4.2)	0.03	1.60	0.02			
	R_{out}			0.04			
Total				0.59	1.699	680.0	1,154.99
Wall Surfaces (outer, reinforced concrete wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.25	2.50	0.10			
	Plaster (4.2)	0.03	1.60	0.02			
	R_{out}			0.04			
Total				0.31	3.239	535.0	1,732.79
Ceiling (with roof)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.12	2.50	0.05			
	R_{out}			0.08			
Total				0.28	3.597	500	1,438.85
Basement (in contact with soil)	R_{in}			0.17			
	Wood Product (8.1.1)	0.01	0.13	0.08			
	Cement Finish (4.6)	0.05	1.40	0.04			
	Reinforced Concrete (5.1.1)	0.15	2.50	0.06			
	Plain Concrete (5.1.2)	0.10	1.65	0.06			
	Blockage (3.1)	0.20	0.7	0.29			
	R_{out}			0.00			
Total				0.69	1.451	500	362.87
External Doors					5.50	5.00	27.50
Windows					2.40	130.00	312.00
Heat Loss Occurred in Consequence of Conduction and Convection (H_{tr}) =							5,029.00
Heat Loss Occurred in Consequence of Ventilation (H_{ven}) =							1,584.00
Specific Heat Loss of the Building (H) =							6,613.00

Table A.2. Specific Heat Loss of the Building with Insulation (EPS) Thickness 7cm.

1	2	3	4	5	6	7	8
Surface Losing Heat	Constructional Elements	Thickness d (m)	Thermal Conductivity λ_h (W/mK)	Thermal Resistance R (m^2K/W)	Conductance U (W/m^2K)	Area A (m^2)	Heat Loss A x U W/K
Wall surfaces (outer, infilled wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Brick (7.1.2.1)	0.19	0.50	0.38			
	Plaster (4.2)	0.03	1.60	0.02			
	Insulation Material*	0.07	0.035	2.00			
	Plaster* (4.8.2)	0.008	0.35	0.02			
	R_{out}			0.04			
Total				2.61	0.383	680.0	260.38
Wall Surfaces (outer, reinforced concrete wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.25	2.50	0.10			
	Plaster (4.2)	0.03	1.60	0.02			
	Insulation Material*	0.07	0.035	2.00			
	Plaster* (4.8.2)	0.008	0.35	0.02			
	R_{out}			0.04			
Total				2.33	0.429	535.0	229.46
Ceiling (with roof)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.12	2.50	0.05			
	Stone Wool* (10.5.1)	0.15	0.035	4.29			
	R_{out}			0.08			
Total				4.56	0.219	500	87.65
Basement (in contact with soil)	R_{in}			0.17			
	Wood Product (8.1.1)	0.01	0.13	0.08			
	Cement Finish (4.6)	0.05	1.40	0.04			
	Reinforced Concrete (5.1.1)	0.15	2.50	0.06			
	Plain Concrete (5.1.2)	0.10	1.65	0.06			
	Blockage (3.1)	0.20	0.7	0.29			
	R_{out}			0.00			
Total				0.69	1.451	500	362.87
External Doors					5.50	5.00	27.50
Windows					2.40	130.00	312.00
Heat Loss Occurred in Consequence of Conduction and Convection (H_{tr}) =							1,279.85
Heat Loss Occurred in Consequence of Ventilation (H_{ven}) =							1,584.00
Specific Heat Loss of the Building (H) =							2,863.85

Table A.3. Specific Heat Loss of the Building with Insulation (EPS) Thickness 12cm.

1	2	3	4	5	6	7	8
Surface Losing Heat	Constructional Elements	Thickness d (m)	Thermal Conductivity λ_h (W/mK)	Thermal Resistance R (m^2K/W)	Conductance U (W/m^2K)	Area A (m^2)	Heat Loss A x U W/K
Wall surfaces (outer, infilled wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Brick (7.1.2.1)	0.19	0.50	0.38			
	Plaster (4.2)	0.03	1.60	0.02			
	Insulation Material*	0.12	0.035	3.43			
	Plaster* (4.8.2)	0.008	0.35	0.02			
	R_{out}			0.04			
Total				4.04	0.248	680.0	168.31
Wall Surfaces (outer, reinforced concrete wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.25	2.50	0.10			
	Plaster (4.2)	0.03	1.60	0.02			
	Insulation Material*	0.12	0.035	3.43			
	Plaster* (4.8.2)	0.008	0.35	0.02			
	R_{out}			0.04			
Total				3.76	0.266	535.0	142.28
Ceiling (with roof)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.12	2.50	0.05			
	Stone Wool* (10.5.1)	0.15	0.035	4.29			
	R_{out}			0.08			
Total				4.56	0.219	500	87.65
Basement (in contact with soil)	R_{in}			0.17			
	Wood Product (8.1.1)	0.01	0.13	0.08			
	Cement Finish (4.6)	0.05	1.40	0.04			
	Reinforced Concrete (5.1.1)	0.15	2.50	0.06			
	Plain Concrete (5.1.2)	0.10	1.65	0.06			
	Blockage (3.1)	0.20	0.7	0.29			
	R_{out}			0.00			
Total				0.69	1.451	500	362.87
External Doors					5.50	5.00	27.50
Windows					2.40	130.00	312.00
Heat Loss Occurred in Consequence of Conduction and Convection (H_{tr}) =							1,100.60
Heat Loss Occurred in Consequence of Ventilation (H_{ven}) =							1,584.00
Specific Heat Loss of the Building (H) =							2,684.60

Table A.4. Specific Heat Loss of the Building with Insulation (EPS) Thickness 17cm.

1	2	3	4	5	6	7	8
Surface Losing Heat	Constructional Elements	Thickness d (m)	Thermal Conductivity λ_h (W/mK)	Thermal Resistance R (m^2K/W)	Conductance U (W/m^2K)	Area A (m^2)	Heat Loss A x U W/K
Wall surfaces (outer, infilled wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Brick (7.1.2.1)	0.19	0.50	0.38			
	Plaster (4.2)	0.03	1.60	0.02			
	Insulation Material*	0.17	0.035	4.86			
	Plaster* (4.8.2)	0.008	0.35	0.02			
	R_{out}			0.04			
Total				5.47	0.183	680.0	124.34
Wall Surfaces (outer, reinforced concrete wall)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.25	2.50	0.10			
	Plaster (4.2)	0.03	1.60	0.02			
	Insulation Material*	0.17	0.035	4.86			
	Plaster* (4.8.2)	0.008	0.35	0.02			
	R_{out}			0.04			
Total				5.19	0.193	535.0	103.11
Ceiling (with roof)	R_{in}			0.13			
	Plaster (4.1)	0.02	1.00	0.02			
	Reinforced Concrete (5.1.1)	0.12	2.50	0.05			
	Stone Wool* (10.5.1)	0.15	0.035	4.29			
	R_{out}			0.08			
Total				4.56	0.219	500	87.65
Basement (in contact with soil)	R_{in}			0.17			
	Wood Product (8.1.1)	0.01	0.13	0.08			
	Cement Finish (4.6)	0.05	1.40	0.04			
	Reinforced Concrete (5.1.1)	0.15	2.50	0.06			
	Plain Concrete (5.1.2)	0.10	1.65	0.06			
	Blockage (3.1)	0.20	0.7	0.29			
	R_{out}			0.00			
Total				0.69	1.451	500	362.87
External Doors					5.50	5.00	27.50
Windows					2.40	130.00	312.00
Heat Loss Occurred in Consequence of Conduction and Convection (H_{tr}) =							1,017.47
Heat Loss Occurred in Consequence of Ventilation (H_{ven}) =							1,584.00
Specific Heat Loss of the Building (H) =							2,601.47

APPENDIX B: ANNUAL ENERGY REQUIREMENT OF THE BUILDING

Table B.1. Annual Energy Requirement of the Uninsulated Building in the Region 1.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,°C)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	6,613.00	10.6	70,098	12,000	3,216	15,216	0.22	0.99	142,647,331
February		10.0	66,130		4,013	16,013	0.24	0.98	130,571,394
March		7.4	48,936		4,805	16,805	0.34	0.95	85,652,595
April		3.2	21,162		5,386	17,386	0.82	0.70	23,128,903
May		0.0	0		6,250	18,250	0.00	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		0.5	3,306		4,051	16,051	4.85	0.00	0
November		6.0	39,678		3,048	15,048	0.38	0.93	66,633,374
December		9.7	64,146		2,813	14,813	0.23	0.99	128,377,221
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**577,010,817**
Total heat loss		**Q_{year} =**	**160,409**	**kWh**					

Table B.2. Annual Energy Requirement of the Uninsulated Building in the Region 2.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,°C)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	6,613.00	16.1	106,469	12,000	3,216	15,216	0.14	1.00	236,564,569
February		14.6	96,550		4,013	16,013	0.17	1.00	208,851,745
March		11.7	77,372		4,805	16,805	0.22	0.99	157,426,423
April		6.2	41,001		5,386	17,386	0.42	0.91	65,472,171
May		1.0	6,613		6,250	18,250	2.76	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		4.9	32,404		4,051	16,051	0.50	0.87	47,911,545
November		10.5	69,436		3,048	15,048	0.22	0.99	141,361,446
December		15.2	100,518		2,813	14,813	0.15	1.00	222,190,167
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**1,079,778,067**
Total heat loss		**Q_{year} =**	**300,178**	**kWh**					

Table B.3. Annual Energy Requirement of the Uninsulated Building in the Region 3.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,°C)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	6,613.00	19.3	127,631	12,000	3,216	15,216	0.12	1.00	291,388,337
February		18.9	124,986		4,013	16,013	0.13	1.00	282,474,613
March		14.9	98,534		4,805	16,805	0.17	1.00	211,965,033
April		8.9	58,856		5,386	17,386	0.30	0.97	109,016,639
May		4.6	30,420		6,250	18,250	0.60	0.81	40,477,662
June		0.5	3,306		6,590	18,590	5.62	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		1.8	11,903		5,016	17,016	1.43	0.50	8,660,309
October		7.4	48,936		4,051	16,051	0.33	0.95	87,210,704
November		13.4	88,614		3,048	15,048	0.17	1.00	190,791,606
December		17.7	117,050		2,813	14,813	0.13	1.00	265,013,233
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**1,486,998,137**
Total heat loss		**Q_{year} =**	**413,385**	**kWh**					

Table B.4. Annual Energy Requirement of the Uninsulated Building in the Region 4.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,°C)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	6,613.00	24.4	161,357	12,000	3,216	15,216	0.09	1.00	378,798,893
February		23.7	156,728		4,013	16,013	0.10	1.00	364,736,314
March		18.7	123,663		4,805	16,805	0.14	1.00	277,004,401
April		11.1	73,404		5,386	17,386	0.24	0.99	145,861,398
May		6.2	41,001		6,250	18,250	0.45	0.89	63,972,963
June		1.7	11,242		6,590	18,590	1.65	0.45	7,273,728
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		2.5	16,532		5,016	17,016	1.03	0.62	15,439,910
October		8.7	57,533		4,051	16,051	0.28	0.97	108,675,786
November		15.9	105,147		3,048	15,048	0.14	1.00	233,571,799
December		21.8	144,163		2,813	14,813	0.10	1.00	335,278,966
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**1,930,614,157**
Total heat loss		**Q_{year} =**	**536,711**	**kWh**					

Table B.5. Annual Energy Requirement of the Building with an EPS Thickness of 7cm in the Region 1.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,863.85	10.6	30,357	12,000	3,216	15,216	0.50	0.86	44,608,942
February		10.0	28,638		4,013	16,013	0.56	0.83	39,666,021
March		7.4	21,192		4,805	16,805	0.79	0.72	23,714,705
April		3.2	9,164		5,386	17,386	1.90	0.41	5,291,482
May		0.0	0		6,250	18,250	0.00	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		0.5	1,432		4,051	16,051	11.21	0.00	0
November		6.0	17,183		3,048	15,048	0.88	0.68	17,984,991
December		9.7	27,779		2,813	14,813	0.53	0.85	39,495,114
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**170,761,255**
Total heat loss		**Q_{year} =**	**47,472**	**kWh**					

Table B.6. Annual Energy Requirement of the Building with an EPS Thickness of 7cm in the Region 2.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,863.85	16.1	46,108	12,000	3,216	15,216	0.33	0.95	81,977,006
February		14.6	41,812		4,013	16,013	0.38	0.93	69,920,428
March		11.7	33,507		4,805	16,805	0.50	0.86	49,223,150
April		6.2	17,756		5,386	17,386	0.98	0.64	17,188,294
May		1.0	2,864		6,250	18,250	6.37	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		4.9	14,033		4,051	16,051	1.14	0.58	12,124,773
November		10.5	30,070		3,048	15,048	0.50	0.86	44,225,694
December		15.2	43,530		2,813	14,813	0.34	0.95	76,468,585
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**351,127,930**
Total heat loss		**Q_{year} =**	**97,614**	**kWh**					

Table B.7. Annual Energy Requirement of the Building with an EPS Thickness of 7cm in the Region 3.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,863.85	19.3	55,272	12,000	3,216	15,216	0.28	0.97	104,868,939
February		18.9	54,127		4,013	16,013	0.30	0.97	100,204,064
March		14.9	42,671		4,805	16,805	0.39	0.92	70,483,898
April		8.9	25,488		5,386	17,386	0.68	0.77	31,404,230
May		4.6	13,174		6,250	18,250	1.39	0.51	9,825,241
June		0.5	1,432		6,590	18,590	12.98	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		1.8	5,155		5,016	17,016	3.30	0.00	0
October		7.4	21,192		4,051	16,051	0.76	0.73	24,436,864
November		13.4	38,376		3,048	15,048	0.39	0.92	63,509,883
December		17.7	50,690		2,813	14,813	0.29	0.97	94,247,333
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**498,980,452**
Total heat loss		**Q_{year} =**	**138,717**	**kWh**					

Table B.8. Annual Energy Requirement of the Building with an EPS Thickness of 7cm in the Region 4.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,863.85	24.4	69,878	12,000	3,216	15,216	0.22	0.99	142,082,992
February		23.7	67,873		4,013	16,013	0.24	0.99	135,020,832
March		18.7	53,554		4,805	16,805	0.31	0.96	97,052,812
April		11.1	31,789		5,386	17,386	0.55	0.84	44,572,831
May		6.2	17,756		6,250	18,250	1.03	0.62	16,599,223
June		1.7	4,869		6,590	18,590	3.82	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		2.5	7,160		5,016	17,016	2.38	0.34	3,409,658
October		8.7	24,915		4,051	16,051	0.64	0.79	31,786,847
November		15.9	45,535		3,048	15,048	0.33	0.95	80,914,801
December		21.8	62,432		2,813	14,813	0.24	0.99	123,995,919
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**675,435,916**
Total heat loss		**Q_{year} =**	**187,771**	**kWh**					

Table B.9. Annual Energy Requirement of the Building with an EPS Thickness of 12cm in the Region 1.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,684.60	10.6	28,457	12,000	3,216	15,216	0.53	0.85	40,397,643
February		10.0	26,846		4,013	16,013	0.60	0.81	35,842,099
March		7.4	19,866		4,805	16,805	0.85	0.69	21,290,316
April		3.2	8,591		5,386	17,386	2.02	0.39	4,697,021
May		0.0	0		6,250	18,250	0.00	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		0.5	1,342		4,051	16,051	11.96	0.00	0
November		6.0	16,108		3,048	15,048	0.93	0.66	16,119,832
December		9.7	26,041		2,813	14,813	0.57	0.83	35,721,583
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**154,068,494**
Total heat loss		**Q_{year} =**	**42,831**	**kWh**					

Table B.10. Annual Energy Requirement of the Building with an EPS Thickness of 12cm in the Region 2.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,684.60	16.1	43,222	12,000	3,216	15,216	0.35	0.94	74,894,890
February		14.6	39,195		4,013	16,013	0.41	0.91	63,678,578
March		11.7	31,410		4,805	16,805	0.54	0.85	44,575,716
April		6.2	16,645		5,386	17,386	1.04	0.62	15,379,023
May		1.0	2,685		6,250	18,250	6.80	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		4.9	13,155		4,051	16,051	1.22	0.56	10,824,422
November		10.5	28,188		3,048	15,048	0.53	0.85	40,051,911
December		15.2	40,806		2,813	14,813	0.36	0.94	69,817,148
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**319,221,688**
Total heat loss		**Q_{year} =**	**88,744**	**kWh**					

Table B.11. Annual Energy Requirement of the Building with an EPS Thickness of 12cm in the Region 3.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H(\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,684.60	19.3	51,813	12,000	3,216	15,216	0.29	0.97	96,168,558
February		18.9	50,739		4,013	16,013	0.32	0.96	91,756,102
March		14.9	40,001		4,805	16,805	0.42	0.91	64,153,619
April		8.9	23,893		5,386	17,386	0.73	0.75	28,268,976
May		4.6	12,349		6,250	18,250	1.48	0.49	8,750,239
June		0.5	1,342		6,590	18,590	13.85	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		1.8	4,832		5,016	17,016	3.52	0.00	0
October		7.4	19,866		4,051	16,051	0.81	0.71	21,955,998
November		13.4	35,974		3,048	15,048	0.42	0.91	57,811,253
December		17.7	47,518		2,813	14,813	0.31	0.96	86,323,384
$Q_m = [H(\theta_{in} - \theta_{out}) - \eta(\phi_{in,m} + \phi_{s,m})] \cdot t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**455,188,130**
Total heat loss		**Q_{year} =**	**126,542**	**kWh**					

Table B.12. Annual Energy Requirement of the Building with an EPS Thickness of 12cm in the Region 4.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H(\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,684.60	24.4	65,504	12,000	3,216	15,216	0.23	0.99	130,879,910
February		23.7	63,625		4,013	16,013	0.25	0.98	124,191,859
March		18.7	50,202		4,805	16,805	0.33	0.95	88,762,021
April		11.1	29,799		5,386	17,386	0.58	0.82	40,293,639
May		6.2	16,645		6,250	18,250	1.10	0.60	14,841,302
June		1.7	4,564		6,590	18,590	4.07	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		2.5	6,712		5,016	17,016	2.54	0.00	0
October		8.7	23,356		4,051	16,051	0.69	0.77	28,643,808
November		15.9	42,685		3,048	15,048	0.35	0.94	73,922,274
December		21.8	58,524		2,813	14,813	0.25	0.98	114,039,015
$Q_m = [H(\theta_{in} - \theta_{out}) - \eta(\phi_{in,m} + \phi_{s,m})] \cdot t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**615,573,828**
Total heat loss		**Q_{year} =**	**171,130**	**kWh**					

Table B.13. Annual Energy Requirement of the Building with an EPS Thickness of 17cm in the Region 1.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,601.47	10.6	27,576	12,000	3,216	15,216	0.55	0.84	38,475,760
February		10.0	26,015		4,013	16,013	0.62	0.80	34,100,798
March		7.4	19,251		4,805	16,805	0.87	0.68	20,193,649
April		3.2	8,325		5,386	17,386	2.09	0.38	4,431,386
May		0.0	0		6,250	18,250	0.00	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		0.5	1,301		4,051	16,051	12.34	0.00	0
November		6.0	15,609		3,048	15,048	0.96	0.65	15,277,598
December		9.7	25,234		2,813	14,813	0.59	0.82	34,001,606
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**146,480,796**
Total heat loss		**Q_{year} =**	**40,722**	**kWh**					

Table B.14. Annual Energy Requirement of the Building with an EPS Thickness of 17cm in the Region 2.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,601.47	16.1	41,884	12,000	3,216	15,216	0.36	0.94	71,637,156
February		14.6	37,981		4,013	16,013	0.42	0.91	60,815,014
March		11.7	30,437		4,805	16,805	0.55	0.84	42,454,821
April		6.2	16,129		5,386	17,386	1.08	0.60	14,563,541
May		1.0	2,601		6,250	18,250	7.02	0.00	0
June		0.0	0		6,590	18,590	0.00	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		0.0	0		5,016	17,016	0.00	0.00	0
October		4.9	12,747		4,051	16,051	1.26	0.55	10,239,724
November		10.5	27,315		3,048	15,048	0.55	0.84	38,147,086
December		15.2	39,542		2,813	14,813	0.37	0.93	66,759,140
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**304,616,482**
Total heat loss		**Q_{year} =**	**84,683**	**kWh**					

Table B.15. Annual Energy Requirement of the Building with an EPS Thickness of 17cm in the Region 3.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,601.47	19.3	50,208	12,000	3,216	15,216	0.30	0.96	92,155,096
February		18.9	49,168		4,013	16,013	0.33	0.95	87,863,199
March		14.9	38,762		4,805	16,805	0.43	0.90	61,251,015
April		8.9	23,153		5,386	17,386	0.75	0.74	26,846,794
May		4.6	11,967		6,250	18,250	1.53	0.48	8,268,141
June		0.5	1,301		6,590	18,590	14.29	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		1.8	4,683		5,016	17,016	3.63	0.00	0
October		7.4	19,251		4,051	16,051	0.83	0.70	20,832,850
November		13.4	34,860		3,048	15,048	0.43	0.90	55,198,064
December		17.7	46,046		2,813	14,813	0.32	0.96	82,671,268
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**435,086,428**
Total heat loss		**Q_{year} =**	**120,954**	**kWh**					

Table B.16. Annual Energy Requirement of the Building with an EPS Thickness of 17cm in the Region 4.

