# An Investigation on Benefit-Cost Analysis of Greenhouse Structures in Antalya

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## Abstract

*Significant population increase across the world, loss of cultivable land and increasing demand for food put pressure on agriculture. To meet the demand, greenhouses are built, which are, light structures with transparent cladding material in order to provide controlled microclimatic environment proper for plant production. Conceptually, greenhouses are similar with manufacturing buildings where a controlled environment for manufacturing and production have been provided and proper spaces for standardized production processes have been enabled. Parallel with the trends in the world, particularly in southern regions, greenhouse structures have been increasingly constructed and operated in Turkey. A significant number of greenhouses are located at Antalya. The satellite images demonstrated that for over last three decades, there has been a continuous invasion of greenhouses on all cultivable land. There are various researches and attempts for the improvement of greenhouse design and for increasing food production by decreasing required energy consumption. However, the majority of greenhouses in Turkey are very rudimentary structures where capital required for investment is low, but maintenance requirements are high when compared with new generation greenhouse structures. In this research paper, life-long capital requirements for construction and operation of greenhouse buildings in Antalya has been investigated by using benefit-cost analysis study.*

***Keywords:*** *solar greenhouse structures, benefit-cost analysis, solar greenhouses in Antalya*

## Introduction

Massive increase in world population, shortage of water and loss of cultivable farm lands cause higher demand in food production and need for higher amount of food (Esmaeli & Roshandel, 2020). It has been assumed that by 2050 the world population will be reached to 9.1 billion and to feed this population, it is required to 70% increase current food production (Blakeney, 2019). Together with increasing pressure on need for higher amount of food, it has been revealed that traditional farming techniques cannot fulfil the requirements of market. Solar greenhouses were introduced earlier as a concept proposed for providing a rapid solution by transforming traditional farming lands to transparently covered light structures for enabling more stable and controllable microclimate proper for growth of plants (Choab et al., 2019; Esmaeli &

Roshandel, 2020; Yilmaz et al., 2005) There are various parameters affecting solar greenhouse design. These are climate, plant type, soil, shape of the greenhouse, cladding material and orientation. Crops are continuously harvested in each production cycle (Choab et al., 2019; Yilmaz et al., 2005).

Especially some agricultural lands are transformed into solar greenhouse fields to have an appropriate environment with small investments to construct and operate. These transformation processes within these fields preserve certain problems related with not only environment of the fields but also the quality of the foods (Tüzel et al., 2018). Some of these shortcomings were noticed in literature but these hazards generally focus on healthy of food and earth due to contaminants released by materials used in not only construction of greenhouse but also additives to feed the plants during the crop yield. However, other environmental impacts of these built structures were ignored or put at to the background.

Compared with traditional farming in which there is one season crop, solar greenhouse structures enable two crop yield. One crop yield uses the soil a short time in a year and the remaining time is used for resting of the soil. During this resting time, the soil regains its nutrients in natural ways. However, when second or more crop yields are introduced by greenhouses, it has been experienced that timely the soil within the greenhouse has not regain necessary nutrients from nature. Therefore, additives and fertilizers are introduced to support the soil nutrients. Together with other problems, these additives and fertilizers cause hazardous pest contamination and due to that reason, pesticides are used for these purposes. However, long term use of these pesticides represents hazardous situations for not only soil but also humans fed by these products. Soil includes lots of components and particles necessary for livings. Involvement of these fertilizers and other additives are also negatively affecting other components within the soil.

Regarding the aforementioned limitations on increasing the crop yield by soil, new farming methods are introduced eliminating usage of soil to grow the plants. Although research about soilless farming go backs to 19th century, in the 1990s, it has gained popularity and various greenhouses were constructed to produce crops without using soil. Instead of soil, water or roots of some plants are used. Necessary nutrients for growth of the plants are provided by a water mixture. Together with more efficient irrigation system, soilless food production increases the crop amount collected from unit area. Furthermore, at the following phases of soilless farms, expansion of plantation has gained vertical dimension and called as vertical farming.