Months	Heat Losses			Heat Gains			GLR	Usage Factor	Heating Energy Requirement
	Specific Heat Loss	Temperature Difference	Heat Loss	Internal Heat Gain	Solar Energy Gain	Total			
	$H = H_{tr} + H_{ven}$ (W/K)	$\theta_{in} - \theta_{out}$ (K,ºC)	$H (\theta_{in} - \theta_{out})$ (W)	ϕ_{in} (W)	ϕ_s (W)	$\phi_t = \phi_{in} + \phi_s$ (W)	γ (-)	η (-)	Q_m (kJ)
January	2,601.47	24.4	63,476	12,000	3,216	15,216	0.24	0.98	125,697,722
February		23.7	61,655		4,013	16,013	0.26	0.98	119,186,803
March		18.7	48,647		4,805	16,805	0.35	0.94	84,945,103
April		11.1	28,876		5,386	17,386	0.60	0.81	38,344,164
May		6.2	16,129		6,250	18,250	1.13	0.59	14,049,576
June		1.7	4,422		6,590	18,590	4.20	0.00	0
July		0.0	0		6,408	18,408	0.00	0.00	0
August		0.0	0		5,986	17,986	0.00	0.00	0
September		2.5	6,504		5,016	17,016	2.62	0.00	0
October		8.7	22,633		4,051	16,051	0.71	0.76	27,216,533
November		15.9	41,363		3,048	15,048	0.36	0.94	70,705,828
December		21.8	56,712		2,813	14,813	0.26	0.98	109,437,310
$Q_m = [H (\theta_{in} - \theta_{out}) - \eta (\phi_{in,m} + \phi_{s,m})] . t$ (J)				1 kJ = 0.278 x 10^{-3} kWh				$Q_{an} = \Sigma Q_m$	**589,583,038**
Total heat loss		**Q_{year} =**	**163,904**	**kWh**					

APPENDIX C: CASH FLOW DIAGRAM

Table C.1. Cash Flow Diagram for Discount Rate 7% and Escalation Rate 7%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1103	0.1180	0.1263	0.1351	0.1446	0.2028	0.2844	0.3989				
Region 1, 4 cm	-87,809	12,565	13,444	14,385	15,392	16,470	23,100	32,398	45,441	147,045 TL	19.82%	2.67	7-8 years
Region 1, 5 cm	-90,088	12,926	13,831	14,799	15,835	16,943	23,764	33,330	46,747	151,518 TL	19.87%	2.68	7-8 years
Region 1, 6 cm	-92,081	13,189	14,112	15,100	16,157	17,288	24,247	34,008	47,698	154,442 TL	19.84%	2.68	7-8 years
Region 1, 7 cm	-94,635	13,389	14,326	15,329	16,402	17,550	24,615	34,524	48,421	155,625 TL	19.63%	2.64	7-8 years
Region 1, 8 cm	-96,986	13,546	14,494	15,509	16,595	17,756	24,904	34,929	48,990	156,212 TL	19.41%	2.61	7-8 years
Region 1, 9 cm	-99,195	13,673	14,630	15,654	16,750	17,922	25,137	35,256	49,448	156,371 TL	19.19%	2.58	7-8 years
Region 1, 10 cm	-101,188	13,777	14,742	15,774	16,878	18,059	25,329	35,525	49,826	156,330 TL	18.99%	2.54	7-8 years
Region 1, 11 cm	-104,801	13,865	14,835	15,874	16,985	18,174	25,490	35,751	50,142	154,353 TL	18.52%	2.47	8-9 years
Region 1, 12 cm	-107,037	13,939	14,915	15,959	17,076	18,271	25,626	35,942	50,411	153,506 TL	18.26%	2.43	8-9 years
Region 1, 13 cm	-109,231	14,003	14,983	16,032	17,154	18,355	25,744	36,107	50,643	152,509 TL	18.01%	2.40	8-9 years
Region 1, 14 cm	-111,969	14,059	15,043	16,096	17,222	18,428	25,846	36,251	50,844	150,810 TL	17.68%	2.35	8-9 years
Region 1, 15 cm	-114,378	14,108	15,095	16,152	17,282	18,492	25,936	36,377	51,020	149,314 TL	17.41%	2.31	8-9 years
Region 1, 16 cm	-116,744	14,151	15,141	16,201	17,335	18,549	26,015	36,488	51,176	147,755 TL	17.14%	2.27	8-9 years
Region 1, 17 cm	-119,432	14,189	15,182	16,245	17,382	18,599	26,086	36,587	51,315	145,785 TL	16.83%	2.22	9-10 years
Region 1, 18 cm	-121,747	14,224	15,219	16,285	17,425	18,644	26,149	36,676	51,440	144,114 TL	16.58%	2.18	9-10 years
Region 1, 19 cm	-124,665	14,255	15,253	16,320	17,463	18,685	26,207	36,756	51,553	141,779 TL	16.26%	2.14	9-10 years
Region 1, 20 cm	-126,694	14,283	15,283	16,352	17,497	18,722	26,258	36,829	51,654	140,276 TL	16.05%	2.11	9-10 years
Region 2, 5 cm	-90,088	23,137	24,756	26,489	28,344	30,328	42,536	59,659	83,675	342,375 TL	32.31%	4.80	4-5 years
Region 2, 6 cm	-92,081	23,634	25,289	27,059	28,953	30,980	43,451	60,942	85,475	349,684 TL	32.30%	4.80	4-5 years
Region 2, 7 cm	-94,635	24,014	25,695	27,494	29,419	31,478	44,149	61,922	86,848	354,231 TL	31.99%	4.74	4-5 years
Region 2, 8 cm	-96,986	24,314	26,016	27,837	29,785	31,870	44,700	62,694	87,931	357,477 TL	31.67%	4.69	4-5 years
Region 2, 9 cm	-99,195	24,556	26,275	28,114	30,082	32,188	45,145	63,318	88,807	359,792 TL	31.34%	4.63	4-5 years
Region 2, 10 cm	-101,188	24,756	26,488	28,343	30,327	32,450	45,512	63,833	89,529	361,533 TL	31.04%	4.57	4-5 years
Region 2, 11 cm	-104,801	24,923	26,668	28,535	30,532	32,669	45,820	64,265	90,136	361,054 TL	30.32%	4.45	4-5 years
Region 2, 12 cm	-107,037	25,066	26,820	28,698	30,707	32,856	46,083	64,633	90,651	361,483 TL	29.94%	4.38	4-5 years
Region 2, 13 cm	-109,231	25,189	26,952	28,839	30,857	33,017	46,309	64,950	91,096	361,587 TL	29.56%	4.31	4-5 years
Region 2, 14 cm	-111,969	25,296	27,067	28,961	30,988	33,158	46,505	65,226	91,483	360,850 TL	29.06%	4.22	4-5 years
Region 2, 15 cm	-114,378	25,390	27,167	29,069	31,104	33,281	46,678	65,469	91,823	360,198 TL	28.64%	4.15	4-5 years
Region 2, 16 cm	-116,744	25,473	27,256	29,164	31,206	33,390	46,831	65,683	92,124	359,388 TL	28.24%	4.08	4-5 years
Region 2, 17 cm	-119,432	25,547	27,336	29,249	31,297	33,487	46,968	65,875	92,392	358,087 TL	27.78%	4.00	5-6 years
Region 2, 18 cm	-121,747	25,614	27,407	29,325	31,378	33,574	47,090	66,046	92,633	357,015 TL	27.40%	3.93	5-6 years
Region 2, 19 cm	-124,665	25,674	27,471	29,394	31,451	33,653	47,200	66,201	92,850	355,219 TL	26.92%	3.85	5-6 years
Region 2, 20 cm	-126,694	25,728	27,529	29,456	31,518	33,725	47,300	66,341	93,047	354,209 TL	26.61%	3.80	5-6 years
Region 3, 6 cm	-92,081	32,042	34,285	36,685	39,253	42,001	58,908	82,622	115,882	506,839 TL	41.67%	6.50	3-4 years
Region 3, 7 cm	-94,635	32,562	34,842	37,281	39,890	42,683	59,865	83,963	117,763	514,007 TL	41.28%	6.43	3-4 years
Region 3, 8 cm	-96,986	32,973	35,281	37,751	40,393	43,221	60,619	85,021	119,247	519,327 TL	40.86%	6.35	3-4 years
Region 3, 9 cm	-99,195	33,305	35,636	38,131	40,800	43,656	61,230	85,878	120,448	523,327 TL	40.43%	6.28	3-4 years
Region 3, 10 cm	-101,188	33,579	35,930	38,445	41,136	44,015	61,734	86,585	121,440	526,460 TL	40.03%	6.20	3-4 years
Region 3, 11 cm	-104,801	33,809	36,176	38,708	41,418	44,317	62,157	87,179	122,273	527,152 TL	39.09%	6.03	3-4 years
Region 3, 12 cm	-107,037	34,006	36,386	38,933	41,658	44,575	62,518	87,685	122,983	528,583 TL	38.59%	5.94	3-4 years
Region 3, 13 cm	-109,231	34,175	36,567	39,127	41,866	44,796	62,829	88,121	123,594	529,549 TL	38.10%	5.85	3-4 years
Region 3, 14 cm	-111,969	34,322	36,725	39,295	42,046	44,989	63,100	88,500	124,126	529,563 TL	37.45%	5.73	3-4 years
Region 3, 15 cm	-114,378	34,451	36,863	39,443	42,204	45,159	63,337	88,834	124,594	529,572 TL	36.90%	5.63	3-4 years
Region 3, 16 cm	-116,744	34,566	36,986	39,575	42,345	45,309	63,548	89,130	125,009	529,349 TL	36.38%	5.53	3-4 years
Region 3, 17 cm	-119,432	34,668	37,095	39,692	42,470	45,443	63,736	89,393	125,378	528,571 TL	35.78%	5.43	3-4 years
Region 3, 18 cm	-121,747	34,760	37,193	39,796	42,582	45,563	63,904	89,629	125,710	527,969 TL	35.29%	5.34	3-4 years
Region 3, 19 cm	-124,665	34,843	37,282	39,891	42,684	45,671	64,057	89,843	126,009	526,598 TL	34.67%	5.22	3-4 years
Region 3, 20 cm	-126,694	34,918	37,362	39,977	42,776	45,770	64,195	90,036	126,280	525,972 TL	34.27%	5.15	3-4 years
Region 4, 8 cm	-96,986	41,899	44,832	47,971	51,328	54,921	77,030	108,039	151,530	686,179 TL	50.15%	8.08	2-3 years
Region 4, 9 cm	-99,195	42,330	45,293	48,464	51,856	55,486	77,822	109,150	153,089	692,025 TL	49.62%	7.98	2-3 years
Region 4, 10 cm	-101,188	42,686	45,674	48,872	52,293	55,953	78,477	110,068	154,377	696,689 TL	49.13%	7.89	2-3 years
Region 4, 11 cm	-104,801	43,087	46,103	49,330	52,783	56,478	79,214	111,101	155,825	700,563 TL	48.05%	7.68	2-3 years
Region 4, 12 cm	-107,037	43,340	46,374	49,620	53,094	56,810	79,679	111,754	156,741	703,060 TL	47.42%	7.57	2-3 years
Region 4, 13 cm	-109,231	43,559	46,608	49,870	53,361	57,097	80,081	112,318	157,531	704,950 TL	46.81%	7.45	2-3 years
Region 4, 14 cm	-111,969	43,749	46,812	50,088	53,595	57,346	80,431	112,809	158,220	705,771 TL	45.99%	7.30	2-3 years
Region 4, 15 cm	-114,378	43,916	46,991	50,280	53,799	57,565	80,738	113,240	158,825	706,489 TL	45.31%	7.18	2-3 years
Region 4, 16 cm	-116,744	44,065	47,149	50,450	53,981	57,760	81,011	113,622	159,361	706,893 TL	44.65%	7.06	2-3 years
Region 4, 17 cm	-119,432	44,197	47,291	50,601	54,143	57,933	81,254	113,963	159,839	706,678 TL	43.91%	6.92	2-3 years
Region 4, 18 cm	-121,747	44,316	47,418	50,737	54,288	58,089	81,472	114,269	160,268	706,580 TL	43.29%	6.80	2-3 years
Region 4, 19 cm	-124,665	44,423	47,532	50,860	54,420	58,229	81,669	114,545	160,656	705,666 TL	42.52%	6.66	3-4 years
Region 4, 20 cm	-126,694	44,520	47,636	50,971	54,539	58,357	81,848	114,796	161,008	705,454 TL	42.02%	6.57	3-4 years

Table C.2. Cash Flow Diagram for Discount Rate 7% and Escalation Rate 8.5%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1119	0.1214	0.1317	0.1429	0.1550	0.2331	0.3505	0.5270				
Region 1, 4 cm	-87,809	12,656	13,731	14,899	16,165	17,539	26,373	39,656	59,628	183,066 TL	21.39%	3.08	7-8 years
Region 1, 5 cm	-90,088	13,020	14,126	15,327	16,630	18,043	27,131	40,796	61,343	188,574 TL	21.43%	3.09	7-8 years
Region 1, 6 cm	-92,081	13,285	14,414	15,639	16,968	18,411	27,683	41,626	62,591	192,253 TL	21.40%	3.09	7-8 years
Region 1, 7 cm	-94,635	13,486	14,632	15,876	17,225	18,690	28,103	42,257	63,540	194,008 TL	21.19%	3.05	7-8 years
Region 1, 8 cm	-96,986	13,644	14,804	16,062	17,428	18,909	28,433	42,753	64,286	195,046 TL	20.97%	3.01	7-8 years
Region 1, 9 cm	-99,195	13,772	14,942	16,213	17,591	19,086	28,699	43,153	64,887	195,569 TL	20.75%	2.97	7-8 years
Region 1, 10 cm	-101,188	13,877	15,057	16,336	17,725	19,232	28,918	43,482	65,383	195,827 TL	20.54%	2.94	7-8 years
Region 1, 11 cm	-104,801	13,965	15,152	16,440	17,838	19,354	29,101	43,759	65,798	194,101 TL	20.07%	2.85	7-8 years
Region 1, 12 cm	-107,037	14,040	15,233	16,528	17,933	19,458	29,257	43,993	66,151	193,467 TL	19.81%	2.81	7-8 years
Region 1, 13 cm	-109,231	14,105	15,303	16,604	18,016	19,547	29,392	44,195	66,454	192,653 TL	19.56%	2.76	7-8 years
Region 1, 14 cm	-111,969	14,161	15,364	16,670	18,087	19,625	29,509	44,371	66,718	191,113 TL	19.23%	2.71	8-9 years
Region 1, 15 cm	-114,378	14,210	15,418	16,728	18,150	19,693	29,611	44,525	66,950	189,758 TL	18.95%	2.66	8-9 years
Region 1, 16 cm	-116,744	14,253	15,465	16,779	18,205	19,753	29,702	44,661	67,155	188,323 TL	18.68%	2.61	8-9 years
Region 1, 17 cm	-119,432	14,292	15,507	16,825	18,255	19,807	29,782	44,782	67,337	186,462 TL	18.37%	2.56	8-9 years
Region 1, 18 cm	-121,747	14,327	15,544	16,866	18,299	19,855	29,855	44,891	67,501	184,891 TL	18.11%	2.52	8-9 years
Region 1, 19 cm	-124,665	14,358	15,578	16,903	18,339	19,898	29,920	44,990	67,649	182,645 TL	17.79%	2.47	8-9 years
Region 1, 20 cm	-126,694	14,386	15,609	16,936	18,376	19,937	29,979	45,078	67,782	181,222 TL	17.58%	2.43	8-9 years
Region 2, 5 cm	-90,088	23,304	25,285	27,435	29,766	32,297	48,563	73,022	109,800	408,704 TL	33.99%	5.54	4-5 years
Region 2, 6 cm	-92,081	23,806	25,829	28,025	30,407	32,991	49,608	74,593	112,162	417,440 TL	33.97%	5.53	4-5 years
Region 2, 7 cm	-94,635	24,188	26,244	28,475	30,895	33,522	50,405	75,792	113,965	423,076 TL	33.67%	5.47	4-5 years
Region 2, 8 cm	-96,986	24,490	26,572	28,830	31,281	33,940	51,033	76,737	115,386	427,180 TL	33.34%	5.40	4-5 years
Region 2, 9 cm	-99,195	24,734	26,836	29,117	31,592	34,278	51,542	77,501	116,535	430,190 TL	33.01%	5.34	4-5 years
Region 2, 10 cm	-101,188	24,935	27,054	29,354	31,849	34,556	51,961	78,131	117,483	432,503 TL	32.70%	5.27	4-5 years
Region 2, 11 cm	-104,801	25,104	27,238	29,553	32,065	34,790	52,313	78,660	118,278	432,504 TL	31.98%	5.13	4-5 years
Region 2, 12 cm	-107,037	25,247	27,394	29,722	32,248	34,989	52,612	79,111	118,955	433,342 TL	31.59%	5.05	4-5 years
Region 2, 13 cm	-109,231	25,371	27,528	29,868	32,406	35,161	52,870	79,499	119,538	433,799 TL	31.21%	4.97	4-5 years
Region 2, 14 cm	-111,969	25,479	27,645	29,995	32,544	35,310	53,095	79,836	120,047	433,369 TL	30.71%	4.87	4-5 years
Region 2, 15 cm	-114,378	25,574	27,748	30,106	32,665	35,442	53,292	80,133	120,493	432,987 TL	30.28%	4.79	4-5 years
Region 2, 16 cm	-116,744	25,658	27,839	30,205	32,772	35,558	53,467	80,396	120,888	432,415 TL	29.88%	4.70	4-5 years
Region 2, 17 cm	-119,432	25,732	27,920	30,293	32,868	35,661	53,623	80,630	121,240	431,327 TL	29.41%	4.61	4-5 years
Region 2, 18 cm	-121,747	25,799	27,992	30,372	32,953	35,754	53,762	80,840	121,555	430,445 TL	29.03%	4.54	4-5 years
Region 2, 19 cm	-124,665	25,860	28,058	30,443	33,030	35,838	53,888	81,029	121,840	428,821 TL	28.54%	4.44	5-6 years
Region 2, 20 cm	-126,694	25,915	28,117	30,507	33,101	35,914	54,003	81,201	122,099	427,968 TL	28.23%	4.38	5-6 years
Region 3, 6 cm	-92,081	32,274	35,018	37,994	41,224	44,728	67,255	101,129	152,063	598,699 TL	43.42%	7.50	3-4 years
Region 3, 7 cm	-94,635	32,798	35,586	38,611	41,893	45,454	68,347	102,770	154,531	607,358 TL	43.02%	7.42	3-4 years
Region 3, 8 cm	-96,986	33,212	36,035	39,098	42,421	46,027	69,208	104,066	156,479	613,855 TL	42.60%	7.33	3-4 years
Region 3, 9 cm	-99,195	33,546	36,398	39,492	42,848	46,490	69,906	105,114	158,055	618,807 TL	42.17%	7.24	3-4 years
Region 3, 10 cm	-101,188	33,822	36,697	39,817	43,201	46,873	70,481	105,979	159,357	622,725 TL	41.77%	7.15	3-4 years
Region 3, 11 cm	-104,801	34,054	36,949	40,090	43,497	47,195	70,965	106,706	160,450	624,078 TL	40.82%	6.95	3-4 years
Region 3, 12 cm	-107,037	34,252	37,164	40,322	43,750	47,469	71,376	107,326	161,381	626,072 TL	40.31%	6.85	3-4 years
Region 3, 13 cm	-109,231	34,422	37,348	40,523	43,967	47,705	71,731	107,859	162,183	627,523 TL	39.82%	6.74	3-4 years
Region 3, 14 cm	-111,969	34,571	37,509	40,697	44,157	47,910	72,040	108,324	162,882	627,958 TL	39.16%	6.61	3-4 years
Region 3, 15 cm	-114,378	34,701	37,651	40,851	44,323	48,091	72,312	108,732	163,496	628,338 TL	38.61%	6.49	3-4 years
Region 3, 16 cm	-116,744	34,816	37,776	40,987	44,471	48,251	72,552	109,094	164,040	628,444 TL	38.08%	6.38	3-4 years
Region 3, 17 cm	-119,432	34,919	37,888	41,108	44,602	48,393	72,767	109,417	164,525	627,959 TL	37.48%	6.26	3-4 years
Region 3, 18 cm	-121,747	35,012	37,988	41,217	44,720	48,521	72,959	109,706	164,960	627,619 TL	36.99%	6.16	3-4 years
Region 3, 19 cm	-124,665	35,095	38,078	41,315	44,827	48,637	73,133	109,967	165,352	626,486 TL	36.36%	6.03	3-4 years
Region 3, 20 cm	-126,694	35,171	38,160	41,404	44,923	48,742	73,290	110,204	165,709	626,075 TL	35.96%	5.94	3-4 years
Region 4, 8 cm	-96,986	42,203	45,790	49,682	53,905	58,487	87,945	132,239	198,842	806,298 TL	51.96%	9.31	2-3 years
Region 4, 9 cm	-99,195	42,637	46,261	50,193	54,460	59,089	88,849	133,599	200,887	813,379 TL	51.43%	9.20	2-3 years
Region 4, 10 cm	-101,188	42,996	46,650	50,616	54,918	59,586	89,597	134,723	202,577	819,063 TL	50.93%	9.09	2-3 years
Region 4, 11 cm	-104,801	43,399	47,088	51,091	55,433	60,145	90,438	135,987	204,478	824,086 TL	49.85%	8.86	2-3 years
Region 4, 12 cm	-107,037	43,654	47,365	51,391	55,759	60,499	90,969	136,786	205,680	827,309 TL	49.21%	8.73	2-3 years
Region 4, 13 cm	-109,231	43,874	47,604	51,650	56,040	60,804	91,428	137,476	206,717	829,826 TL	48.59%	8.60	2-3 years
Region 4, 14 cm	-111,969	44,066	47,812	51,876	56,285	61,069	91,827	138,077	207,620	831,192 TL	47.77%	8.42	2-3 years
Region 4, 15 cm	-114,378	44,235	47,995	52,074	56,500	61,303	92,179	138,605	208,414	832,390 TL	47.09%	8.28	2-3 years
Region 4, 16 cm	-116,744	44,384	48,156	52,250	56,691	61,510	92,490	139,073	209,117	833,219 TL	46.42%	8.14	2-3 years
Region 4, 17 cm	-119,432	44,517	48,301	52,407	56,861	61,694	92,767	139,490	209,745	833,383 TL	45.67%	7.98	2-3 years
Region 4, 18 cm	-121,747	44,637	48,431	52,547	57,014	61,860	93,016	139,865	210,308	833,626 TL	45.05%	7.85	2-3 years
Region 4, 19 cm	-124,665	44,745	48,548	52,674	57,152	62,010	93,241	140,203	210,817	833,019 TL	44.27%	7.68	2-3 years
Region 4, 20 cm	-126,694	44,843	48,654	52,790	57,277	62,145	93,445	140,510	211,278	833,086 TL	43.77%	7.58	2-3 years

Table C.3. Cash Flow Diagram for Discount Rate 7% and Escalation Rate 10%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1134	0.1247	0.1372	0.1509	0.1660	0.2674	0.4306	0.6935				
Region 1, 4 cm	-87,809	12,747	14,021	15,424	16,966	18,663	30,056	48,406	77,958	225,981 TL	22.95%	3.57	6-7 years
Region 1, 5 cm	-90,088	13,113	14,425	15,867	17,454	19,199	30,920	49,798	80,199	232,722 TL	23.00%	3.58	6-7 years
Region 1, 6 cm	-92,081	13,380	14,718	16,190	17,809	19,590	31,550	50,811	81,832	237,299 TL	22.97%	3.58	6-7 years
Region 1, 7 cm	-94,635	13,583	14,941	16,435	18,079	19,887	32,028	51,581	83,072	239,738 TL	22.75%	3.53	6-7 years
Region 1, 8 cm	-96,986	13,742	15,117	16,628	18,291	20,120	32,404	52,187	84,047	241,312 TL	22.53%	3.49	6-7 years
Region 1, 9 cm	-99,195	13,871	15,258	16,784	18,462	20,308	32,707	52,675	84,833	242,268 TL	22.31%	3.44	7-8 years
Region 1, 10 cm	-101,188	13,977	15,375	16,912	18,603	20,464	32,957	53,077	85,481	242,883 TL	22.10%	3.40	7-8 years
Region 1, 11 cm	-104,801	14,066	15,472	17,019	18,721	20,594	33,166	53,414	86,024	241,455 TL	21.62%	3.30	7-8 years
Region 1, 12 cm	-107,037	14,141	15,555	17,111	18,822	20,704	33,344	53,701	86,486	241,075 TL	21.36%	3.25	7-8 years
Region 1, 13 cm	-109,231	14,206	15,627	17,189	18,908	20,799	33,497	53,947	86,883	240,480 TL	21.11%	3.20	7-8 years
Region 1, 14 cm	-111,969	14,262	15,689	17,258	18,983	20,882	33,630	54,162	87,228	239,131 TL	20.77%	3.14	7-8 years
Region 1, 15 cm	-114,378	14,312	15,743	17,317	19,049	20,954	33,747	54,350	87,531	237,942 TL	20.49%	3.08	7-8 years
Region 1, 16 cm	-116,744	14,356	15,791	17,370	19,108	21,018	33,850	54,516	87,798	236,654 TL	20.21%	3.03	7-8 years
Region 1, 17 cm	-119,432	14,395	15,834	17,418	19,159	21,075	33,942	54,664	88,037	234,925 TL	19.90%	2.97	8-9 years
Region 1, 18 cm	-121,747	14,430	15,873	17,460	19,206	21,127	34,025	54,797	88,251	233,471 TL	19.65%	2.92	8-9 years
Region 1, 19 cm	-124,665	14,461	15,907	17,498	19,248	21,173	34,099	54,917	88,444	231,332 TL	19.32%	2.86	8-9 years
Region 1, 20 cm	-126,694	14,490	15,939	17,533	19,286	21,215	34,166	55,025	88,619	230,005 TL	19.11%	2.82	8-9 years
Region 2, 5 cm	-90,088	23,472	25,819	28,401	31,241	34,365	55,346	89,135	143,553	487,727 TL	35.66%	6.41	3-4 years
Region 2, 6 cm	-92,081	23,977	26,375	29,012	31,913	35,105	56,536	91,053	146,641	498,163 TL	35.65%	6.41	3-4 years
Region 2, 7 cm	-94,635	24,362	26,799	29,478	32,426	35,669	57,445	92,516	148,998	505,096 TL	35.34%	6.34	3-4 years
Region 2, 8 cm	-96,986	24,666	27,133	29,846	32,831	36,114	58,161	93,670	150,856	510,223 TL	35.01%	6.26	4-5 years
Region 2, 9 cm	-99,195	24,912	27,403	30,143	33,157	36,473	58,741	94,602	152,358	514,060 TL	34.68%	6.18	4-5 years
Region 2, 10 cm	-101,188	25,114	27,626	30,388	33,427	36,770	59,218	95,372	153,597	517,056 TL	34.37%	6.11	4-5 years
Region 2, 11 cm	-104,801	25,284	27,813	30,594	33,654	37,019	59,619	96,018	154,637	517,629 TL	33.63%	5.94	4-5 years
Region 2, 12 cm	-107,037	25,429	27,972	30,769	33,846	37,231	59,961	96,567	155,522	518,954 TL	33.24%	5.85	4-5 years
Region 2, 13 cm	-109,231	25,554	28,109	30,920	34,012	37,413	60,255	97,041	156,285	519,831 TL	32.86%	5.76	4-5 years
Region 2, 14 cm	-111,969	25,662	28,229	31,052	34,157	37,572	60,511	97,453	156,949	519,766 TL	32.35%	5.64	4-5 years
Region 2, 15 cm	-114,378	25,758	28,334	31,167	34,284	37,712	60,736	97,815	157,532	519,705 TL	31.93%	5.54	4-5 years
Region 2, 16 cm	-116,744	25,842	28,426	31,269	34,396	37,836	60,935	98,136	158,049	519,418 TL	31.51%	5.45	4-5 years
Region 2, 17 cm	-119,432	25,918	28,509	31,360	34,496	37,946	61,112	98,422	158,509	518,583 TL	31.05%	5.34	4-5 years
Region 2, 18 cm	-121,747	25,985	28,583	31,442	34,586	38,045	61,271	98,678	158,922	517,929 TL	30.66%	5.25	4-5 years
Region 2, 19 cm	-124,665	26,046	28,650	31,515	34,667	38,134	61,415	98,909	159,294	516,509 TL	30.17%	5.14	4-5 years
Region 2, 20 cm	-126,694	26,101	28,711	31,582	34,741	38,215	61,545	99,119	159,632	515,843 TL	29.86%	5.07	4-5 years
Region 3, 6 cm	-92,081	32,507	35,757	39,333	43,266	47,593	76,649	123,444	198,808	708,139 TL	45.16%	8.69	2-3 years
Region 3, 7 cm	-94,635	33,034	36,338	39,971	43,969	48,365	77,893	125,447	202,034	718,574 TL	44.76%	8.59	2-3 years
Region 3, 8 cm	-96,986	33,451	36,796	40,475	44,523	48,975	78,875	127,029	204,581	726,472 TL	44.34%	8.49	3-4 years
Region 3, 9 cm	-99,195	33,788	37,166	40,883	44,971	49,468	79,669	128,308	206,642	732,559 TL	43.90%	8.39	3-4 years
Region 3, 10 cm	-101,188	34,066	37,472	41,220	45,342	49,876	80,325	129,365	208,343	737,414 TL	43.50%	8.29	3-4 years
Region 3, 11 cm	-104,801	34,299	37,729	41,502	45,653	50,218	80,876	130,252	209,773	739,554 TL	42.54%	8.06	3-4 years
Region 3, 12 cm	-107,037	34,499	37,948	41,743	45,918	50,509	81,346	131,008	210,990	742,217 TL	42.04%	7.93	3-4 years
Region 3, 13 cm	-109,231	34,670	38,137	41,951	46,146	50,760	81,750	131,659	212,039	744,246 TL	41.53%	7.81	3-4 years
Region 3, 14 cm	-111,969	34,819	38,301	42,131	46,345	50,979	82,102	132,227	212,952	745,184 TL	40.88%	7.66	3-4 years
Region 3, 15 cm	-114,378	34,951	38,446	42,290	46,519	51,171	82,412	132,725	213,755	746,006 TL	40.32%	7.52	3-4 years
Region 3, 16 cm	-116,744	35,067	38,574	42,431	46,674	51,341	82,686	133,167	214,466	746,503 TL	39.79%	7.39	3-4 years
Region 3, 17 cm	-119,432	35,171	38,688	42,556	46,812	51,493	82,930	133,560	215,100	746,367 TL	39.18%	7.25	3-4 years
Region 3, 18 cm	-121,747	35,264	38,790	42,669	46,936	51,629	83,150	133,913	215,669	746,340 TL	38.68%	7.13	3-4 years
Region 3, 19 cm	-124,665	35,348	38,882	42,770	47,048	51,752	83,348	134,232	216,182	745,489 TL	38.05%	6.98	3-4 years
Region 3, 20 cm	-126,694	35,424	38,966	42,863	47,149	51,864	83,527	134,521	216,648	745,335 TL	37.64%	6.88	3-4 years
Region 4, 8 cm	-96,986	42,507	46,757	51,433	56,576	62,234	100,228	161,419	259,966	949,404 TL	53.77%	10.79	2-3 years
Region 4, 9 cm	-99,195	42,944	47,238	51,962	57,158	62,874	101,259	163,079	262,640	957,957 TL	53.24%	10.66	2-3 years
Region 4, 10 cm	-101,188	43,305	47,636	52,399	57,639	63,403	102,111	164,451	264,850	964,858 TL	52.74%	10.54	2-3 years
Region 4, 11 cm	-104,801	43,711	48,083	52,891	58,180	63,998	103,069	165,994	267,335	971,249 TL	51.64%	10.27	2-3 years
Region 4, 12 cm	-107,037	43,968	48,365	53,202	58,522	64,374	103,675	166,970	268,906	975,336 TL	51.00%	10.11	2-3 years
Region 4, 13 cm	-109,231	44,190	48,609	53,470	58,817	64,699	104,198	167,811	270,262	978,599 TL	50.38%	9.96	2-3 years
Region 4, 14 cm	-111,969	44,383	48,821	53,704	59,074	64,981	104,653	168,545	271,443	980,616 TL	49.55%	9.76	2-3 years
Region 4, 15 cm	-114,378	44,553	49,008	53,909	59,300	65,230	105,053	169,189	272,481	982,385 TL	48.86%	9.59	2-3 years
Region 4, 16 cm	-116,744	44,703	49,173	54,091	59,500	65,450	105,408	169,760	273,401	983,720 TL	48.19%	9.43	2-3 years
Region 4, 17 cm	-119,432	44,837	49,321	54,253	59,679	65,646	105,724	170,270	274,221	984,336 TL	47.44%	9.24	2-3 years
Region 4, 18 cm	-121,747	44,958	49,454	54,399	59,839	65,823	106,008	170,727	274,958	984,984 TL	46.81%	9.09	2-3 years
Region 4, 19 cm	-124,665	45,067	49,573	54,530	59,984	65,982	106,264	171,140	275,623	984,743 TL	46.02%	8.90	2-3 years
Region 4, 20 cm	-126,694	45,165	49,682	54,650	60,115	66,126	106,497	171,515	276,226	985,142 TL	45.52%	8.78	2-3 years