Turkey is the 5th fruit and 4th vegetables producer in the world in terms of total production (BÜGEM, 2017). Majority of the production comes from solar greenhouses. The solar greenhouses in Turkey can be divided into two categories regarding their technology involvement and farming concept. These are (i) traditional, short term usage greenhouse structures and (ii) high technology – long term usage greenhouse structures (BÜGEM, 2017). Market of the first category is domestic markets with 80% ratio while market of the second category is totally international markets. This is due to fact that, the foods produced by first category greenhouses cannot fulfil the standards and requirements depicted by other countries. In other words, domestic foods have not proper quality for exportation. On the other hand, foods of second category greenhouses are sustaining certain level of quality by the opportunities of higher amount of technology involved contemporary farming techniques and thus successfully maintaining their exportation. For vulnerable Turkish economy, exportation and foreign currency brought by the exportation is much more valuable than domestic trade.

Considering its life-cycle, a greenhouse can be designed for long-term or short-term investments policies (Benli, 2020; BÜGEM, 2017; Yilmaz et al., 2005). Long-term policies include, smaller operation cost of greenhouses by making higher amount of investment for design and construction. Short-term policies, on the other hand; require small amount of investment for design and construction while relying upon higher amount of operation cost. Furthermore, renovation period of greenhouse cladding materials of short-term policies are also shorter than cladding materials of long-term policy greenhouse projects. Microclimatic conditions inside the greenhouse is controlled by computerized systems in long-term policy greenhouses while farmers manually check and control the microclimatic conditions in short-term policy greenhouses. The literature indicates that the majority of the greenhouses in these Mediterranean regions of Turkey are within short-term policy greenhouses (Benli, 2020; BÜGEM, 2017; Yilmaz et al., 2005). However, these greenhouses are lack of efficient operation system causing not only higher amount of operation cost during heating and cooling the indoor environment of the greenhouses but also environmental impact due to use of fossil-based cooling and heating system (Yilmaz et al., 2005).

Since 1990s, the total solar greenhouses in Turkey has doubled (BÜGEM, 2017). Especially majority of solar greenhouses are located in Antalya by having 40% of the total greenhouses in Turkey (BÜGEM, 2017). Turkey is the second country among Mediterranean countries and fourth country in the world by having 700,000 decare of solar greenhouse area (BÜGEM, 2017). Food production was 7.17 million tones with providing 13.5 billion Turkish Lira economic income in 2016 (BÜGEM, 2017). Southern region of Turkey has proper environment for solar greenhouses due to high amount of annual daylight illumination and having warm climatic conditions in all around the year. Thus Antalya, Mersin and Adana provinces have capacity of more than 70% of total greenhouses in Turkey. Majority of the greenhouses in these regions are short-term greenhouses and 80%-85% of their production are consumed in domestic market. Satellite images presented in Figure 1 demonstrated these massive solar greenhouse transformations between 1980 and 2020 in Antalya. The dense construction of the greenhouse structures changes the built environment at located region.

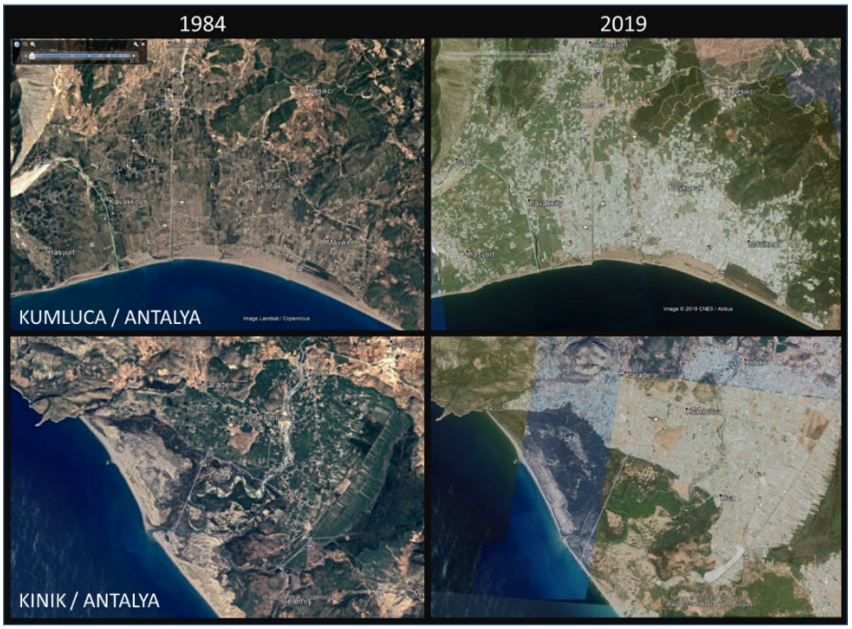


Figure 1: Satellite images illustrating farming land transformation in Kumluca and Kınık.