Table C.4. Cash Flow Diagram for Discount Rate 7% and Escalation Rate 12%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1155	0.1293	0.1448	0.1622	0.1817	0.3202	0.5643	0.9944				
Region 1, 4 cm	-87,809	12,868	14,412	16,142	18,079	20,248	35,684	62,888	110,831	296,380 TL	25.03%	4.38	6-7 years
Region 1, 5 cm	-90,088	13,238	14,827	16,606	18,599	20,830	36,710	64,696	114,017	305,146 TL	25.08%	4.39	6-7 years
Region 1, 6 cm	-92,081	13,508	15,128	16,944	18,977	21,254	37,458	66,013	116,337	311,197 TL	25.05%	4.38	6-7 years
Region 1, 7 cm	-94,635	13,712	15,358	17,201	19,265	21,577	38,025	67,013	118,100	314,755 TL	24.84%	4.33	6-7 years
Region 1, 8 cm	-96,986	13,873	15,538	17,403	19,491	21,830	38,472	67,800	119,487	317,210 TL	24.61%	4.27	6-7 years
Region 1, 9 cm	-99,195	14,003	15,683	17,565	19,673	22,034	38,832	68,434	120,605	318,876 TL	24.38%	4.21	6-7 years
Region 1, 10 cm	-101,188	14,110	15,803	17,700	19,824	22,202	39,128	68,957	121,526	320,077 TL	24.17%	4.16	6-7 years
Region 1, 11 cm	-104,801	14,200	15,904	17,812	19,949	22,343	39,377	69,395	122,298	319,139 TL	23.69%	4.05	6-7 years
Region 1, 12 cm	-107,037	14,276	15,989	17,908	20,056	22,463	39,588	69,767	122,954	319,175 TL	23.43%	3.98	6-7 years
Region 1, 13 cm	-109,231	14,341	16,062	17,990	20,149	22,566	39,770	70,088	123,518	318,939 TL	23.17%	3.92	7-8 years
Region 1, 14 cm	-111,969	14,398	16,126	18,061	20,229	22,656	39,928	70,366	124,009	317,901 TL	22.83%	3.84	7-8 years
Region 1, 15 cm	-114,378	14,448	16,182	18,124	20,299	22,735	40,066	70,610	124,440	316,986 TL	22.54%	3.77	7-8 years
Region 1, 16 cm	-116,744	14,492	16,232	18,179	20,361	22,804	40,189	70,826	124,820	315,940 TL	22.26%	3.71	7-8 years
Region 1, 17 cm	-119,432	14,532	16,276	18,229	20,416	22,866	40,298	71,019	125,159	314,426 TL	21.95%	3.63	7-8 years
Region 1, 18 cm	-121,747	14,567	16,315	18,273	20,466	22,922	40,396	71,191	125,463	313,165 TL	21.69%	3.57	7-8 years
Region 1, 19 cm	-124,665	14,599	16,351	18,313	20,511	22,972	40,484	71,347	125,738	311,201 TL	21.36%	3.50	7-8 years
Region 1, 20 cm	-126,694	14,628	16,383	18,349	20,551	23,017	40,564	71,488	125,986	310,031 TL	21.14%	3.45	7-8 years
Region 2, 5 cm	-90,088	23,696	26,539	29,724	33,291	37,286	65,710	115,803	204,085	617,361 TL	37.89%	7.85	3-4 years
Region 2, 6 cm	-92,081	24,205	27,110	30,363	34,007	38,088	67,123	118,294	208,475	630,586 TL	37.88%	7.85	3-4 years
Region 2, 7 cm	-94,635	24,594	27,546	30,851	34,553	38,700	68,202	120,195	211,825	639,647 TL	37.56%	7.76	3-4 years
Region 2, 8 cm	-96,986	24,901	27,889	31,236	34,984	39,182	69,053	121,694	214,467	646,452 TL	37.23%	7.67	3-4 years
Region 2, 9 cm	-99,195	25,149	28,167	31,547	35,332	39,572	69,740	122,906	216,602	651,645 TL	36.90%	7.57	3-4 years
Region 2, 10 cm	-101,188	25,354	28,396	31,803	35,620	39,894	70,307	123,906	218,364	655,760 TL	36.58%	7.48	3-4 years
Region 2, 11 cm	-104,801	25,525	28,588	32,019	35,861	40,164	70,783	124,745	219,843	657,273 TL	35.84%	7.27	4-5 years
Region 2, 12 cm	-107,037	25,671	28,752	32,202	36,066	40,394	71,189	125,458	221,101	659,397 TL	35.45%	7.16	4-5 years
Region 2, 13 cm	-109,231	25,797	28,893	32,360	36,243	40,592	71,538	126,074	222,185	660,963 TL	35.06%	7.05	4-5 years
Region 2, 14 cm	-111,969	25,907	29,016	32,498	36,397	40,765	71,842	126,610	223,129	661,498 TL	34.55%	6.91	4-5 years
Region 2, 15 cm	-114,378	26,003	29,123	32,618	36,533	40,916	72,109	127,080	223,959	661,964 TL	34.12%	6.79	4-5 years
Region 2, 16 cm	-116,744	26,088	29,219	32,725	36,652	41,051	72,345	127,497	224,693	662,143 TL	33.70%	6.67	4-5 years
Region 2, 17 cm	-119,432	26,164	29,304	32,821	36,759	41,170	72,556	127,868	225,347	661,724 TL	33.23%	6.54	4-5 years
Region 2, 18 cm	-121,747	26,232	29,380	32,906	36,855	41,277	72,745	128,201	225,934	661,442 TL	32.84%	6.43	4-5 years
Region 2, 19 cm	-124,665	26,294	29,449	32,983	36,941	41,374	72,915	128,501	226,463	660,358 TL	32.34%	6.30	4-5 years
Region 2, 20 cm	-126,694	26,350	29,512	33,053	37,020	41,462	73,070	128,774	226,944	659,997 TL	32.02%	6.21	4-5 years
Region 3, 6 cm	-92,081	32,816	36,754	41,165	46,104	51,637	91,002	160,377	282,638	887,670 TL	47.49%	10.64	2-3 years
Region 3, 7 cm	-94,635	33,349	37,351	41,833	46,853	52,475	92,479	162,980	287,226	901,019 TL	47.09%	10.52	2-3 years
Region 3, 8 cm	-96,986	33,769	37,822	42,360	47,443	53,136	93,645	165,034	290,846	911,218 TL	46.66%	10.40	2-3 years
Region 3, 9 cm	-99,195	34,109	38,203	42,787	47,921	53,672	94,588	166,696	293,776	919,165 TL	46.22%	10.27	2-3 years
Region 3, 10 cm	-101,188	34,390	38,517	43,139	48,316	54,114	95,367	168,069	296,195	925,557 TL	45.81%	10.15	3-4 years
Region 3, 11 cm	-104,801	34,626	38,781	43,435	48,647	54,485	96,021	169,222	298,227	928,987 TL	44.85%	9.86	3-4 years
Region 3, 12 cm	-107,037	34,827	39,006	43,687	48,930	54,801	96,578	170,204	299,957	932,750 TL	44.33%	9.71	3-4 years
Region 3, 13 cm	-109,231	35,000	39,200	43,904	49,173	55,074	97,058	171,050	301,449	935,726 TL	43.83%	9.57	3-4 years
Region 3, 14 cm	-111,969	35,151	39,369	44,093	49,385	55,311	97,477	171,787	302,747	937,489 TL	43.16%	9.37	3-4 years
Region 3, 15 cm	-114,378	35,283	39,518	44,260	49,571	55,519	97,844	172,434	303,888	939,035 TL	42.60%	9.21	3-4 years
Region 3, 16 cm	-116,744	35,401	39,649	44,407	49,736	55,704	98,169	173,008	304,899	940,175 TL	42.06%	9.05	3-4 years
Region 3, 17 cm	-119,432	35,506	39,766	44,538	49,883	55,869	98,460	173,520	305,801	940,612 TL	41.45%	8.88	3-4 years
Region 3, 18 cm	-121,747	35,599	39,871	44,656	50,015	56,016	98,720	173,978	306,609	941,098 TL	40.95%	8.73	3-4 years
Region 3, 19 cm	-124,665	35,684	39,966	44,762	50,134	56,150	98,955	174,392	307,339	940,711 TL	40.31%	8.55	3-4 years
Region 3, 20 cm	-126,694	35,761	40,052	44,859	50,242	56,271	99,168	174,768	308,001	940,977 TL	39.90%	8.43	3-4 years
Region 4, 8 cm	-96,986	42,911	48,061	53,828	60,287	67,522	118,997	209,713	369,586	1,184,164 TL	56.19%	13.21	2-3 years
Region 4, 9 cm	-99,195	43,353	48,555	54,382	60,907	68,216	120,221	211,870	373,387	1,195,132 TL	55.64%	13.05	2-3 years
Region 4, 10 cm	-101,188	43,717	48,964	54,839	61,420	68,790	121,232	213,652	376,528	1,204,028 TL	55.14%	12.90	2-3 years
Region 4, 11 cm	-104,801	44,128	49,423	55,354	61,996	69,436	122,370	215,657	380,062	1,212,664 TL	54.03%	12.57	2-3 years
Region 4, 12 cm	-107,037	44,387	49,714	55,679	62,361	69,844	123,089	216,925	382,295	1,218,170 TL	53.39%	12.38	2-3 years
Region 4, 13 cm	-109,231	44,611	49,964	55,960	62,675	70,196	123,709	218,018	384,223	1,222,657 TL	52.76%	12.19	2-3 years
Region 4, 14 cm	-111,969	44,806	50,183	56,204	62,949	70,503	124,250	218,971	385,902	1,225,741 TL	51.93%	11.95	2-3 years
Region 4, 15 cm	-114,378	44,977	50,374	56,419	63,190	70,772	124,725	219,808	387,377	1,228,447 TL	51.23%	11.74	2-3 years
Region 4, 16 cm	-116,744	45,129	50,544	56,610	63,403	71,011	125,146	220,550	388,685	1,230,612 TL	50.55%	11.54	2-3 years
Region 4, 17 cm	-119,432	45,264	50,696	56,780	63,593	71,224	125,522	221,212	389,852	1,231,970 TL	49.79%	11.32	2-3 years
Region 4, 18 cm	-121,747	45,386	50,832	56,932	63,764	71,416	125,859	221,806	390,898	1,233,283 TL	49.16%	11.13	2-3 years
Region 4, 19 cm	-124,665	45,496	50,955	57,070	63,918	71,588	126,163	222,343	391,844	1,233,642 TL	48.36%	10.90	2-3 years
Region 4, 20 cm	-126,694	45,595	51,067	57,195	64,058	71,745	126,439	222,829	392,701	1,234,586 TL	47.85%	10.74	2-3 years

Table C.5. Cash Flow Diagram for Discount Rate 9% and Escalation Rate 7%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1103	0.1180	0.1263	0.1351	0.1446	0.2028	0.2844	0.3989				
Region 1, 4 cm	-87,809	12,565	13,444	14,385	15,392	16,470	23,100	32,398	45,441	106,648 TL	19.82%	2.21	8-9 years
Region 1, 5 cm	-90,088	12,926	13,831	14,799	15,835	16,943	23,764	33,330	46,747	109,959 TL	19.87%	2.22	8-9 years
Region 1, 6 cm	-92,081	13,189	14,112	15,100	16,157	17,288	24,247	34,008	47,698	112,037 TL	19.84%	2.22	8-9 years
Region 1, 7 cm	-94,635	13,389	14,326	15,329	16,402	17,550	24,615	34,524	48,421	112,577 TL	19.63%	2.19	8-9 years
Region 1, 8 cm	-96,986	13,546	14,494	15,509	16,595	17,756	24,904	34,929	48,990	112,659 TL	19.41%	2.16	8-9 years
Region 1, 9 cm	-99,195	13,673	14,630	15,654	16,750	17,922	25,137	35,256	49,448	112,411 TL	19.19%	2.13	8-9 years
Region 1, 10 cm	-101,188	13,777	14,742	15,774	16,878	18,059	25,329	35,525	49,826	112,035 TL	18.99%	2.11	8-9 years
Region 1, 11 cm	-104,801	13,865	14,835	15,874	16,985	18,174	25,490	35,751	50,142	109,776 TL	18.52%	2.05	8-9 years
Region 1, 12 cm	-107,037	13,939	14,915	15,959	17,076	18,271	25,626	35,942	50,411	108,689 TL	18.26%	2.02	9-10 years
Region 1, 13 cm	-109,231	14,003	14,983	16,032	17,154	18,355	25,744	36,107	50,643	107,487 TL	18.01%	1.98	9-10 years
Region 1, 14 cm	-111,969	14,059	15,043	16,096	17,222	18,428	25,846	36,251	50,844	105,609 TL	17.68%	1.94	9-10 years
Region 1, 15 cm	-114,378	14,108	15,095	16,152	17,282	18,492	25,936	36,377	51,020	103,956 TL	17.41%	1.91	9-10 years
Region 1, 16 cm	-116,744	14,151	15,141	16,201	17,335	18,549	26,015	36,488	51,176	102,258 TL	17.14%	1.88	9-10 years
Region 1, 17 cm	-119,432	14,189	15,182	16,245	17,382	18,599	26,086	36,587	51,315	100,165 TL	16.83%	1.84	9-10 years
Region 1, 18 cm	-121,747	14,224	15,219	16,285	17,425	18,644	26,149	36,676	51,440	98,383 TL	16.58%	1.81	10-11 years
Region 1, 19 cm	-124,665	14,255	15,253	16,320	17,463	18,685	26,207	36,756	51,553	95,948 TL	16.26%	1.77	10-11 years
Region 1, 20 cm	-126,694	14,283	15,283	16,352	17,497	18,722	26,258	36,829	51,654	94,354 TL	16.05%	1.74	10-11 years
Region 2, 5 cm	-90,088	23,137	24,756	26,489	28,344	30,328	42,536	59,659	83,675	267,986 TL	32.31%	3.97	4-5 years
Region 2, 6 cm	-92,081	23,634	25,289	27,059	28,953	30,980	43,451	60,942	85,475	273,696 TL	32.30%	3.97	4-5 years
Region 2, 7 cm	-94,635	24,014	25,695	27,494	29,419	31,478	44,149	61,922	86,848	277,021 TL	31.99%	3.93	4-5 years
Region 2, 8 cm	-96,986	24,314	26,016	27,837	29,785	31,870	44,700	62,694	87,931	279,304 TL	31.67%	3.88	4-5 years
Region 2, 9 cm	-99,195	24,556	26,275	28,114	30,082	32,188	45,145	63,318	88,807	280,842 TL	31.34%	3.83	4-5 years
Region 2, 10 cm	-101,188	24,756	26,488	28,343	30,327	32,450	45,512	63,833	89,529	281,940 TL	31.04%	3.79	4-5 years
Region 2, 11 cm	-104,801	24,923	26,668	28,535	30,532	32,669	45,820	64,265	90,136	280,922 TL	30.32%	3.68	4-5 years
Region 2, 12 cm	-107,037	25,066	26,820	28,698	30,707	32,856	46,083	64,633	90,651	280,892 TL	29.94%	3.62	4-5 years
Region 2, 13 cm	-109,231	25,189	26,952	28,839	30,857	33,017	46,309	64,950	91,096	280,601 TL	29.56%	3.57	4-5 years
Region 2, 14 cm	-111,969	25,296	27,067	28,961	30,988	33,158	46,505	65,226	91,483	279,520 TL	29.06%	3.50	5-6 years
Region 2, 15 cm	-114,378	25,390	27,167	29,069	31,104	33,281	46,678	65,469	91,823	278,566 TL	28.64%	3.44	5-6 years
Region 2, 16 cm	-116,744	25,473	27,256	29,164	31,206	33,390	46,831	65,683	92,124	277,489 TL	28.24%	3.38	5-6 years
Region 2, 17 cm	-119,432	25,547	27,336	29,249	31,297	33,487	46,968	65,875	92,392	275,949 TL	27.78%	3.31	5-6 years
Region 2, 18 cm	-121,747	25,614	27,407	29,325	31,378	33,574	47,090	66,046	92,633	274,663 TL	27.40%	3.26	5-6 years
Region 2, 19 cm	-124,665	25,674	27,471	29,394	31,451	33,653	47,200	66,201	92,850	272,674 TL	26.92%	3.19	5-6 years
Region 2, 20 cm	-126,694	25,728	27,529	29,456	31,518	33,725	47,300	66,341	93,047	271,489 TL	26.61%	3.14	5-6 years
Region 3, 6 cm	-92,081	32,042	34,285	36,685	39,253	42,001	58,908	82,622	115,882	403,819 TL	41.67%	5.39	3-4 years
Region 3, 7 cm	-94,635	32,562	34,842	37,281	39,890	42,683	59,865	83,963	117,763	409,314 TL	41.28%	5.33	3-4 years
Region 3, 8 cm	-96,986	32,973	35,281	37,751	40,393	43,221	60,619	85,021	119,247	413,315 TL	40.86%	5.26	3-4 years
Region 3, 9 cm	-99,195	33,305	35,636	38,131	40,800	43,656	61,230	85,878	120,448	416,247 TL	40.43%	5.20	3-4 years
Region 3, 10 cm	-101,188	33,579	35,930	38,445	41,136	44,015	61,734	86,585	121,440	418,498 TL	40.03%	5.14	3-4 years
Region 3, 11 cm	-104,801	33,809	36,176	38,708	41,418	44,317	62,157	87,179	122,273	418,450 TL	39.09%	4.99	3-4 years
Region 3, 12 cm	-107,037	34,006	36,386	38,933	41,658	44,575	62,518	87,685	122,983	419,250 TL	38.59%	4.92	3-4 years
Region 3, 13 cm	-109,231	34,175	36,567	39,127	41,866	44,796	62,829	88,121	123,594	419,672 TL	38.10%	4.84	3-4 years
Region 3, 14 cm	-111,969	34,322	36,725	39,295	42,046	44,989	63,100	88,500	124,126	419,213 TL	37.45%	4.74	3-4 years
Region 3, 15 cm	-114,378	34,451	36,863	39,443	42,204	45,159	63,337	88,834	124,594	418,806 TL	36.90%	4.66	3-4 years
Region 3, 16 cm	-116,744	34,566	36,986	39,575	42,345	45,309	63,548	89,130	125,009	418,214 TL	36.38%	4.58	3-4 years
Region 3, 17 cm	-119,432	34,668	37,095	39,692	42,470	45,443	63,736	89,393	125,378	417,108 TL	35.78%	4.49	3-4 years
Region 3, 18 cm	-121,747	34,760	37,193	39,796	42,582	45,563	63,904	89,629	125,710	416,211 TL	35.29%	4.42	3-4 years
Region 3, 19 cm	-124,665	34,843	37,282	39,891	42,684	45,671	64,057	89,843	126,009	414,574 TL	34.67%	4.33	4-5 years
Region 3, 20 cm	-126,694	34,918	37,362	39,977	42,776	45,770	64,195	90,036	126,280	413,706 TL	34.27%	4.27	4-5 years
Region 4, 8 cm	-96,986	41,899	44,832	47,971	51,328	54,921	77,030	108,039	151,530	551,467 TL	50.15%	6.69	2-3 years
Region 4, 9 cm	-99,195	42,330	45,293	48,464	51,856	55,486	77,822	109,150	153,089	555,927 TL	49.62%	6.60	2-3 years
Region 4, 10 cm	-101,188	42,686	45,674	48,872	52,293	55,953	78,477	110,068	154,377	559,445 TL	49.13%	6.53	2-3 years
Region 4, 11 cm	-104,801	43,087	46,103	49,330	52,783	56,478	79,214	111,101	155,825	562,032 TL	48.05%	6.36	2-3 years
Region 4, 12 cm	-107,037	43,340	46,374	49,620	53,094	56,810	79,679	111,754	156,741	563,715 TL	47.42%	6.27	2-3 years
Region 4, 13 cm	-109,231	43,559	46,608	49,870	53,361	57,097	80,081	112,318	157,531	564,902 TL	46.81%	6.17	2-3 years
Region 4, 14 cm	-111,969	43,749	46,812	50,088	53,595	57,346	80,431	112,809	158,220	565,111 TL	45.99%	6.05	2-3 years
Region 4, 15 cm	-114,378	43,916	46,991	50,280	53,799	57,565	80,738	113,240	158,825	565,291 TL	45.31%	5.94	2-3 years
Region 4, 16 cm	-116,744	44,065	47,149	50,450	53,981	57,760	81,011	113,622	159,361	565,219 TL	44.65%	5.84	2-3 years
Region 4, 17 cm	-119,432	44,197	47,291	50,601	54,143	57,933	81,254	113,963	159,839	564,578 TL	43.91%	5.73	3-4 years
Region 4, 18 cm	-121,747	44,316	47,418	50,737	54,288	58,089	81,472	114,269	160,268	564,099 TL	43.29%	5.63	3-4 years
Region 4, 19 cm	-124,665	44,423	47,532	50,860	54,420	58,229	81,669	114,545	160,656	562,840 TL	42.52%	5.51	3-4 years
Region 4, 20 cm	-126,694	44,520	47,636	50,971	54,539	58,357	81,848	114,796	161,008	562,316 TL	42.02%	5.44	3-4 years

Table C.6. Cash Flow Diagram for Discount Rate 9% and Escalation Rate 8.5%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1119	0.1214	0.1317	0.1429	0.1550	0.2331	0.3505	0.5270				
Region 1, 4 cm	-87,809	12,656	13,731	14,899	16,165	17,539	26,373	39,656	59,628	134,560 TL	21.39%	2.53	7-8 years
Region 1, 5 cm	-90,088	13,020	14,126	15,327	16,630	18,043	27,131	40,796	61,343	138,674 TL	21.43%	2.54	7-8 years
Region 1, 6 cm	-92,081	13,285	14,414	15,639	16,968	18,411	27,683	41,626	62,591	141,337 TL	21.40%	2.53	7-8 years
Region 1, 7 cm	-94,635	13,486	14,632	15,876	17,225	18,690	28,103	42,257	63,540	142,321 TL	21.19%	2.50	7-8 years
Region 1, 8 cm	-96,986	13,644	14,804	16,062	17,428	18,909	28,433	42,753	64,286	142,751 TL	20.97%	2.47	7-8 years
Region 1, 9 cm	-99,195	13,772	14,942	16,213	17,591	19,086	28,699	43,153	64,887	142,785 TL	20.75%	2.44	7-8 years
Region 1, 10 cm	-101,188	13,877	15,057	16,336	17,725	19,232	28,918	43,482	65,383	142,641 TL	20.54%	2.41	8-9 years
Region 1, 11 cm	-104,801	13,965	15,152	16,440	17,838	19,354	29,101	43,759	65,798	140,576 TL	20.07%	2.34	8-9 years
Region 1, 12 cm	-107,037	14,040	15,233	16,528	17,933	19,458	29,257	43,993	66,151	139,655 TL	19.81%	2.30	8-9 years
Region 1, 13 cm	-109,231	14,105	15,303	16,604	18,016	19,547	29,392	44,195	66,454	138,595 TL	19.56%	2.27	8-9 years
Region 1, 14 cm	-111,969	14,161	15,364	16,670	18,087	19,625	29,509	44,371	66,718	136,840 TL	19.23%	2.22	8-9 years
Region 1, 15 cm	-114,378	14,210	15,418	16,728	18,150	19,693	29,611	44,525	66,950	135,296 TL	18.95%	2.18	8-9 years
Region 1, 16 cm	-116,744	14,253	15,465	16,779	18,205	19,753	29,702	44,661	67,155	133,694 TL	18.68%	2.15	9-10 years
Region 1, 17 cm	-119,432	14,292	15,507	16,825	18,255	19,807	29,782	44,782	67,337	131,686 TL	18.37%	2.10	9-10 years
Region 1, 18 cm	-121,747	14,327	15,544	16,866	18,299	19,855	29,855	44,891	67,501	129,981 TL	18.11%	2.07	9-10 years
Region 1, 19 cm	-124,665	14,358	15,578	16,903	18,339	19,898	29,920	44,990	67,649	127,615 TL	17.79%	2.02	9-10 years
Region 1, 20 cm	-126,694	14,386	15,609	16,936	18,376	19,937	29,979	45,078	67,782	126,084 TL	17.58%	2.00	9-10 years
Region 2, 5 cm	-90,088	23,304	25,285	27,435	29,766	32,297	48,563	73,022	109,800	319,385 TL	33.99%	4.55	4-5 years
Region 2, 6 cm	-92,081	23,806	25,829	28,025	30,407	32,991	49,608	74,593	112,162	326,200 TL	33.97%	4.54	4-5 years
Region 2, 7 cm	-94,635	24,188	26,244	28,475	30,895	33,522	50,405	75,792	113,965	330,369 TL	33.67%	4.49	4-5 years
Region 2, 8 cm	-96,986	24,490	26,572	28,830	31,281	33,940	51,033	76,737	115,386	333,317 TL	33.34%	4.44	4-5 years
Region 2, 9 cm	-99,195	24,734	26,836	29,117	31,592	34,278	51,542	77,501	116,535	335,392 TL	33.01%	4.38	4-5 years
Region 2, 10 cm	-101,188	24,935	27,054	29,354	31,849	34,556	51,961	78,131	117,483	336,935 TL	32.70%	4.33	4-5 years
Region 2, 11 cm	-104,801	25,104	27,238	29,553	32,065	34,790	52,313	78,660	118,278	336,289 TL	31.98%	4.21	4-5 years
Region 2, 12 cm	-107,037	25,247	27,394	29,722	32,248	34,989	52,612	79,111	118,955	336,576 TL	31.59%	4.14	4-5 years
Region 2, 13 cm	-109,231	25,371	27,528	29,868	32,406	35,161	52,870	79,499	119,538	336,558 TL	31.21%	4.08	4-5 years
Region 2, 14 cm	-111,969	25,479	27,645	29,995	32,544	35,310	53,095	79,836	120,047	335,715 TL	30.71%	4.00	4-5 years
Region 2, 15 cm	-114,378	25,574	27,748	30,106	32,665	35,442	53,292	80,133	120,493	334,970 TL	30.28%	3.93	4-5 years
Region 2, 16 cm	-116,744	25,658	27,839	30,205	32,772	35,558	53,467	80,396	120,888	334,077 TL	29.88%	3.86	5-6 years
Region 2, 17 cm	-119,432	25,732	27,920	30,293	32,868	35,661	53,623	80,630	121,240	332,702 TL	29.41%	3.79	5-6 years
Region 2, 18 cm	-121,747	25,799	27,992	30,372	32,953	35,754	53,762	80,840	121,555	331,564 TL	29.03%	3.72	5-6 years
Region 2, 19 cm	-124,665	25,860	28,058	30,443	33,030	35,838	53,888	81,029	121,840	329,708 TL	28.54%	3.64	5-6 years
Region 2, 20 cm	-126,694	25,915	28,117	30,507	33,101	35,914	54,003	81,201	122,099	328,644 TL	28.23%	3.59	5-6 years
Region 3, 6 cm	-92,081	32,274	35,018	37,994	41,224	44,728	67,255	101,129	152,063	475,000 TL	43.42%	6.16	3-4 years
Region 3, 7 cm	-94,635	32,798	35,586	38,611	41,893	45,454	68,347	102,770	154,531	481,651 TL	43.02%	6.09	3-4 years
Region 3, 8 cm	-96,986	33,212	36,035	39,098	42,421	46,027	69,208	104,066	156,479	486,564 TL	42.60%	6.02	3-4 years
Region 3, 9 cm	-99,195	33,546	36,398	39,492	42,848	46,490	69,906	105,114	158,055	490,233 TL	42.17%	5.94	3-4 years
Region 3, 10 cm	-101,188	33,822	36,697	39,817	43,201	46,873	70,481	105,979	159,357	493,094 TL	41.77%	5.87	3-4 years
Region 3, 11 cm	-104,801	34,054	36,949	40,090	43,497	47,195	70,965	106,706	160,450	493,557 TL	40.82%	5.71	3-4 years
Region 3, 12 cm	-107,037	34,252	37,164	40,322	43,750	47,469	71,376	107,326	161,381	494,793 TL	40.31%	5.62	3-4 years
Region 3, 13 cm	-109,231	34,422	37,348	40,523	43,967	47,705	71,731	107,859	162,183	495,591 TL	39.82%	5.54	3-4 years
Region 3, 14 cm	-111,969	34,571	37,509	40,697	44,157	47,910	72,040	108,324	162,882	495,459 TL	39.16%	5.42	3-4 years
Region 3, 15 cm	-114,378	34,701	37,651	40,851	44,323	48,091	72,312	108,732	163,496	495,339 TL	38.61%	5.33	3-4 years
Region 3, 16 cm	-116,744	34,816	37,776	40,987	44,471	48,251	72,552	109,094	164,040	495,003 TL	38.08%	5.24	3-4 years
Region 3, 17 cm	-119,432	34,919	37,888	41,108	44,602	48,393	72,767	109,417	164,525	494,123 TL	37.48%	5.14	3-4 years
Region 3, 18 cm	-121,747	35,012	37,988	41,217	44,720	48,521	72,959	109,706	164,960	493,429 TL	36.99%	5.05	3-4 years
Region 3, 19 cm	-124,665	35,095	38,078	41,315	44,827	48,637	73,133	109,967	165,352	491,976 TL	36.36%	4.95	3-4 years
Region 3, 20 cm	-126,694	35,171	38,160	41,404	44,923	48,742	73,290	110,204	165,709	491,276 TL	35.96%	4.88	3-4 years
Region 4, 8 cm	-96,986	42,203	45,790	49,682	53,905	58,487	87,945	132,239	198,842	644,546 TL	51.96%	7.65	2-3 years
Region 4, 9 cm	-99,195	42,637	46,261	50,193	54,460	59,089	88,849	133,599	200,887	649,963 TL	51.43%	7.55	2-3 years
Region 4, 10 cm	-101,188	42,996	46,650	50,616	54,918	59,586	89,597	134,723	202,577	654,273 TL	50.93%	7.47	2-3 years
Region 4, 11 cm	-104,801	43,399	47,088	51,091	55,433	60,145	90,438	135,987	204,478	657,750 TL	49.85%	7.28	2-3 years
Region 4, 12 cm	-107,037	43,654	47,365	51,391	55,759	60,499	90,969	136,786	205,680	659,995 TL	49.21%	7.17	2-3 years
Region 4, 13 cm	-109,231	43,874	47,604	51,650	56,040	60,804	91,428	137,476	206,717	661,668 TL	48.59%	7.06	2-3 years
Region 4, 14 cm	-111,969	44,066	47,812	51,876	56,285	61,069	91,827	138,077	207,620	662,299 TL	47.77%	6.92	2-3 years
Region 4, 15 cm	-114,378	44,235	47,995	52,074	56,500	61,303	92,179	138,605	208,414	662,851 TL	47.09%	6.80	2-3 years
Region 4, 16 cm	-116,744	44,384	48,156	52,250	56,691	61,510	92,490	139,073	209,117	663,108 TL	46.42%	6.68	2-3 years
Region 4, 17 cm	-119,432	44,517	48,301	52,407	56,861	61,694	92,767	139,490	209,745	662,761 TL	45.67%	6.55	2-3 years
Region 4, 18 cm	-121,747	44,637	48,431	52,547	57,014	61,860	93,016	139,865	210,308	662,546 TL	45.05%	6.44	2-3 years
Region 4, 19 cm	-124,665	44,745	48,548	52,674	57,152	62,010	93,241	140,203	210,817	661,525 TL	44.27%	6.31	3-4 years
Region 4, 20 cm	-126,694	44,843	48,654	52,790	57,277	62,145	93,445	140,510	211,278	661,217 TL	43.77%	6.22	3-4 years

Table C.7. Cash Flow Diagram for Discount Rate 9% and Escalation Rate 10%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1134	0.1247	0.1372	0.1509	0.1660	0.2674	0.4306	0.6935				
Region 1, 4 cm	-87,809	12,747	14,021	15,424	16,966	18,663	30,056	48,406	77,958	167,629 TL	22.95%	2.91	7-8 years
Region 1, 5 cm	-90,088	13,113	14,425	15,867	17,454	19,199	30,920	49,798	80,199	172,693 TL	23.00%	2.92	7-8 years
Region 1, 6 cm	-92,081	13,380	14,718	16,190	17,809	19,590	31,550	50,811	81,832	176,048 TL	22.97%	2.91	7-8 years
Region 1, 7 cm	-94,635	13,583	14,941	16,435	18,079	19,887	32,028	51,581	83,072	177,558 TL	22.75%	2.88	7-8 years
Region 1, 8 cm	-96,986	13,742	15,117	16,628	18,291	20,120	32,404	52,187	84,047	178,403 TL	22.53%	2.84	7-8 years
Region 1, 9 cm	-99,195	13,871	15,258	16,784	18,462	20,308	32,707	52,675	84,833	178,770 TL	22.31%	2.80	7-8 years
Region 1, 10 cm	-101,188	13,977	15,375	16,912	18,603	20,464	32,957	53,077	85,481	178,901 TL	22.10%	2.77	7-8 years
Region 1, 11 cm	-104,801	14,066	15,472	17,019	18,721	20,594	33,166	53,414	86,024	177,066 TL	21.62%	2.69	7-8 years
Region 1, 12 cm	-107,037	14,141	15,555	17,111	18,822	20,704	33,344	53,701	86,486	176,341 TL	21.36%	2.65	7-8 years
Region 1, 13 cm	-109,231	14,206	15,627	17,189	18,908	20,799	33,497	53,947	86,883	175,449 TL	21.11%	2.61	8-9 years
Region 1, 14 cm	-111,969	14,262	15,689	17,258	18,983	20,882	33,630	54,162	87,228	173,841 TL	20.77%	2.55	8-9 years
Region 1, 15 cm	-114,378	14,312	15,743	17,317	19,049	20,954	33,747	54,350	87,531	172,425 TL	20.49%	2.51	8-9 years
Region 1, 16 cm	-116,744	14,356	15,791	17,370	19,108	21,018	33,850	54,516	87,798	170,937 TL	20.21%	2.46	8-9 years
Region 1, 17 cm	-119,432	14,395	15,834	17,418	19,159	21,075	33,942	54,664	88,037	169,030 TL	19.90%	2.42	8-9 years
Region 1, 18 cm	-121,747	14,430	15,873	17,460	19,206	21,127	34,025	54,797	88,251	167,415 TL	19.65%	2.38	8-9 years
Region 1, 19 cm	-124,665	14,461	15,907	17,498	19,248	21,173	34,099	54,917	88,444	165,132 TL	19.32%	2.32	9-10 years
Region 1, 20 cm	-126,694	14,490	15,939	17,533	19,286	21,215	34,166	55,025	88,619	163,674 TL	19.11%	2.29	9-10 years
Region 2, 5 cm	-90,088	23,472	25,819	28,401	31,241	34,365	55,346	89,135	143,553	380,278 TL	35.66%	5.22	4-5 years
Region 2, 6 cm	-92,081	23,977	26,375	29,012	31,913	35,105	56,536	91,053	146,641	388,403 TL	35.65%	5.22	4-5 years
Region 2, 7 cm	-94,635	24,362	26,799	29,478	32,426	35,669	57,445	92,516	148,998	393,571 TL	35.34%	5.16	4-5 years
Region 2, 8 cm	-96,986	24,666	27,133	29,846	32,831	36,114	58,161	93,670	150,856	397,308 TL	35.01%	5.10	4-5 years
Region 2, 9 cm	-99,195	24,912	27,403	30,143	33,157	36,473	58,741	94,602	152,358	400,020 TL	34.68%	5.03	4-5 years
Region 2, 10 cm	-101,188	25,114	27,626	30,388	33,427	36,770	59,218	95,372	153,597	402,088 TL	34.37%	4.97	4-5 years
Region 2, 11 cm	-104,801	25,284	27,813	30,594	33,654	37,019	59,619	96,018	154,637	401,883 TL	33.63%	4.83	4-5 years
Region 2, 12 cm	-107,037	25,429	27,972	30,769	33,846	37,231	59,961	96,567	155,522	402,546 TL	33.24%	4.76	4-5 years
Region 2, 13 cm	-109,231	25,554	28,109	30,920	34,012	37,413	60,255	97,041	156,285	402,852 TL	32.86%	4.69	4-5 years
Region 2, 14 cm	-111,969	25,662	28,229	31,052	34,157	37,572	60,511	97,453	156,949	402,290 TL	32.35%	4.59	4-5 years
Region 2, 15 cm	-114,378	25,758	28,334	31,167	34,284	37,712	60,736	97,815	157,532	401,792 TL	31.93%	4.51	4-5 years
Region 2, 16 cm	-116,744	25,842	28,426	31,269	34,396	37,836	60,935	98,136	158,049	401,119 TL	31.51%	4.44	4-5 years
Region 2, 17 cm	-119,432	25,918	28,509	31,360	34,496	37,946	61,112	98,422	158,509	399,939 TL	31.05%	4.35	4-5 years
Region 2, 18 cm	-121,747	25,985	28,583	31,442	34,586	38,045	61,271	98,678	158,922	398,976 TL	30.66%	4.28	5-6 years
Region 2, 19 cm	-124,665	26,046	28,650	31,515	34,667	38,134	61,415	98,909	159,294	397,278 TL	30.17%	4.19	5-6 years
Region 2, 20 cm	-126,694	26,101	28,711	31,582	34,741	38,215	61,545	99,119	159,632	396,358 TL	29.86%	4.13	5-6 years
Region 3, 6 cm	-92,081	32,507	35,757	39,333	43,266	47,593	76,649	123,444	198,808	559,331 TL	45.16%	7.07	3-4 years
Region 3, 7 cm	-94,635	33,034	36,338	39,971	43,969	48,365	77,893	125,447	202,034	567,351 TL	44.76%	7.00	3-4 years
Region 3, 8 cm	-96,986	33,451	36,796	40,475	44,523	48,975	78,875	127,029	204,581	573,344 TL	44.34%	6.91	3-4 years
Region 3, 9 cm	-99,195	33,788	37,166	40,883	44,971	49,468	79,669	128,308	206,642	577,888 TL	43.90%	6.83	3-4 years
Region 3, 10 cm	-101,188	34,066	37,472	41,220	45,342	49,876	80,325	129,365	208,343	581,470 TL	43.50%	6.75	3-4 years
Region 3, 11 cm	-104,801	34,299	37,729	41,502	45,653	50,218	80,876	130,252	209,773	582,539 TL	42.54%	6.56	3-4 years
Region 3, 12 cm	-107,037	34,499	37,948	41,743	45,918	50,509	81,346	131,008	210,990	584,292 TL	42.04%	6.46	3-4 years
Region 3, 13 cm	-109,231	34,670	38,137	41,951	46,146	50,760	81,750	131,659	212,039	585,535 TL	41.53%	6.36	3-4 years
Region 3, 14 cm	-111,969	34,819	38,301	42,131	46,345	50,979	82,102	132,227	212,952	585,790 TL	40.88%	6.23	3-4 years
Region 3, 15 cm	-114,378	34,951	38,446	42,290	46,519	51,171	82,412	132,725	213,755	586,011 TL	40.32%	6.12	3-4 years
Region 3, 16 cm	-116,744	35,067	38,574	42,431	46,674	51,341	82,686	133,167	214,466	585,976 TL	39.79%	6.02	3-4 years
Region 3, 17 cm	-119,432	35,171	38,688	42,556	46,812	51,493	82,930	133,560	215,100	585,365 TL	39.18%	5.90	3-4 years
Region 3, 18 cm	-121,747	35,264	38,790	42,669	46,936	51,629	83,150	133,913	215,669	584,913 TL	38.68%	5.80	3-4 years
Region 3, 19 cm	-124,665	35,348	38,882	42,770	47,048	51,752	83,348	134,232	216,182	583,677 TL	38.05%	5.68	3-4 years
Region 3, 20 cm	-126,694	35,424	38,966	42,863	47,149	51,864	83,527	134,521	216,648	583,174 TL	37.64%	5.60	3-4 years
Region 4, 8 cm	-96,986	42,507	46,757	51,433	56,576	62,234	100,228	161,419	259,966	754,820 TL	53.77%	8.78	2-3 years
Region 4, 9 cm	-99,195	42,944	47,238	51,962	57,158	62,874	101,259	163,079	262,640	761,371 TL	53.24%	8.68	2-3 years
Region 4, 10 cm	-101,188	43,305	47,636	52,399	57,639	63,403	102,111	164,451	264,850	766,618 TL	52.74%	8.58	2-3 years
Region 4, 11 cm	-104,801	43,711	48,083	52,891	58,180	63,998	103,069	165,994	267,335	771,149 TL	51.64%	8.36	2-3 years
Region 4, 12 cm	-107,037	43,968	48,365	53,202	58,522	64,374	103,675	166,970	268,906	774,061 TL	51.00%	8.23	2-3 years
Region 4, 13 cm	-109,231	44,190	48,609	53,470	58,817	64,699	104,198	167,811	270,262	776,309 TL	50.38%	8.11	2-3 years
Region 4, 14 cm	-111,969	44,383	48,821	53,704	59,074	64,981	104,653	168,545	271,443	777,441 TL	49.55%	7.94	2-3 years
Region 4, 15 cm	-114,378	44,553	49,008	53,909	59,300	65,230	105,053	169,189	272,481	778,433 TL	48.86%	7.81	2-3 years
Region 4, 16 cm	-116,744	44,703	49,173	54,091	59,500	65,450	105,408	169,760	273,401	779,080 TL	48.19%	7.67	2-3 years
Region 4, 17 cm	-119,432	44,837	49,321	54,253	59,679	65,646	105,724	170,270	274,221	779,082 TL	47.44%	7.52	2-3 years
Region 4, 18 cm	-121,747	44,958	49,454	54,399	59,839	65,823	106,008	170,727	274,958	779,179 TL	46.81%	7.40	2-3 years
Region 4, 19 cm	-124,665	45,067	49,573	54,530	59,984	65,982	106,264	171,140	275,623	778,440 TL	46.02%	7.24	2-3 years
Region 4, 20 cm	-126,694	45,165	49,682	54,650	60,115	66,126	106,497	171,515	276,226	778,388 TL	45.52%	7.14	3-4 years