## Problem Statement

Majority of the greenhouses are short-term policy greenhouses in Antalya and neighboring cities. The farmers choose short-term policy greenhouses for their low initial construction cost. However, long-term maintenance cost of short-term policy greenhouses are not clearly stated in literature. This means that existing greenhouse transformation occurs for short-term benefits without knowing neither long-term cost nor environmental impacts. Considering the gap in this field, a benefit-cost assessment study has conducted for sample greenhouse structures located at Antalya in order to unveil both short-term and long-term cost impact of short-term policy greenhouses.

## Aim & Objective

The aim of the study is unveiling short term and long term performance of the existing greenhouse structures located at Antalya in order to not only assess cost of the structures but also user benefits and outputs of the structures to environment. The objective of the research is presented as follows:

- Analyzing both construction and operation cost items of the greenhouse structures
- Finding maintenance period of the structures
- Determining short-term and long-term performance of the structures
- Evaluating environmental impact of the structures in short-term and long-term performances

## Research Method

There are two methods used for assessing cost performance of a project. Benefit-Cost Analysis (BCA) and Life-Cycle Cost Analysis (LCCA). LCCA is a subset of BCA (U.S. Department of Transportation, 2002). BCA is more comprehensive in terms of evaluating impact of the project to both user and environment while LCCA is focusing on only cost of the project. The primary objective of major ratio of greenhouse farmers to choose short-term policy greenhouse structures is to achieving low initial construction cost. When, farmer objective is considered, LCCA is the proper tool. However, goal of this study, is not only unveiling short-term and long-term cost performance of the greenhouses but also assessing user benefit and various outputs of the greenhouse structures. Thus, Benefit-Cost Analysis (BCA) is the proper analysis method to be used in this research. A research framework has established and implemented for this study as stated at Figure 2. Four greenhouse structures located at Antalya are randomly found and their construction and operation information are collected. After construction and maintenance cost items are described, their cost definitions and expenditures are retrieved from governmental sources. The cost items, definitions and codes are annually published by various governmental institutions. Then, regarding the maintenance period, initial construction cost, ten years, thirty years and fifty years performance costs of the construction items are listed and described. At the last step, the findings of the study are evaluated.

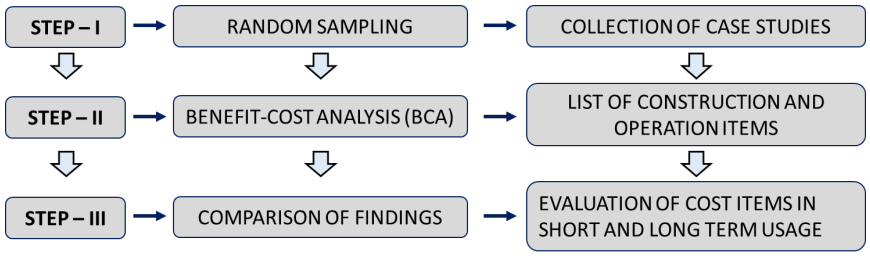


Figure 2: Research framework of the study.

## Benefit-Cost Assessment (BCA) versus Life-Cycle Cost Assessment (LCCA)

LCCA is a tool used to compare costs of competing alternatives. LCCA is a subset of BCA, an economic analysis tool that includes the comparison of benefits as well as costs in selecting optimal alternatives. LCCA is used when the project is decided to be undertaken and is looked for most cost-effective means to accomplish the project objective. Use of LCCA is proper only the project implementation alternatives would yield same level of services and benefits to the project user. For example LCCA is an appropriate tool to use when comparing two alternatives to replace a greenhouse structures that has reached the end of its service life, where each design alternative will result in the same level of service to the user. Costs taken into account in LCCA is typically include expenses to the owner such as construction, operation and maintenance costs. Unlike LCCA, BCA considers the benefits of an improvement as well as its costs and, therefore; can be used to compare design alternatives that do not yield identical benefits together with comparing projects that accomplish different objectives. Benefits measured in BCA are typically those associated with the desired results of the projects. From this perspective, LCCA is a cost-centric approach used to select the most cost-effective alternative that accomplishes a preselected project at a specific level of benefits that is assumed to be equal among project alternatives being considered. BCA, on the other hand; is the proper tool to use when design alternatives will not yield equal benefits. The elements typically considered in BCA and LCCA are illustrated at Figure 3. Therefore, BCA considers also user benefits and externalities resulting from project while LCCA is consider only construction, maintenance and operation costs items.

| PROJECT ELEMENTS | LCCA | BCA |
|---|---|---|
| CONSTRUCTION, REHAILITATION AND MAINTENANCE EXPENDITURES | ✓ | ✓ |
| USER COSTS DURING CONSTRUCTION, REHABILITATION OR MAINTENANCE | ✓ | ✓ |
| USER COSTS DURING NORMAL OPERATIONS | ✓ | ✓ |
| USER BENEFITS RESULTING FROM PROJECT | X | ✓ |
| EXTERNALITIES RESULTING FROM PROJECT | X | ✓ |

Figure 3: Comparison of analysis elements of LCCA and BCA. Source: (U.S. Department of Transportation, 2002).

## Benefit-Cost Analysis Study

BCA study has implemented regarding the implementation step as demonstrated at Figure 4. These are collection of alternative greenhouse structures, acquire of construction and maintenance costs, computation of life-cycle costs, describe of potential benefits and analyzing

the results. The following sample greenhouse structures are studies considering this implementation steps.

**BENEFIT-COST ANALYSIS IMPLEMENTATION STEPS:**
- ACQUIRE ALTERNATIVE GREENHOUSE STRUCTURES
- DETERMINE CONSTRUCTION, SERVICE & MANITENANCE LIFE OF BUILDING COMPONENTS
- DETERMINE COSTS
- COMPUTE LIFE-CYCLE COSTS
- DETERMINE POTENTIAL BENEFITS
- ANALYZE THE RESULTS

Figure 4: BCA implementation steps. Adopted from: (U.S. Department of Transportation, 2002).

## Greenhouse Structure #1

The greenhouse structure of #1 has 22,8 by 50 m area with 2 m tunnel height as illustrated at Figure 5. The structure is made of light steel structure covered with metal paint. The cladding material is plastic sheet. The construction cost items and maintenance period of them are presented at Table 1. Life-cycle costs of construction items with respect to the maintenance period of the construction items of Greenhouse #1 is stated at Table 2. The ten, thirty and fifty year's performance of the cost items are considered for the analysis. As a result of the study, cost of maintenance of construction components of greenhouse #1 is 58,8%, 198,4% and 353,9% of initial construction cost.

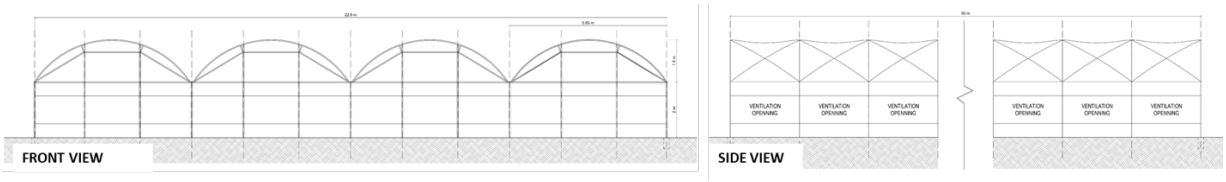


Figure 5: Dimensions of Greenhouse Structure #1.

Table 1. Construction and maintenance cost requirements of Greenhouse #1.

| Ministry Code | Explanation | Amount | Unit | Unit Price | Cost | Maintenance Requirement |
|---|---|---|---|---|---|---|
| **Special – 1** | Plastic Greehnouse Cladding | 1800 | m2 | 3.75 | **6,750 ₺** | 3 years cycle |
| **Special – 2** | Greenhouse Gutter | 156 | mt | 30 | **4680 ₺** | 50 years |
| **15.165.1001** | Steel construction of greenhouse structures | 1.88 | ton | 7695.99 | **14,468 ₺** | No Maintenance Requirement |
| **15.540.1103** | Two layered epoxy paint application to Steel Components | 124.53 | m2 | 37.46 | **4,665 ₺** | 5 years cycle |
| **15.150.1101** | C 8/10 type concrete pouring at construction site. | 11.68 | m3 | 265.55 | **3,101 ₺** | No Maintenance Requirement |
| **15.180.1002** | Wood formwork for greenhouse footings | 116.8 | m2 | 63.98 | **7,472 ₺** | No Maintenance Requirement |
| **15.120.1001** | Excavation work for footing of greenhouse structure | 226 | m3 | 5.46 | **1,234 ₺** | No Maintenance Requirement |
| **Total** | | | | | **42,370 ₺** | |