Table C.8. Cash Flow Diagram for Discount Rate 9% and Escalation Rate 12%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1155	0.1293	0.1448	0.1622	0.1817	0.3202	0.5643	0.9944				
Region 1, 4 cm	-87,809	12,868	14,412	16,142	18,079	20,248	35,684	62,888	110,831	221,541 TL	25.03%	3.52	6-7 years
Region 1, 5 cm	-90,088	13,238	14,827	16,606	18,599	20,830	36,710	64,696	114,017	228,155 TL	25.08%	3.53	6-7 years
Region 1, 6 cm	-92,081	13,508	15,128	16,944	18,977	21,254	37,458	66,013	116,337	232,639 TL	25.05%	3.53	6-7 years
Region 1, 7 cm	-94,635	13,712	15,358	17,201	19,265	21,577	38,025	67,013	118,100	235,007 TL	24.84%	3.48	6-7 years
Region 1, 8 cm	-96,986	13,873	15,538	17,403	19,491	21,830	38,472	67,800	119,487	236,526 TL	24.61%	3.44	7-8 years
Region 1, 9 cm	-99,195	14,003	15,683	17,565	19,673	22,034	38,832	68,434	120,605	237,437 TL	24.38%	3.39	7-8 years
Region 1, 10 cm	-101,188	14,110	15,803	17,700	19,824	22,202	39,128	68,957	121,526	238,015 TL	24.17%	3.35	7-8 years
Region 1, 11 cm	-104,801	14,200	15,904	17,812	19,949	22,343	39,377	69,395	122,298	236,556 TL	23.69%	3.26	7-8 years
Region 1, 12 cm	-107,037	14,276	15,989	17,908	20,056	22,463	39,588	69,767	122,954	236,150 TL	23.43%	3.21	7-8 years
Region 1, 13 cm	-109,231	14,341	16,062	17,990	20,149	22,566	39,770	70,088	123,518	235,533 TL	23.17%	3.16	7-8 years
Region 1, 14 cm	-111,969	14,398	16,126	18,061	20,229	22,656	39,928	70,366	124,009	234,163 TL	22.83%	3.09	7-8 years
Region 1, 15 cm	-114,378	14,448	16,182	18,124	20,299	22,735	40,066	70,610	124,440	232,957 TL	22.54%	3.04	7-8 years
Region 1, 16 cm	-116,744	14,492	16,232	18,179	20,361	22,804	40,189	70,826	124,820	231,654 TL	22.26%	2.98	7-8 years
Region 1, 17 cm	-119,432	14,532	16,276	18,229	20,416	22,866	40,298	71,019	125,159	229,911 TL	21.95%	2.93	8-9 years
Region 1, 18 cm	-121,747	14,567	16,315	18,273	20,466	22,922	40,396	71,191	125,463	228,445 TL	21.69%	2.88	8-9 years
Region 1, 19 cm	-124,665	14,599	16,351	18,313	20,511	22,972	40,484	71,347	125,738	226,295 TL	21.36%	2.82	8-9 years
Region 1, 20 cm	-126,694	14,628	16,383	18,349	20,551	23,017	40,564	71,488	125,986	224,959 TL	21.14%	2.78	8-9 years
Region 2, 5 cm	-90,088	23,696	26,539	29,724	33,291	37,286	65,710	115,803	204,085	479,552 TL	37.89%	6.32	3-4 years
Region 2, 6 cm	-92,081	24,205	27,110	30,363	34,007	38,088	67,123	118,294	208,475	489,812 TL	37.88%	6.32	3-4 years
Region 2, 7 cm	-94,635	24,594	27,546	30,851	34,553	38,700	68,202	120,195	211,825	496,611 TL	37.56%	6.25	4-5 years
Region 2, 8 cm	-96,986	24,901	27,889	31,236	34,984	39,182	69,053	121,694	214,467	501,632 TL	37.23%	6.17	4-5 years
Region 2, 9 cm	-99,195	25,149	28,167	31,547	35,332	39,572	69,740	122,906	216,602	505,383 TL	36.90%	6.09	4-5 years
Region 2, 10 cm	-101,188	25,354	28,396	31,803	35,620	39,894	70,307	123,906	218,364	508,309 TL	36.58%	6.02	4-5 years
Region 2, 11 cm	-104,801	25,525	28,588	32,019	35,861	40,164	70,783	124,745	219,843	508,823 TL	35.84%	5.86	4-5 years
Region 2, 12 cm	-107,037	25,671	28,752	32,202	36,066	40,394	71,189	125,458	221,101	510,098 TL	35.45%	5.77	4-5 years
Region 2, 13 cm	-109,231	25,797	28,893	32,360	36,243	40,592	71,538	126,074	222,185	510,931 TL	35.06%	5.68	4-5 years
Region 2, 14 cm	-111,969	25,907	29,016	32,498	36,397	40,765	71,842	126,610	223,129	510,828 TL	34.55%	5.56	4-5 years
Region 2, 15 cm	-114,378	26,003	29,123	32,618	36,533	40,916	72,109	127,080	223,959	510,734 TL	34.12%	5.47	4-5 years
Region 2, 16 cm	-116,744	26,088	29,219	32,725	36,652	41,051	72,345	127,497	224,693	510,417 TL	33.70%	5.37	4-5 years
Region 2, 17 cm	-119,432	26,164	29,304	32,821	36,759	41,170	72,556	127,868	225,347	509,556 TL	33.23%	5.27	4-5 years
Region 2, 18 cm	-121,747	26,232	29,380	32,906	36,855	41,277	72,745	128,201	225,934	508,878 TL	32.84%	5.18	4-5 years
Region 2, 19 cm	-124,665	26,294	29,449	32,983	36,941	41,374	72,915	128,501	226,463	507,438 TL	32.34%	5.07	4-5 years
Region 2, 20 cm	-126,694	26,350	29,512	33,053	37,020	41,462	73,070	128,774	226,944	506,752 TL	32.02%	5.00	4-5 years
Region 3, 6 cm	-92,081	32,816	36,754	41,165	46,104	51,637	91,002	160,377	282,638	696,817 TL	47.49%	8.57	2-3 years
Region 3, 7 cm	-94,635	33,349	37,351	41,833	46,853	52,475	92,479	162,980	287,226	707,068 TL	47.09%	8.47	3-4 years
Region 3, 8 cm	-96,986	33,769	37,822	42,360	47,443	53,136	93,645	165,034	290,846	714,822 TL	46.66%	8.37	3-4 years
Region 3, 9 cm	-99,195	34,109	38,203	42,787	47,921	53,672	94,588	166,696	293,776	720,791 TL	46.22%	8.27	3-4 years
Region 3, 10 cm	-101,188	34,390	38,517	43,139	48,316	54,114	95,367	168,069	296,195	725,549 TL	45.81%	8.17	3-4 years
Region 3, 11 cm	-104,801	34,626	38,781	43,435	48,647	54,485	96,021	169,222	298,227	727,608 TL	44.85%	7.94	3-4 years
Region 3, 12 cm	-107,037	34,827	39,006	43,687	48,930	54,801	96,578	170,204	299,957	730,202 TL	44.33%	7.82	3-4 years
Region 3, 13 cm	-109,231	35,000	39,200	43,904	49,173	55,074	97,058	171,050	301,449	732,170 TL	43.83%	7.70	3-4 years
Region 3, 14 cm	-111,969	35,151	39,369	44,093	49,385	55,311	97,477	171,787	302,747	733,057 TL	43.16%	7.55	3-4 years
Region 3, 15 cm	-114,378	35,283	39,518	44,260	49,571	55,519	97,844	172,434	303,888	733,833 TL	42.60%	7.42	3-4 years
Region 3, 16 cm	-116,744	35,401	39,649	44,407	49,736	55,704	98,169	173,008	304,899	734,290 TL	42.06%	7.29	3-4 years
Region 3, 17 cm	-119,432	35,506	39,766	44,538	49,883	55,869	98,460	173,520	305,801	734,118 TL	41.45%	7.15	3-4 years
Region 3, 18 cm	-121,747	35,599	39,871	44,656	50,015	56,016	98,720	173,978	306,609	734,059 TL	40.95%	7.03	3-4 years
Region 3, 19 cm	-124,665	35,684	39,966	44,762	50,134	56,150	98,955	174,392	307,339	733,178 TL	40.31%	6.88	3-4 years
Region 3, 20 cm	-126,694	35,761	40,052	44,859	50,242	56,271	99,168	174,768	308,001	732,997 TL	39.90%	6.79	3-4 years
Region 4, 8 cm	-96,986	42,911	48,061	53,828	60,287	67,522	118,997	209,713	369,586	934,599 TL	56.19%	10.64	2-3 years
Region 4, 9 cm	-99,195	43,353	48,555	54,382	60,907	68,216	120,221	211,870	373,387	943,000 TL	55.64%	10.51	2-3 years
Region 4, 10 cm	-101,188	43,717	48,964	54,839	61,420	68,790	121,232	213,652	376,528	949,775 TL	55.14%	10.39	2-3 years
Region 4, 11 cm	-104,801	44,128	49,423	55,354	61,996	69,436	122,370	215,657	380,062	956,025 TL	54.03%	10.12	2-3 years
Region 4, 12 cm	-107,037	44,387	49,714	55,679	62,361	69,844	123,089	216,925	382,295	960,023 TL	53.39%	9.97	2-3 years
Region 4, 13 cm	-109,231	44,611	49,964	55,960	62,675	70,196	123,709	218,018	384,223	963,209 TL	52.76%	9.82	2-3 years
Region 4, 14 cm	-111,969	44,806	50,183	56,204	62,949	70,503	124,250	218,971	385,902	965,158 TL	51.93%	9.62	2-3 years
Region 4, 15 cm	-114,378	44,977	50,374	56,419	63,190	70,772	124,725	219,808	387,377	966,868 TL	51.23%	9.45	2-3 years
Region 4, 16 cm	-116,744	45,129	50,544	56,610	63,403	71,011	125,146	220,550	388,685	968,151 TL	50.55%	9.29	2-3 years
Region 4, 17 cm	-119,432	45,264	50,696	56,780	63,593	71,224	125,522	221,212	389,852	968,720 TL	49.79%	9.11	2-3 years
Region 4, 18 cm	-121,747	45,386	50,832	56,932	63,764	71,416	125,859	221,806	390,898	969,326 TL	49.16%	8.96	2-3 years
Region 4, 19 cm	-124,665	45,496	50,955	57,070	63,918	71,588	126,163	222,343	391,844	969,047 TL	48.36%	8.77	2-3 years
Region 4, 20 cm	-126,694	45,595	51,067	57,195	64,058	71,745	126,439	222,829	392,701	969,412 TL	47.85%	8.65	2-3 years

Table C.9. Cash Flow Diagram for Discount Rate 11% and Escalation Rate 7%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1103	0.1180	0.1263	0.1351	0.1446	0.2028	0.2844	0.3989				
Region 1, 4 cm	-87,809	12,565	13,444	14,385	15,392	16,470	23,100	32,398	45,441	75,541 TL	19.82%	1.86	8-9 years
Region 1, 5 cm	-90,088	12,926	13,831	14,799	15,835	16,943	23,764	33,330	46,747	77,958 TL	19.87%	1.87	8-9 years
Region 1, 6 cm	-92,081	13,189	14,112	15,100	16,157	17,288	24,247	34,008	47,698	79,385 TL	19.84%	1.86	8-9 years
Region 1, 7 cm	-94,635	13,389	14,326	15,329	16,402	17,550	24,615	34,524	48,421	79,430 TL	19.63%	1.84	9-10 years
Region 1, 8 cm	-96,986	13,546	14,494	15,509	16,595	17,756	24,904	34,929	48,990	79,122 TL	19.41%	1.82	9-10 years
Region 1, 9 cm	-99,195	13,673	14,630	15,654	16,750	17,922	25,137	35,256	49,448	78,561 TL	19.19%	1.79	9-10 years
Region 1, 10 cm	-101,188	13,777	14,742	15,774	16,878	18,059	25,329	35,525	49,826	77,926 TL	18.99%	1.77	9-10 years
Region 1, 11 cm	-104,801	13,865	14,835	15,874	16,985	18,174	25,490	35,751	50,142	75,450 TL	18.52%	1.72	9-10 years
Region 1, 12 cm	-107,037	13,939	14,915	15,959	17,076	18,271	25,626	35,942	50,411	74,180 TL	18.26%	1.69	9-10 years
Region 1, 13 cm	-109,231	14,003	14,983	16,032	17,154	18,355	25,744	36,107	50,643	72,819 TL	18.01%	1.67	10-11 years
Region 1, 14 cm	-111,969	14,059	15,043	16,096	17,222	18,428	25,846	36,251	50,844	70,803 TL	17.68%	1.63	10-11 years
Region 1, 15 cm	-114,378	14,108	15,095	16,152	17,282	18,492	25,936	36,377	51,020	69,030 TL	17.41%	1.60	10-11 years
Region 1, 16 cm	-116,744	14,151	15,141	16,201	17,335	18,549	26,015	36,488	51,176	67,225 TL	17.14%	1.58	10-11 years
Region 1, 17 cm	-119,432	14,189	15,182	16,245	17,382	18,599	26,086	36,587	51,315	65,036 TL	16.83%	1.54	11-12 years
Region 1, 18 cm	-121,747	14,224	15,219	16,285	17,425	18,644	26,149	36,676	51,440	63,169 TL	16.58%	1.52	11-12 years
Region 1, 19 cm	-124,665	14,255	15,253	16,320	17,463	18,685	26,207	36,756	51,553	60,657 TL	16.26%	1.49	11-12 years
Region 1, 20 cm	-126,694	14,283	15,283	16,352	17,497	18,722	26,258	36,829	51,654	58,994 TL	16.05%	1.47	11-12 years
Region 2, 5 cm	-90,088	23,137	24,756	26,489	28,344	30,328	42,536	59,659	83,675	210,706 TL	32.31%	3.34	4-5 years
Region 2, 6 cm	-92,081	23,634	25,289	27,059	28,953	30,980	43,451	60,942	85,475	215,183 TL	32.30%	3.34	4-5 years
Region 2, 7 cm	-94,635	24,014	25,695	27,494	29,419	31,478	44,149	61,922	86,848	217,568 TL	31.99%	3.30	4-5 years
Region 2, 8 cm	-96,986	24,314	26,016	27,837	29,785	31,870	44,700	62,694	87,931	219,110 TL	31.67%	3.26	4-5 years
Region 2, 9 cm	-99,195	24,556	26,275	28,114	30,082	32,188	45,145	63,318	88,807	220,048 TL	31.34%	3.22	4-5 years
Region 2, 10 cm	-101,188	24,756	26,488	28,343	30,327	32,450	45,512	63,833	89,529	220,652 TL	31.04%	3.18	4-5 years
Region 2, 11 cm	-104,801	24,923	26,668	28,535	30,532	32,669	45,820	64,265	90,136	219,218 TL	30.32%	3.09	5-6 years
Region 2, 12 cm	-107,037	25,066	26,820	28,698	30,707	32,856	46,083	64,633	90,651	218,836 TL	29.94%	3.04	5-6 years
Region 2, 13 cm	-109,231	25,189	26,952	28,839	30,857	33,017	46,309	64,950	91,096	218,241 TL	29.56%	3.00	5-6 years
Region 2, 14 cm	-111,969	25,296	27,067	28,961	30,988	33,158	46,505	65,226	91,483	216,894 TL	29.06%	2.94	5-6 years
Region 2, 15 cm	-114,378	25,390	27,167	29,069	31,104	33,281	46,678	65,469	91,823	215,708 TL	28.64%	2.89	5-6 years
Region 2, 16 cm	-116,744	25,473	27,256	29,164	31,206	33,390	46,831	65,683	92,124	214,424 TL	28.24%	2.84	5-6 years
Region 2, 17 cm	-119,432	25,547	27,336	29,249	31,297	33,487	46,968	65,875	92,392	212,701 TL	27.78%	2.78	5-6 years
Region 2, 18 cm	-121,747	25,614	27,407	29,325	31,378	33,574	47,090	66,046	92,633	211,250 TL	27.40%	2.74	5-6 years
Region 2, 19 cm	-124,665	25,674	27,471	29,394	31,451	33,653	47,200	66,201	92,850	209,112 TL	26.92%	2.68	5-6 years
Region 2, 20 cm	-126,694	25,728	27,529	29,456	31,518	33,725	47,300	66,341	93,047	207,792 TL	26.61%	2.64	5-6 years
Region 3, 6 cm	-92,081	32,042	34,285	36,685	39,253	42,001	58,908	82,622	115,882	324,490 TL	41.67%	4.52	3-4 years
Region 3, 7 cm	-94,635	32,562	34,842	37,281	39,890	42,683	59,865	83,963	117,763	328,698 TL	41.28%	4.47	3-4 years
Region 3, 8 cm	-96,986	32,973	35,281	37,751	40,393	43,221	60,619	85,021	119,247	331,683 TL	40.86%	4.42	3-4 years
Region 3, 9 cm	-99,195	33,305	35,636	38,131	40,800	43,656	61,230	85,878	120,448	333,792 TL	40.43%	4.37	3-4 years
Region 3, 10 cm	-101,188	33,579	35,930	38,445	41,136	44,015	61,734	86,585	121,440	335,364 TL	40.03%	4.31	3-4 years
Region 3, 11 cm	-104,801	33,809	36,176	38,708	41,418	44,317	62,157	87,179	122,273	334,746 TL	39.09%	4.19	3-4 years
Region 3, 12 cm	-107,037	34,006	36,386	38,933	41,658	44,575	62,518	87,685	122,983	335,060 TL	38.59%	4.13	3-4 years
Region 3, 13 cm	-109,231	34,175	36,567	39,127	41,866	44,796	62,829	88,121	123,594	335,065 TL	38.10%	4.07	3-4 years
Region 3, 14 cm	-111,969	34,322	36,725	39,295	42,046	44,989	63,100	88,500	124,126	334,240 TL	37.45%	3.99	3-4 years
Region 3, 15 cm	-114,378	34,451	36,863	39,443	42,204	45,159	63,337	88,834	124,594	333,513 TL	36.90%	3.92	3-4 years
Region 3, 16 cm	-116,744	34,566	36,986	39,575	42,345	45,309	63,548	89,130	125,009	332,638 TL	36.38%	3.85	3-4 years
Region 3, 17 cm	-119,432	34,668	37,095	39,692	42,470	45,443	63,736	89,393	125,378	331,278 TL	35.78%	3.77	4-5 years
Region 3, 18 cm	-121,747	34,760	37,193	39,796	42,582	45,563	63,904	89,629	125,710	330,154 TL	35.29%	3.71	4-5 years
Region 3, 19 cm	-124,665	34,843	37,282	39,891	42,684	45,671	64,057	89,843	126,009	328,313 TL	34.67%	3.63	4-5 years
Region 3, 20 cm	-126,694	34,918	37,362	39,977	42,776	45,770	64,195	90,036	126,280	327,260 TL	34.27%	3.58	4-5 years
Region 4, 8 cm	-96,986	41,899	44,832	47,971	51,328	54,921	77,030	108,039	151,530	447,735 TL	50.15%	5.62	2-3 years
Region 4, 9 cm	-99,195	42,330	45,293	48,464	51,856	55,486	77,822	109,150	153,089	451,128 TL	49.62%	5.55	2-3 years
Region 4, 10 cm	-101,188	42,686	45,674	48,872	52,293	55,953	78,477	110,068	154,377	453,765 TL	49.13%	5.48	2-3 years
Region 4, 11 cm	-104,801	43,087	46,103	49,330	52,783	56,478	79,214	111,101	155,825	455,360 TL	48.05%	5.34	2-3 years
Region 4, 12 cm	-107,037	43,340	46,374	49,620	53,094	56,810	79,679	111,754	156,741	456,415 TL	47.42%	5.26	2-3 years
Region 4, 13 cm	-109,231	43,559	46,608	49,870	53,361	57,097	80,081	112,318	157,531	457,062 TL	46.81%	5.18	2-3 years
Region 4, 14 cm	-111,969	43,749	46,812	50,088	53,595	57,346	80,431	112,809	158,220	456,799 TL	45.99%	5.08	2-3 years
Region 4, 15 cm	-114,378	43,916	46,991	50,280	53,799	57,565	80,738	113,240	158,825	456,565 TL	45.31%	4.99	2-3 years
Region 4, 16 cm	-116,744	44,065	47,149	50,450	53,981	57,760	81,011	113,622	159,361	456,126 TL	44.65%	4.91	3-4 years
Region 4, 17 cm	-119,432	44,197	47,291	50,601	54,143	57,933	81,254	113,963	159,839	455,158 TL	43.91%	4.81	3-4 years
Region 4, 18 cm	-121,747	44,316	47,418	50,737	54,288	58,089	81,472	114,269	160,268	454,386 TL	43.29%	4.73	3-4 years
Region 4, 19 cm	-124,665	44,423	47,532	50,860	54,420	58,229	81,669	114,545	160,656	452,861 TL	42.52%	4.63	3-4 years
Region 4, 20 cm	-126,694	44,520	47,636	50,971	54,539	58,357	81,848	114,796	161,008	452,096 TL	42.02%	4.57	3-4 years