Table 2. Life-cycle costs of construction items of Greenhouse #1.

| Ministry Code | Explanation | Initial Cost | Cost for 10 years | Cost for 30 years | Cost for 50 years |
|---|---|---|---|---|---|
| Special – 1 | Plastic Greehnouse Cladding | 6,750 ₺ | 20,250 ₺ | 67,500 ₺ | 108,000 ₺ |
| Special – 2 | Greenhouse Gutter | 4680 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.165.1001 | Steel construction of greenhouse structures | 14,468 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.540.1103 | Two layered epoxy paint application to Steel Components | 4,665 ₺ | 9,330 ₺ | 27,990 ₺ | 46,650 ₺ |
| 15.150.1101 | C 8/10 type concrete pouring at construction site. | 3,101 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.180.1002 | Wood formwork for greenhouse footings | 7,472 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.120.1001 | Excavation work for footing of greenhouse structure | 1,234 ₺ | No Maintenance | No Maintenance | No Maintenance |
| Total | | 42,370 ₺ | 67,285 ₺ | 126,445 ₺ | 192,355 ₺ |
| Change Ratio | | %0 | %58.8 | %198.4 | %353.9 |

## Greenhouse Structure #2

The greenhouse structure #2 has 27 by 70 m area with 2,5 m tunnel height as illustrated at Figure 6. The structure is made of light steel structure covered with hot-dip galvanized paint. The cladding material is plastic sheet. The construction cost items and maintenance requirement of them are presented at Table 3. Life-cycle costs of construction items with respect to the maintenance period of the construction items of Greenhouse #2 is stated at Table 4. The ten, thirty- and fifty-years performance of the cost items are considered for the analysis. As a result of the study, cost of maintenance of construction components of greenhouse #2 is 4,5%, 18,3% and 38,6% of initial construction cost.

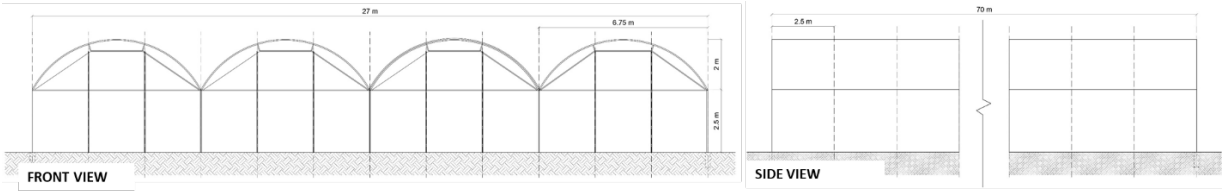


Figure 6: Dimensions of Greenhouse Structure #2.

Table 3. Construction and maintenance cost requirements of Greenhouse #2.

| Ministry Code | Explanation | Amount | Unit | Unit Price | Cost | Maintenance Requirements |
|---|---|---|---|---|---|---|
| Special – 1 | Plastic Greehnouse Cladding | 2694 | m2 | 3.75 | 10,102 ₺ | 6 years cycle |
| Special – 2 | Greenhouse Gutter | 216 | mt | 30 | 6,480 ₺ | 50 years cycle |
| 15.165.1001 | Steel construction of greenhouse structures | 13.349 | ton | 7695.99 | 102,734 ₺ | No Maintentance Requirments |
| V.0720 | Hot-dip galvanizing of steel components | 13,349 | kg | 5.43 | 72,485 ₺ | 50 years cycle |
| 15.150.1101 | C 8/10 type concrete pouring at construction site. | 30 | m3 | 265.55 | 7,966 ₺ | No Maintentance Requirments |
| 15.180.1002 | Wood formwork for greenhouse footings | 300 | m2 | 63.98 | 19,194 ₺ | No Maintentance Requirments |
| 15.120.1001 | Excavation work for footing of greenhouse structure | 302 | m3 | 5.46 | 1,649 ₺ | No Maintentance Requirments |
| Total | | | | | 220,610 ₺ | |

Table 4. Life-cycle costs of construction items of Greenhouse #2.