Table C.10. Cash Flow Diagram for Discount Rate 11% and Escalation Rate 8.5%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1119	0.1214	0.1317	0.1429	0.1550	0.2331	0.3505	0.5270				
Region 1, 4 cm	-87,809	12,656	13,731	14,899	16,165	17,539	26,373	39,656	59,628	97,437 TL	21.39%	2.11	8-9 years
Region 1, 5 cm	-90,088	13,020	14,126	15,327	16,630	18,043	27,131	40,796	61,343	100,483 TL	21.43%	2.12	8-9 years
Region 1, 6 cm	-92,081	13,285	14,414	15,639	16,968	18,411	27,683	41,626	62,591	102,369 TL	21.40%	2.11	8-9 years
Region 1, 7 cm	-94,635	13,486	14,632	15,876	17,225	18,690	28,103	42,257	63,540	102,763 TL	21.19%	2.09	8-9 years
Region 1, 8 cm	-96,986	13,644	14,804	16,062	17,428	18,909	28,433	42,753	64,286	102,729 TL	20.97%	2.06	8-9 years
Region 1, 9 cm	-99,195	13,772	14,942	16,213	17,591	19,086	28,699	43,153	64,887	102,388 TL	20.75%	2.03	8-9 years
Region 1, 10 cm	-101,188	13,877	15,057	16,336	17,725	19,232	28,918	43,482	65,383	101,935 TL	20.54%	2.01	8-9 years
Region 1, 11 cm	-104,801	13,965	15,152	16,440	17,838	19,354	29,101	43,759	65,798	99,612 TL	20.07%	1.95	9-10 years
Region 1, 12 cm	-107,037	14,040	15,233	16,528	17,933	19,458	29,257	43,993	66,151	98,471 TL	19.81%	1.92	9-10 years
Region 1, 13 cm	-109,231	14,105	15,303	16,604	18,016	19,547	29,392	44,195	66,454	97,222 TL	19.56%	1.89	9-10 years
Region 1, 14 cm	-111,969	14,161	15,364	16,670	18,087	19,625	29,509	44,371	66,718	95,303 TL	19.23%	1.85	9-10 years
Region 1, 15 cm	-114,378	14,210	15,418	16,728	18,150	19,693	29,611	44,525	66,950	93,615 TL	18.95%	1.82	9-10 years
Region 1, 16 cm	-116,744	14,253	15,465	16,779	18,205	19,753	29,702	44,661	67,155	91,885 TL	18.68%	1.79	10-11 years
Region 1, 17 cm	-119,432	14,292	15,507	16,825	18,255	19,807	29,782	44,782	67,337	89,763 TL	18.37%	1.75	10-11 years
Region 1, 18 cm	-121,747	14,327	15,544	16,866	18,299	19,855	29,855	44,891	67,501	87,957 TL	18.11%	1.72	10-11 years
Region 1, 19 cm	-124,665	14,358	15,578	16,903	18,339	19,898	29,920	44,990	67,649	85,499 TL	17.79%	1.69	10-11 years
Region 1, 20 cm	-126,694	14,386	15,609	16,936	18,376	19,937	29,979	45,078	67,782	83,884 TL	17.58%	1.66	10-11 years
Region 2, 5 cm	-90,088	23,304	25,285	27,435	29,766	32,297	48,563	73,022	109,800	251,026 TL	33.99%	3.79	4-5 years
Region 2, 6 cm	-92,081	23,806	25,829	28,025	30,407	32,991	49,608	74,593	112,162	256,371 TL	33.97%	3.78	4-5 years
Region 2, 7 cm	-94,635	24,188	26,244	28,475	30,895	33,522	50,405	75,792	113,965	259,417 TL	33.67%	3.74	4-5 years
Region 2, 8 cm	-96,986	24,490	26,572	28,830	31,281	33,940	51,033	76,737	115,386	261,481 TL	33.34%	3.70	4-5 years
Region 2, 9 cm	-99,195	24,734	26,836	29,117	31,592	34,278	51,542	77,501	116,535	262,841 TL	33.01%	3.65	4-5 years
Region 2, 10 cm	-101,188	24,935	27,054	29,354	31,849	34,556	51,961	78,131	117,483	263,793 TL	32.70%	3.61	4-5 years
Region 2, 11 cm	-104,801	25,104	27,238	29,553	32,065	34,790	52,313	78,660	118,278	262,652 TL	31.98%	3.51	4-5 years
Region 2, 12 cm	-107,037	25,247	27,394	29,722	32,248	34,989	52,612	79,111	118,955	262,518 TL	31.59%	3.45	4-5 years
Region 2, 13 cm	-109,231	25,371	27,528	29,868	32,406	35,161	52,870	79,499	119,538	262,137 TL	31.21%	3.40	4-5 years
Region 2, 14 cm	-111,969	25,479	27,645	29,995	32,544	35,310	53,095	79,836	120,047	260,977 TL	30.71%	3.33	5-6 years
Region 2, 15 cm	-114,378	25,574	27,748	30,106	32,665	35,442	53,292	80,133	120,493	259,954 TL	30.28%	3.27	5-6 years
Region 2, 16 cm	-116,744	25,658	27,839	30,205	32,772	35,558	53,467	80,396	120,888	258,816 TL	29.88%	3.22	5-6 years
Region 2, 17 cm	-119,432	25,732	27,920	30,293	32,868	35,661	53,623	80,630	121,240	257,222 TL	29.41%	3.15	5-6 years
Region 2, 18 cm	-121,747	25,799	27,992	30,372	32,953	35,754	53,762	80,840	121,555	255,887 TL	29.03%	3.10	5-6 years
Region 2, 19 cm	-124,665	25,860	28,058	30,443	33,030	35,838	53,888	81,029	121,840	253,853 TL	28.54%	3.04	5-6 years
Region 2, 20 cm	-126,694	25,915	28,117	30,507	33,101	35,914	54,003	81,201	122,099	252,629 TL	28.23%	2.99	5-6 years
Region 3, 6 cm	-92,081	32,274	35,018	37,994	41,224	44,728	67,255	101,129	152,063	380,330 TL	43.42%	5.13	3-4 years
Region 3, 7 cm	-94,635	32,798	35,586	38,611	41,893	45,454	68,347	102,770	154,531	385,444 TL	43.02%	5.07	3-4 years
Region 3, 8 cm	-96,986	33,212	36,035	39,098	42,421	46,027	69,208	104,066	156,479	389,144 TL	42.60%	5.01	3-4 years
Region 3, 9 cm	-99,195	33,546	36,398	39,492	42,848	46,490	69,906	105,114	158,055	391,832 TL	42.17%	4.95	3-4 years
Region 3, 10 cm	-101,188	33,822	36,697	39,817	43,201	46,873	70,481	105,979	159,357	393,882 TL	41.77%	4.89	3-4 years
Region 3, 11 cm	-104,801	34,054	36,949	40,090	43,497	47,195	70,965	106,706	160,450	393,665 TL	40.82%	4.76	3-4 years
Region 3, 12 cm	-107,037	34,252	37,164	40,322	43,750	47,469	71,376	107,326	161,381	394,322 TL	40.31%	4.68	3-4 years
Region 3, 13 cm	-109,231	34,422	37,348	40,523	43,967	47,705	71,731	107,859	162,183	394,620 TL	39.82%	4.61	3-4 years
Region 3, 14 cm	-111,969	34,571	37,509	40,697	44,157	47,910	72,040	108,324	162,882	394,053 TL	39.16%	4.52	3-4 years
Region 3, 15 cm	-114,378	34,701	37,651	40,851	44,323	48,091	72,312	108,732	163,496	393,551 TL	38.61%	4.44	3-4 years
Region 3, 16 cm	-116,744	34,816	37,776	40,987	44,471	48,251	72,552	109,094	164,040	392,876 TL	38.08%	4.37	3-4 years
Region 3, 17 cm	-119,432	34,919	37,888	41,108	44,602	48,393	72,767	109,417	164,525	391,694 TL	37.48%	4.28	3-4 years
Region 3, 18 cm	-121,747	35,012	37,988	41,217	44,720	48,521	72,959	109,706	164,960	390,730 TL	36.99%	4.21	3-4 years
Region 3, 19 cm	-124,665	35,095	38,078	41,315	44,827	48,637	73,133	109,967	165,352	389,032 TL	36.36%	4.12	4-5 years
Region 3, 20 cm	-126,694	35,171	38,160	41,404	44,923	48,742	73,290	110,204	165,709	388,110 TL	35.96%	4.06	4-5 years
Region 4, 8 cm	-96,986	42,203	45,790	49,682	53,905	58,487	87,945	132,239	198,842	520,752 TL	51.96%	6.37	2-3 years
Region 4, 9 cm	-99,195	42,637	46,261	50,193	54,460	59,089	88,849	133,599	200,887	524,896 TL	51.43%	6.29	2-3 years
Region 4, 10 cm	-101,188	42,996	46,650	50,616	54,918	59,586	89,597	134,723	202,577	528,154 TL	50.93%	6.22	2-3 years
Region 4, 11 cm	-104,801	43,399	47,088	51,091	55,433	60,145	90,438	135,987	204,478	530,447 TL	49.85%	6.06	2-3 years
Region 4, 12 cm	-107,037	43,654	47,365	51,391	55,759	60,499	90,969	136,786	205,680	531,944 TL	49.21%	5.97	2-3 years
Region 4, 13 cm	-109,231	43,874	47,604	51,650	56,040	60,804	91,428	137,476	206,717	532,972 TL	48.59%	5.88	2-3 years
Region 4, 14 cm	-111,969	44,066	47,812	51,876	56,285	61,069	91,827	138,077	207,620	533,040 TL	47.77%	5.76	2-3 years
Region 4, 15 cm	-114,378	44,235	47,995	52,074	56,500	61,303	92,179	138,605	208,414	533,098 TL	47.09%	5.66	2-3 years
Region 4, 16 cm	-116,744	44,384	48,156	52,250	56,691	61,510	92,490	139,073	209,117	532,917 TL	46.42%	5.56	2-3 years
Region 4, 17 cm	-119,432	44,517	48,301	52,407	56,861	61,694	92,767	139,490	209,745	532,180 TL	45.67%	5.46	3-4 years
Region 4, 18 cm	-121,747	44,637	48,431	52,547	57,014	61,860	93,016	139,865	210,308	531,614 TL	45.05%	5.37	3-4 years
Region 4, 19 cm	-124,665	44,745	48,548	52,674	57,152	62,010	93,241	140,203	210,817	530,276 TL	44.27%	5.25	3-4 years
Region 4, 20 cm	-126,694	44,843	48,654	52,790	57,277	62,145	93,445	140,510	211,278	529,681 TL	43.77%	5.18	3-4 years

Table C.11. Cash Flow Diagram for Discount Rate 11% and Escalation Rate 10%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1134	0.1247	0.1372	0.1509	0.1660	0.2674	0.4306	0.6935				
Region 1, 4 cm	-87,809	12,747	14,021	15,424	16,966	18,663	30,056	48,406	77,958	123,230 TL	22.95%	2.40	7-8 years
Region 1, 5 cm	-90,088	13,113	14,425	15,867	17,454	19,199	30,920	49,798	80,199	127,017 TL	23.00%	2.41	7-8 years
Region 1, 6 cm	-92,081	13,380	14,718	16,190	17,809	19,590	31,550	50,811	81,832	129,443 TL	22.97%	2.41	7-8 years
Region 1, 7 cm	-94,635	13,583	14,941	16,435	18,079	19,887	32,028	51,581	83,072	130,247 TL	22.75%	2.38	7-8 years
Region 1, 8 cm	-96,986	13,742	15,117	16,628	18,291	20,120	32,404	52,187	84,047	130,536 TL	22.53%	2.35	8-9 years
Region 1, 9 cm	-99,195	13,871	15,258	16,784	18,462	20,308	32,707	52,675	84,833	130,455 TL	22.31%	2.32	8-9 years
Region 1, 10 cm	-101,188	13,977	15,375	16,912	18,603	20,464	32,957	53,077	85,481	130,216 TL	22.10%	2.29	8-9 years
Region 1, 11 cm	-104,801	14,066	15,472	17,019	18,721	20,594	33,166	53,414	86,024	128,073 TL	21.62%	2.22	8-9 years
Region 1, 12 cm	-107,037	14,141	15,555	17,111	18,822	20,704	33,344	53,701	86,486	127,085 TL	21.36%	2.19	8-9 years
Region 1, 13 cm	-109,231	14,206	15,627	17,189	18,908	20,799	33,497	53,947	86,883	125,967 TL	21.11%	2.15	8-9 years
Region 1, 14 cm	-111,969	14,262	15,689	17,258	18,983	20,882	33,630	54,162	87,228	124,162 TL	20.77%	2.11	9-10 years
Region 1, 15 cm	-114,378	14,312	15,743	17,317	19,049	20,954	33,747	54,350	87,531	122,574 TL	20.49%	2.07	9-10 years
Region 1, 16 cm	-116,744	14,356	15,791	17,370	19,108	21,018	33,850	54,516	87,798	120,933 TL	20.21%	2.04	9-10 years
Region 1, 17 cm	-119,432	14,395	15,834	17,418	19,159	21,075	33,942	54,664	88,037	118,890 TL	19.90%	2.00	9-10 years
Region 1, 18 cm	-121,747	14,430	15,873	17,460	19,206	21,127	34,025	54,797	88,251	117,154 TL	19.65%	1.96	9-10 years
Region 1, 19 cm	-124,665	14,461	15,907	17,498	19,248	21,173	34,099	54,917	88,444	114,760 TL	19.32%	1.92	9-10 years
Region 1, 20 cm	-126,694	14,490	15,939	17,533	19,286	21,215	34,166	55,025	88,619	113,203 TL	19.11%	1.89	10-11 years
Region 2, 5 cm	-90,088	23,472	25,819	28,401	31,241	34,365	55,346	89,135	143,553	298,520 TL	35.66%	4.31	4-5 years
Region 2, 6 cm	-92,081	23,977	26,375	29,012	31,913	35,105	56,536	91,053	146,641	304,886 TL	35.65%	4.31	4-5 years
Region 2, 7 cm	-94,635	24,362	26,799	29,478	32,426	35,669	57,445	92,516	148,998	308,713 TL	35.34%	4.26	4-5 years
Region 2, 8 cm	-96,986	24,666	27,133	29,846	32,831	36,114	58,161	93,670	150,856	311,391 TL	35.01%	4.21	4-5 years
Region 2, 9 cm	-99,195	24,912	27,403	30,143	33,157	36,473	58,741	94,602	152,358	313,248 TL	34.68%	4.16	4-5 years
Region 2, 10 cm	-101,188	25,114	27,626	30,388	33,427	36,770	59,218	95,372	153,597	314,610 TL	34.37%	4.11	4-5 years
Region 2, 11 cm	-104,801	25,284	27,813	30,594	33,654	37,019	59,619	96,018	154,637	313,813 TL	33.63%	3.99	4-5 years
Region 2, 12 cm	-107,037	25,429	27,972	30,769	33,846	37,231	59,961	96,567	155,522	313,972 TL	33.24%	3.93	4-5 years
Region 2, 13 cm	-109,231	25,554	28,109	30,920	34,012	37,413	60,255	97,041	156,285	313,843 TL	32.86%	3.87	4-5 years
Region 2, 14 cm	-111,969	25,662	28,229	31,052	34,157	37,572	60,511	97,453	156,949	312,903 TL	32.35%	3.79	4-5 years
Region 2, 15 cm	-114,378	25,758	28,334	31,167	34,284	37,712	60,736	97,815	157,532	312,073 TL	31.93%	3.73	5-6 years
Region 2, 16 cm	-116,744	25,842	28,426	31,269	34,396	37,836	60,935	98,136	158,049	311,105 TL	31.51%	3.66	5-6 years
Region 2, 17 cm	-119,432	25,918	28,509	31,360	34,496	37,946	61,112	98,422	158,509	309,664 TL	31.05%	3.59	5-6 years
Region 2, 18 cm	-121,747	25,985	28,583	31,442	34,586	38,045	61,271	98,678	158,922	308,465 TL	30.66%	3.53	5-6 years
Region 2, 19 cm	-124,665	26,046	28,650	31,515	34,667	38,134	61,415	98,909	159,294	306,555 TL	30.17%	3.46	5-6 years
Region 2, 20 cm	-126,694	26,101	28,711	31,582	34,741	38,215	61,545	99,119	159,632	305,443 TL	29.86%	3.41	5-6 years
Region 3, 6 cm	-92,081	32,507	35,757	39,333	43,266	47,593	76,649	123,444	198,808	446,105 TL	45.16%	5.84	3-4 years
Region 3, 7 cm	-94,635	33,034	36,338	39,971	43,969	48,365	77,893	125,447	202,034	452,287 TL	44.76%	5.78	3-4 years
Region 3, 8 cm	-96,986	33,451	36,796	40,475	44,523	48,975	78,875	127,029	204,581	456,829 TL	44.34%	5.71	3-4 years
Region 3, 9 cm	-99,195	33,788	37,166	40,883	44,971	49,468	79,669	128,308	206,642	460,199 TL	43.90%	5.64	3-4 years
Region 3, 10 cm	-101,188	34,066	37,472	41,220	45,342	49,876	80,325	129,365	208,343	462,812 TL	43.50%	5.57	3-4 years
Region 3, 11 cm	-104,801	34,299	37,729	41,502	45,653	50,218	80,876	130,252	209,773	463,068 TL	42.54%	5.42	3-4 years
Region 3, 12 cm	-107,037	34,499	37,948	41,743	45,918	50,509	81,346	131,008	210,990	464,127 TL	42.04%	5.34	3-4 years
Region 3, 13 cm	-109,231	34,670	38,137	41,951	46,146	50,760	81,750	131,659	212,039	464,773 TL	41.53%	5.25	3-4 years
Region 3, 14 cm	-111,969	34,819	38,301	42,131	46,345	50,979	82,102	132,227	212,952	464,507 TL	40.88%	5.15	3-4 years
Region 3, 15 cm	-114,378	34,951	38,446	42,290	46,519	51,171	82,412	132,725	213,755	464,271 TL	40.32%	5.06	3-4 years
Region 3, 16 cm	-116,744	35,067	38,574	42,431	46,674	51,341	82,686	133,167	214,466	463,831 TL	39.79%	4.97	3-4 years
Region 3, 17 cm	-119,432	35,171	38,688	42,556	46,812	51,493	82,930	133,560	215,100	462,859 TL	39.18%	4.88	3-4 years
Region 3, 18 cm	-121,747	35,264	38,790	42,669	46,936	51,629	83,150	133,913	215,669	462,083 TL	38.68%	4.80	3-4 years
Region 3, 19 cm	-124,665	35,348	38,882	42,770	47,048	51,752	83,348	134,232	216,182	460,555 TL	38.05%	4.69	3-4 years
Region 3, 20 cm	-126,694	35,424	38,966	42,863	47,149	51,864	83,527	134,521	216,648	459,787 TL	37.64%	4.63	4-5 years
Region 4, 8 cm	-96,986	42,507	46,757	51,433	56,576	62,234	100,228	161,419	259,966	606,761 TL	53.77%	7.26	2-3 years
Region 4, 9 cm	-99,195	42,944	47,238	51,962	57,158	62,874	101,259	163,079	262,640	611,790 TL	53.24%	7.17	2-3 years
Region 4, 10 cm	-101,188	43,305	47,636	52,399	57,639	63,403	102,111	164,451	264,850	615,778 TL	52.74%	7.09	2-3 years
Region 4, 11 cm	-104,801	43,711	48,083	52,891	58,180	63,998	103,069	165,994	267,335	618,894 TL	51.64%	6.91	2-3 years
Region 4, 12 cm	-107,037	43,968	48,365	53,202	58,522	64,374	103,675	166,970	268,906	620,910 TL	51.00%	6.80	2-3 years
Region 4, 13 cm	-109,231	44,190	48,609	53,470	58,817	64,699	104,198	167,811	270,262	622,387 TL	50.38%	6.70	2-3 years
Region 4, 14 cm	-111,969	44,383	48,821	53,704	59,074	64,981	104,653	168,545	271,443	622,846 TL	49.55%	6.56	2-3 years
Region 4, 15 cm	-114,378	44,553	49,008	53,909	59,300	65,230	105,053	169,189	272,481	623,247 TL	48.86%	6.45	2-3 years
Region 4, 16 cm	-116,744	44,703	49,173	54,091	59,500	65,450	105,408	169,760	273,401	623,371 TL	48.19%	6.34	2-3 years
Region 4, 17 cm	-119,432	44,837	49,321	54,253	59,679	65,646	105,724	170,270	274,221	622,905 TL	47.44%	6.22	2-3 years
Region 4, 18 cm	-121,747	44,958	49,454	54,399	59,839	65,823	106,008	170,727	274,958	622,582 TL	46.81%	6.11	3-4 years
Region 4, 19 cm	-124,665	45,067	49,573	54,530	59,984	65,982	106,264	171,140	275,623	621,465 TL	46.02%	5.99	3-4 years
Region 4, 20 cm	-126,694	45,165	49,682	54,650	60,115	66,126	106,497	171,515	276,226	621,069 TL	45.52%	5.90	3-4 years

Table C.12. Cash Flow Diagram for Discount Rate 11% and Escalation Rate 12%.