| Ministry Code | Explanation | Initial Cost | Cost for 10 years | Cost for 30 years | Cost for 50 years |
|---|---|---|---|---|---|
| Special – 1 | Plastic Greehnouse Cladding | 10,102 ₺ | 20,204 ₺ | 50,510 ₺ | 90,918 ₺ |
| Special – 2 | Greenhouse Gutter | 6,480 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.165.1001 | Steel construction of greenhouse structures | 102,734 ₺ | No Maintenance | No Maintenance | No Maintenance |
| V.0720 | Hot-dip galvanizing of steel components | 72,485 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.150.1101 | C 8/10 type concrete pouring at construction site. | 7,966 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.180.1002 | Wood formwork for greenhouse footings | 19,194 ₺ | No Maintenance | No Maintenance | No Maintenance |
| 15.120.1001 | Excavation work for footing of greenhouse structure | 1,649 ₺ | No Maintenance | No Maintenance | No Maintenance |
| Total | | 220,610 ₺ | 230,712 ₺ | 261,018 ₺ | 301,426 ₺ |
| Change Ratio | | %0 | %4.5 | %18.3 | %36.6 |

## Greenhouse Structure #3

The greenhouse structure #3 has 11 by 70 m area with 1,5 m tunnel height as illustrated at Figure 7. The structure is made of light steel structure covered with industrial paint. The cladding material is single pane glass. The construction cost items and maintenance requirements of them are presented at Table 5. Life-cycle costs of construction items with respect to the maintenance period of the construction items of Greenhouse #3 is stated at Table 6. The ten, thirty and fifty year's performance of the cost items are considered for the analysis. As a result of the study, cost of maintenance of construction components of greenhouse structure #3 is 11,8%, 59% and 106,3% of initial construction cost.

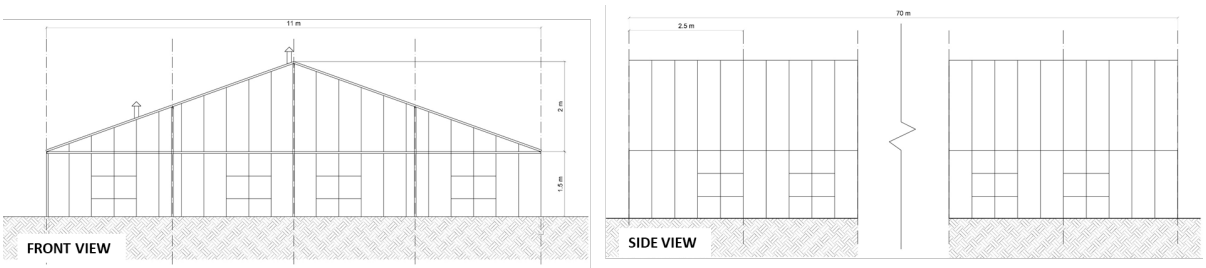


Figure 7: Dimensions of Greenhouse Structure #3.

Table 5. Construction and maintenance cost requirements of Greenhouse #3.

| Ministry Code | Explanation | Amount | Unit | Unit Price | Cost | Maintenance Requirements |
|---|---|---|---|---|---|---|
| 15.165.1001 | Steel construction of greenhouse structures | 5.849 | ton | 7695.99 | 45,014 ₺ | No Maintenance Requirement |
| 15.540.1103 | Two layered epoxy paint application to steel components | 383.84 | m2 | 37.46 | 14,379 ₺ | 5 years cycle |
| 28.063/1 | 5 mm glazing of steel frames | 1075 | m2 | 48.5 | 52,137 ₺ | No Maintenance Requirement |
| 15.150.1101 | C 8/10 type concrete pouring at construction site. | 6.8 | m3 | 265.55 | 1,805 ₺ | No Maintenance Requirement |
| 15.180.1002 | Wood formwork for greenhouse footings | 129.76 | m2 | 63.98 | 8,302 ₺ | No Maintenance Requirement |
| 15.120.1001 | Excavation work for footing of greenhouse structure | 6.65 | m3 | 5.46 | 36 ₺ | No Maintenance Requirement |
| Total | | | | | 121,673 ₺ | |

Table 6. Maintenance requirements of construction items of Greenhouse #3.