Cash Flow Diagram	Years									NS	IRR	SIR	PBP
	0	1	2	3	4	5	10	15	20				
Energy Price	0.1031	0.1155	0.1293	0.1448	0.1622	0.1817	0.3202	0.5643	0.9944				
Region 1, 4 cm	-87,809	12,868	14,412	16,142	18,079	20,248	35,684	62,888	110,831	165,009 TL	25.03%	2.88	7-8 years
Region 1, 5 cm	-90,088	13,238	14,827	16,606	18,599	20,830	36,710	64,696	114,017	169,998 TL	25.08%	2.89	7-8 years
Region 1, 6 cm	-92,081	13,508	15,128	16,944	18,977	21,254	37,458	66,013	116,337	173,298 TL	25.05%	2.88	7-8 years
Region 1, 7 cm	-94,635	13,712	15,358	17,201	19,265	21,577	38,025	67,013	118,100	174,767 TL	24.84%	2.85	7-8 years
Region 1, 8 cm	-96,986	13,873	15,538	17,403	19,491	21,830	38,472	67,800	119,487	175,579 TL	24.61%	2.81	7-8 years
Region 1, 9 cm	-99,195	14,003	15,683	17,565	19,673	22,034	38,832	68,434	120,605	175,919 TL	24.38%	2.77	7-8 years
Region 1, 10 cm	-101,188	14,110	15,803	17,700	19,824	22,202	39,128	68,957	121,526	176,028 TL	24.17%	2.74	7-8 years
Region 1, 11 cm	-104,801	14,200	15,904	17,812	19,949	22,343	39,377	69,395	122,298	174,175 TL	23.69%	2.66	7-8 years
Region 1, 12 cm	-107,037	14,276	15,989	17,908	20,056	22,463	39,588	69,767	122,954	173,435 TL	23.43%	2.62	8-9 years
Region 1, 13 cm	-109,231	14,341	16,062	17,990	20,149	22,566	39,770	70,088	123,518	172,529 TL	23.17%	2.58	8-9 years
Region 1, 14 cm	-111,969	14,398	16,126	18,061	20,229	22,656	39,928	70,366	124,009	170,909 TL	22.83%	2.53	8-9 years
Region 1, 15 cm	-114,378	14,448	16,182	18,124	20,299	22,735	40,066	70,610	124,440	169,484 TL	22.54%	2.48	8-9 years
Region 1, 16 cm	-116,744	14,492	16,232	18,179	20,361	22,804	40,189	70,826	124,820	167,986 TL	22.26%	2.44	8-9 years
Region 1, 17 cm	-119,432	14,532	16,276	18,229	20,416	22,866	40,298	71,019	125,159	166,071 TL	21.95%	2.39	8-9 years
Region 1, 18 cm	-121,747	14,567	16,315	18,273	20,466	22,922	40,396	71,191	125,463	164,450 TL	21.69%	2.35	8-9 years
Region 1, 19 cm	-124,665	14,599	16,351	18,313	20,511	22,972	40,484	71,347	125,738	162,160 TL	21.36%	2.30	9-10 years
Region 1, 20 cm	-126,694	14,628	16,383	18,349	20,551	23,017	40,564	71,488	125,986	160,696 TL	21.14%	2.27	9-10 years
Region 2, 5 cm	-90,088	23,696	26,539	29,724	33,291	37,286	65,710	115,803	204,085	375,454 TL	37.89%	5.17	4-5 years
Region 2, 6 cm	-92,081	24,205	27,110	30,363	34,007	38,088	67,123	118,294	208,475	383,475 TL	37.88%	5.16	4-5 years
Region 2, 7 cm	-94,635	24,594	27,546	30,851	34,553	38,700	68,202	120,195	211,825	388,564 TL	37.56%	5.11	4-5 years
Region 2, 8 cm	-96,986	24,901	27,889	31,236	34,984	39,182	69,053	121,694	214,467	392,238 TL	37.23%	5.04	4-5 years
Region 2, 9 cm	-99,195	25,149	28,167	31,547	35,332	39,572	69,740	122,906	216,602	394,900 TL	36.90%	4.98	4-5 years
Region 2, 10 cm	-101,188	25,354	28,396	31,803	35,620	39,894	70,307	123,906	218,364	396,927 TL	36.58%	4.92	4-5 years
Region 2, 11 cm	-104,801	25,525	28,588	32,019	35,861	40,164	70,783	124,745	219,843	396,687 TL	35.84%	4.79	4-5 years
Region 2, 12 cm	-107,037	25,671	28,752	32,202	36,066	40,394	71,189	125,458	221,101	397,320 TL	35.45%	4.71	4-5 years
Region 2, 13 cm	-109,231	25,797	28,893	32,360	36,243	40,592	71,538	126,074	222,185	397,600 TL	35.06%	4.64	4-5 years
Region 2, 14 cm	-111,969	25,907	29,016	32,498	36,397	40,765	71,842	126,610	223,129	397,016 TL	34.55%	4.55	4-5 years
Region 2, 15 cm	-114,378	26,003	29,123	32,618	36,533	40,916	72,109	127,080	223,959	396,499 TL	34.12%	4.47	4-5 years
Region 2, 16 cm	-116,744	26,088	29,219	32,725	36,652	41,051	72,345	127,497	224,693	395,808 TL	33.70%	4.39	4-5 years
Region 2, 17 cm	-119,432	26,164	29,304	32,821	36,759	41,170	72,556	127,868	225,347	394,613 TL	33.23%	4.30	4-5 years
Region 2, 18 cm	-121,747	26,232	29,380	32,906	36,855	41,277	72,745	128,201	225,934	393,635 TL	32.84%	4.23	5-6 years
Region 2, 19 cm	-124,665	26,294	29,449	32,983	36,941	41,374	72,915	128,501	226,463	391,925 TL	32.34%	4.14	5-6 years
Region 2, 20 cm	-126,694	26,350	29,512	33,053	37,020	41,462	73,070	128,774	226,944	390,993 TL	32.02%	4.09	5-6 years
Region 3, 6 cm	-92,081	32,816	36,754	41,165	46,104	51,637	91,002	160,377	282,638	552,650 TL	47.49%	7.00	3-4 years
Region 3, 7 cm	-94,635	33,349	37,351	41,833	46,853	52,475	92,479	162,980	287,226	560,562 TL	47.09%	6.92	3-4 years
Region 3, 8 cm	-96,986	33,769	37,822	42,360	47,443	53,136	93,645	165,034	290,846	566,469 TL	46.66%	6.84	3-4 years
Region 3, 9 cm	-99,195	34,109	38,203	42,787	47,921	53,672	94,588	166,696	293,776	570,943 TL	46.22%	6.76	3-4 years
Region 3, 10 cm	-101,188	34,390	38,517	43,139	48,316	54,114	95,367	168,069	296,195	574,468 TL	45.81%	6.68	3-4 years
Region 3, 11 cm	-104,801	34,626	38,781	43,435	48,647	54,485	96,021	169,222	298,227	575,490 TL	44.85%	6.49	3-4 years
Region 3, 12 cm	-107,037	34,827	39,006	43,687	48,930	54,801	96,578	170,204	299,957	577,201 TL	44.33%	6.39	3-4 years
Region 3, 13 cm	-109,231	35,000	39,200	43,904	49,173	55,074	97,058	171,050	301,449	578,409 TL	43.83%	6.30	3-4 years
Region 3, 14 cm	-111,969	35,151	39,369	44,093	49,385	55,311	97,477	171,787	302,747	578,634 TL	43.16%	6.17	3-4 years
Region 3, 15 cm	-114,378	35,283	39,518	44,260	49,571	55,519	97,844	172,434	303,888	578,828 TL	42.60%	6.06	3-4 years
Region 3, 16 cm	-116,744	35,401	39,649	44,407	49,736	55,704	98,169	173,008	304,899	578,769 TL	42.06%	5.96	3-4 years
Region 3, 17 cm	-119,432	35,506	39,766	44,538	49,883	55,869	98,460	173,520	305,801	578,137 TL	41.45%	5.84	3-4 years
Region 3, 18 cm	-121,747	35,599	39,871	44,656	50,015	56,016	98,720	173,978	306,609	577,665 TL	40.95%	5.74	3-4 years
Region 3, 19 cm	-124,665	35,684	39,966	44,762	50,134	56,150	98,955	174,392	307,339	576,413 TL	40.31%	5.62	3-4 years
Region 3, 20 cm	-126,694	35,761	40,052	44,859	50,242	56,271	99,168	174,768	308,001	575,894 TL	39.90%	5.55	3-4 years
Region 4, 8 cm	-96,986	42,911	48,061	53,828	60,287	67,522	118,997	209,713	369,586	746,083 TL	56.19%	8.69	2-3 years
Region 4, 9 cm	-99,195	43,353	48,555	54,382	60,907	68,216	120,221	211,870	373,387	752,545 TL	55.64%	8.59	2-3 years
Region 4, 10 cm	-101,188	43,717	48,964	54,839	61,420	68,790	121,232	213,652	376,528	757,718 TL	55.14%	8.49	2-3 years
Region 4, 11 cm	-104,801	44,128	49,423	55,354	61,996	69,436	122,370	215,657	380,062	762,165 TL	54.03%	8.27	2-3 years
Region 4, 12 cm	-107,037	44,387	49,714	55,679	62,361	69,844	123,089	216,925	382,295	765,024 TL	53.39%	8.15	2-3 years
Region 4, 13 cm	-109,231	44,611	49,964	55,960	62,675	70,196	123,709	218,018	384,223	767,227 TL	52.76%	8.02	2-3 years
Region 4, 14 cm	-111,969	44,806	50,183	56,204	62,949	70,503	124,250	218,971	385,902	768,319 TL	51.93%	7.86	2-3 years
Region 4, 15 cm	-114,378	44,977	50,374	56,419	63,190	70,772	124,725	219,808	387,377	769,276 TL	51.23%	7.73	2-3 years
Region 4, 16 cm	-116,744	45,129	50,544	56,610	63,403	71,011	125,146	220,550	388,685	769,893 TL	50.55%	7.59	2-3 years
Region 4, 17 cm	-119,432	45,264	50,696	56,780	63,593	71,224	125,522	221,212	389,852	769,867 TL	49.79%	7.45	2-3 years
Region 4, 18 cm	-121,747	45,386	50,832	56,932	63,764	71,416	125,859	221,806	390,898	769,939 TL	49.16%	7.32	2-3 years
Region 4, 19 cm	-124,665	45,496	50,955	57,070	63,918	71,588	126,163	222,343	391,844	769,178 TL	48.36%	7.17	3-4 years
Region 4, 20 cm	-126,694	45,595	51,067	57,195	64,058	71,745	126,439	222,829	392,701	769,105 TL	47.85%	7.07	3-4 years

REFERENCES

Ang, A. H. S. and J. C. Lee, 2001, "Cost Optimal Design of R/C Buildings", *Reliability Engineering and System Safety*, Vol. 73, pp. 233-238.

Australian Asset Management Collaborative Group, 2008, *Life Cycle Cost Analysis (LCC Report).*

Australian National Audit Office, 2001, "Life-Cycle Costing", *Better Practice Guide*, Canberra, Australian National Audit Office.

Azar, S. A. and N. Noueihed, 2014, "A Probabilistic Internal Rate of Return: Theory and Illustration", *Internal Journal of Business and Management*, Vol. 9, No. 3, pp. 138-147.

Bolattürk, A., 2006, "Determination of Optimum Insulation Thickness for Building Walls with respect to Various Fuels and Climate Zones in Turkey", *Applied Thermal Engineering*, Vol. 26, pp. 1301-1309.

Brady, K., P. Henson and J. A. Fava, 1999, "Sustainability, Eco-efficiency, Life-Cycle Management, and Business Strategy", *Environmental Quality Management*, pp. 33–41.

Çomaklı, K. and B. Yüksel, 2003, "Optimum Insulation Thickness of External Walls for Energy Saving", *Applied Thermal Engineering*, Vol. 23, pp. 473-479.

Daouas, N., 2011, "A Study on Optimum Insulation Thickness in Walls and Energy Savings in Tunusian Builings Based on Analytical Calculation of Cooling and Heating Transmission Loads", *Applied Energy*, Vol. 88, pp. 156-164.

Davis Langdon Management Consulting, 2007, *Life Cycle Costing (LCC) as a Contribution to Sustainable Construction: A Common Methodology*.

Dombaycı, Ö. A., M. Gölcü and Y. Pancar, 2006, "Optimization of Insulation Thickness for External Walls Using Different Energy-Sources", *Applied Energy*, Vol. 83, pp. 921-928.

Dowlatshahi, S., 2001, "Product Life Cycle Analysis: A Goal Programming Approach", *The Journal of the Operational Research Society*, Vol. 52, No. 11, pp. 1201–1214.

Ellis, B. A., 2007, "Life Cycle Cost", http://www.jethroproject.com/Life%20Cycle%20Cost1-3.pdf, [Accessed August 2014].

Estes, A. C. and D. M. Frangopol, 2001, "Bridge Lifetime System Reliability Under Multiple Limit States", *Journal of Bridge Engineering*, Vol. 6, No. 6, pp. 523-528.

Fuller, S. K. and S. R. Petersen, 1996, *Life Cycle Costing Manual for the Federal Energy Management Program*.

Gluch, P., 2004, "The Life Cycle Costing (LCC) Approach: A Conceptual Discussion of Its Usefulness for Environmental Decision-Making", *Build and Environment*, Vol. 39, pp. 571-580.

Hallaway, J., 1982, "A Money Saver: Life Cycle Costing", *Journal of Extension*, pp. 12-17, July/August.

Hazen, G., 2009, "An Extension of the Internal Rate of Return to Stochastic Cash Flows", *Management Science*, Vol. 55, No. 6, pp. 1030-1034.

Hughes, R. D., 1981, "A Computerized Life-Cycle Cost Methodology for Engineering Analysis", *TDA Progress Report*.

Istanbul Gas Distribution Industry & Trade Incorporated Company, 2014, House Gas Prices, http://www.igdas.com.tr/SatisTarifesi?id=140&lang=en&sc=2, [Accessed August 2014].

Kang, Y. J. and Y. K. Wen, 2000, "Minimum Life-Cycle Cost Structural Design Against Natural Hazards", *A Report on a Research Project*.

Kong, J. S. and D. M. Frangopol, 2003, "Life-Cycle Reliability-Based Maintenance Cost Optimization of Deteriorating Structures with Emphasis on Bridges", *Journal of Structural Engineering*, Vol. 129, No. 6, pp. 818-828.

Liu, S. C. and F. Neghabat, 1972, "A Cost Optimization Model for Seismic Design of Structures", *The Bell System Technical Journal*, Vol. 51, No. 10, pp. 2209-2225.

Luehrman, T. A., 1998, "Investment Opportunities as Real Options: Getting Started on the Numbers", *Harvard Business Review*.

Ministry of Energy and Natural Sources, 2007, "Energy Efficiency Law", *Official Gazette Number 26510*, (In Turkish), http://www.resmigazete.gov.tr/eskiler/2007/05/20070502-2.htm, [Accessed October 2014].

Ministry of Energy and Natural Sources, 2014, *Objectives and Facilities of Institutions Related to the Republic of Turkey Ministry of Energy and Natural Sources*.

Ministry of Public Works and Settlement, 2008, "Regulations for Energy Performance of Buildings", *Official Gazette Number 27075*, (In Turkish).

Mishra, S., J. A. Usmani and S. Varshney, 2012, "Energy Saving Analysis in Building Walls Through Thermal Insulation System", *International Journal of Engineering Research and Applications*, Vol. 2, Issue 5, pp. 128-135.

Monden, Y. and K. Hamada, 1991, "Target Costing and Kaizen Costing in Japanese Automobile Companies", *Journal of Management Accounting Research*, Vol. 3, pp. 16–34.

Özkan, D. B. and C. Onan, 2011, "Optimization of Insulation Thicknesses for Different Glazing Areas in Buildings for Various Climatic Regions in Turkey", *Applied Energy*, Vol. 88, pp. 1331-1342.

Pavement Division Interim Technical Bulletin, 1998, *Life-Cycle Cost Analysis in Pavement Design - In Search of Better Investment Decisions*.

Sekhar, S. C. and K. L. C. Toon, 1998, "On the Study of Energy Performance and Life Cycle Cost of Smart Window", *Energy and Buildings*, Vol. 28, pp. 307-316.

Sisman, N., E. Kahya, N. Aras and H. Aras, 2007, "Determination of Optimum Insulation Thicknesses of the External Walls and Roof (Ceiling) for Turkey's Different Degree-Day Regions", *Energy Policy*, Vol. 35, pp. 5151-5155.

Söylemez, M. S., 2012, "Effect of the Energy Price Rate on Insulation Applications", *International Journal of Energy Economics and Policy*, Vol. 2, No. 3, pp. 103-107.

Sundaram, A. S. and A. Bhaskaran, 2014, "Optimum Insulation Thickness of Walls for Energy-Saving in Hot Regions of India", *International Journal of Sustainable Energy*, Vol. 33, No. 1, pp. 213-226.

Total Asset Management, 2004, *Life Cycle Costing Guideline*, September.

Turkish Standards Institution, 1999, "Thermal Insulation Requirements for Buildings, Turkish Standard 825", *Official Gazette Number 23725*, (In Turkish).

Turkish Standards Institution, 2008, "Thermal Insulation Requirements for Buildings, Turkish Standard 825", *Official Gazette Number 27019*, (In Turkish).

Ucar, A. and F. Balo, 2010, "Determination of the Energy Savings and the Optimum Insulation Thickness in the Four Different Insulated Exterior Walls", *Renewable Energy*, Vol. 35, pp. 88-94.

Val, D. V., 2003, "Life-Cycle Cost Analysis of Reinforced Concrete Structures in Marine Environments", *Structural Safety*, Vol. 25, pp. 343-362.

Woodward, D. G., 1997, "Life Cycle Costing - Theory, Information Acquisition and Application", *International Journal of Project Management*, Vol. 15, No. 6, pp. 335-344.

Yu, J., C. Yang, L. Tian and D. Liao, 2009, "A Study on Optimum Insulation Thicknesses of External Walls in Hot Summer and Cold Winter Zone of China", *Applied Energy*, Vol. 86, pp. 2520-2529.