| Ministry Code | Explanation | Initial Cost | Cost for 10 years | Cost for 30 years | Cost for 50 years |
|---|---|---|---|---|---|
| **15.165.1001** | Steel construction of greenhouse structures | **45,014 ₺** | **45,014 ₺** | **45,014 ₺** | **45,014 ₺** |
| **15.540.1103** | Two layered epoxy paint application to steel components | **14,379 ₺** | **28,758 ₺** | **86,274 ₺** | **143,790 ₺** |
| **28.063/1** | 5 mm glazing of steel frames | **52,137 ₺** | **52,137 ₺** | **52,137 ₺** | **52,137 ₺** |
| **15.150.1101** | C 8/10 type concrete pouring at construction site. | **1,805 ₺** | **1,805 ₺** | **1,805 ₺** | **1,805 ₺** |
| **15.180.1002** | Wood formwork for greenhouse footings | **8,302 ₺** | **8,302 ₺** | **8,302 ₺** | **8,302 ₺** |
| **15.120.1001** | Excavation work for footing of greenhouse structure | **36 ₺** | **36 ₺** | **36 ₺** | **36 ₺** |
| **Total** | | **121,673 ₺** | **136,052 ₺** | **193,568 ₺** | **251,084 ₺** |
| **Change Ratio** | | **%0** | **%11.8** | **%59** | **%106.3** |

## Greenhouse Structure #4

The greenhouse structure #4 has 17,2 by 22,5 m area with 1,7 m tunnel height as illustrated at Figure 8. The structure is made of light steel structure covered with industrial paint. The cladding material is single pane glass. The construction cost items and maintenance requirements of them are presented at Table 7. Life-cycle costs of construction items with respect to the maintenance period of the construction items of Greenhouse #3 is stated at Table 8. The ten, thirty and fifty year's performance of the cost items are considered for the analysis. As a result of the study, cost of maintenance of construction components of greenhouse structure #3 is 11,72%, 58,6% and 105,5% of initial construction cost.

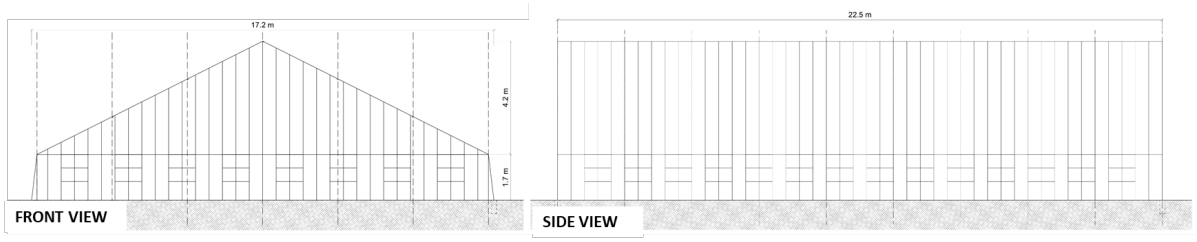


Figure 8: Dimensions of Greenhouse Structure #4.

Table 7. Construction and maintenance cost requirements of Greenhouse #4.

| Ministry Code | Explanation | Amount | Unit | Unit Price | Cost | Maintenance Requirements |
|---|---|---|---|---|---|---|
| **15.165.1001** | Steel construction of greenhouse structures | 3.47884 | ton | 7695.99 | **26,774 ₺** | No Maintenance Requirements |
| **15.540.1103** | Two layered epoxy paint application to steel components | 229.84 | m2 | 37.46 | **8,610 ₺** | 5 years cycle |
| **28.063/1** | 5 mm glazing of steel frames | 632 | m2 | 48.5 | **30,652 ₺** | No Maintenance Requirements |
| **15.150.1101** | C 8/10 type concrete pouring at construction site. | 7.94 | m3 | 265.55 | **2,108 ₺** | No Maintenance Requirements |
| **15.180.1002** | Wood formwork for greenhouse footings | 79.4 | m2 | 63.98 | **5,080 ₺** | No Maintenance Requirements |
| **15.120.1001** | Excavation work for footing of greenhouse structure | 39.4 | m3 | 5.46 | **215 ₺** | No Maintenance Requirements |
| **Total** | | | | | **73,439 ₺** | |

Table 8. Life-cycle costs of construction items of Greenhouse #4.

| Ministry Code | Explanation | Initial Cost | Cost for 10 years | Cost for 30 years | Cost for 50 years |
|---|---|---|---|---|---|
| 15.165.1001 | Steel construction of greenhouse structures | 26,774 ₺ | 26,774 ₺ | 26,774 ₺ | 26,774 ₺ |
| 15.540.1103 | Two layered epoxy paint application to steel components | 8,610 ₺ | 17,220 ₺ | 51,660 ₺ | 86,100 ₺ |
| 28.063/1 | 5 mm glazing of steel frames | 30,652 ₺ | 30,652 ₺ | 30,652 ₺ | 30,652 ₺ |
| 15.150.1101 | C 8/10 type concrete pouring at construction site. | 2,108 ₺ | 2,108 ₺ | 2,108 ₺ | 2,108 ₺ |
| 15.180.1002 | Wood formwork for greenhouse footings | 5,080 ₺ | 5,080 ₺ | 5,080 ₺ | 5,080 ₺ |
| 15.120.1001 | Excavation work for footing of greenhouse structure | 215 ₺ | 215 ₺ | 215 ₺ | 215 ₺ |
| Total | | 73,439 ₺ | 82,049 ₺ | 116,489 ₺ | 150,929 ₺ |
| Change Ratio | | %0 | %11.72 | %58.6 | %105.5 |

## Findings

The findings of the initial construction costs, 10, 30 and 50 years operation costs of construction items of greenhouse structures are presented and compared at Table 9. It has been revealed that, painting type and cladding material selection are the two components have major impact on operation costs of the greenhouse structures. The greenhouse structure #1 uses plastic sheet covering and metal painting present a performance that after 10 years usage, maintenance cost of the structure doubled its initial construction cost while this ratio is not high even 50 years performance is achieved when steel components are covered with hot-dip galvanizing method. When glass panel covering is used instead of plastic sheet as used in Greenhouse Structure #3 & 4, cost of painting in 50 years performance is more than initial construction cost.

Table 9. Comparison table of greenhouse structures regarding their initial construction costs, 10 years, 30 years and 50 years performance costs.

| | Investment Cost of Initial Construction | Investment Cost for 10 years Operation | Investment Cost for 30 years Operation | Investment Cost for 50 years Operation |
|---|---|---|---|---|
| Greenhouse #1 (Plastic Sheet Cladding) | 37.16 TL/m² | 59.02 TL/m² | 110.91 TL/m² | 168.73 TL/m² |
| | %0 | %58.82 | %198.4 | %353.9 |
| Greenhouse #2 (Plastic Sheet Cladding) | 116.72 TL/m² | 122.06 TL/m² | 138.10 TL/m² | 159.48 TL/m² |
| | %0 | %4.57 | %18.3 | %36.63 |
| Greenhouse #3 (Glass Panel Cladding) | 158 TL/m² | 176.69 TL/m² | 251.38 TL/m² | 326.08 TL/m² |
| | %0 | %11.8 | %59 | %106.3 |
| Greenhouse #4 (Glass Panel Cladding) | 189.76 TL/m² | 212.01 TL/m² | 301 TL/m² | 389.99 TL/m² |
| | %0 | %11.72 | %58.6 | %105.5 |

## Potential Benefits

Low maintenance period of greenhouse construction items not only consume time and effort but also cause waste of the material. In a 50 years' service life, accepting that a plastic sheet service life is 3 years, it is necessary to renew plastic sheet 17 times. This means that there will be 17 m2 waste for each unit area of greenhouse structures. Furthermore, regarding that, service life of metal paint is 5 years, it is necessary to renew the metal paint 10 times in 50 years' service life of a greenhouse structures. Although initial construction cost has decreased by using metal paint and plastic sheet covering in greenhouse structures, both maintenance costs and environmental impact of the greenhouse structures has increased. Nevertheless, regarding the

investment cost for 50 years operation, still, plastic sheet covered greenhouse structures are cheaper options than glass panel cladded greenhouse structures as illustrated at Table 13.

## Conclusion

As a result of the study, maintenance costs of various types of greenhouse structures located at Antalya has been examined, their initial construction costs and maintenance costs for 10, 30- and 50-years' service life has illustrated. The cost-benefit analysis indicated that although initial construction cost of plastic sheet covering is cheaper option for investors than glass panel cladding, its maintenance costs over initial construction costs and environmental impact has more than plastic sheet cladding options. Accepting that majority of the farmer has capital shortage in Turkey, plastic sheet covered greenhouse structures will be remained cheaper options. In the coming future, regarding the plastic sheet consumption in agricultural greenhouse market, it is likely to confront with environmental impacts of the solar greenhouses. This study can be expanded by including energy requirements of each greenhouse structure types.

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