ISSN NO. 2320-5407

Journal homepage: http://www.journalijar.com
Journal DOI: 10.21474/IJAR01

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH

RESEARCH ARTICLE

Determining required heat energy and CO_2 emissions resulting from fuel consumption in different greenhouse installations in Mediterranean climate conditions

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Manuscript Info

Manuscript History:

Received: 14 February 2016
Final Accepted: 26 March 2016
Published Online: April 2016

Key words:
Agricultural greenhouse, CO_2emission, Climate adaptation, Life cycle assessment.

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Abstract

As a result of the energy crises of the 1970s, greenhouse cultivation has developed rapidly in the countries on the Mediterranean coast. In order to achieve the expected quality production and productivity, greenhouses should be heated when outside temperature falls below 12°C. In Turkey, small scale family businesses implement very simple heating methods to protect plants from frost, rather than provide regular heating of greenhouses. The modern greenhouses that have been installed in recent years are equipped with hot water tube heating systems.

In addition to affecting production costs in a significant way, heating greenhouses has negative influence on the environment due to carbon emissions of the selected fuel type. The fuel to be used in heating greenhouses should be both cost effective and environment friendly with the lowest level of carbon emissions. This study aims to determine the amount of heating energy required for different inside temperature values desired in plastic greenhouses with different specifications, under Mediterranean climate conditions, to estimate the amounts of coal, natural gas, diesel fuel and fuel oil to be used in heating and to calculate the annual fuel costs and carbon dioxide (CO_2) emissions for each fuel type. The study has shown that the most convenient fuel to meet the annual heat requirements of greenhouses is natural gas. The relative change in the cost of natural gas, diesel fuel and fuel oil has been calculated as an increase of 13%, 73% and 59% respectively. The annual CO_2emission of natural gas has been determined to be 50%, 29% and 30% lower than that of coal, diesel fuel and fuel oil respectively.

Introduction:

In agricultural production, controlling environmental conditions has direct influence on productivity. Forthis reason, environmentally controlled agricultural production techniques have increasingly developed over the past few years. In environmentally controlled plant production systems, there is an attempt to change all aspects of the natural environmental factors in line with the plant requirements for optimum growth. The most common and efficient implementation of environmentally controlled production in plant production is done in greenhouses.

The acclimatization method used for greenhouses during cold periods is heating. While heating greenhouses increases productivity and quality to result in earliness, it also increases initial investment and operating costs. In the Mediterranean and Aegean regions of Turkey, where greenhouse cultivation is very common, it becomes necessary to heat greenhouses during December, January and February in order to achieve high quality production (Zabeltitz. 1992, Baytorunet al. 1994,Baytorunet al.2000). However, producers in this region prefer cold greenhousing as average daily outside temperature in the winter months is above 7ºC. In unheated greenhouses, when the temperature inside the greenhouses falls below the biologically optimum temperature, a lot of agricultural pesticides and chemicals are used to fight plant diseases that arise (Zabeltitz, 1992). This necessity not only affects product quality but also leads to significant harmful impacts on human health.

In Turkey, productivity of tomato production in unheated greenhouses is 8-12 kgm^{-2}while in the Netherlands it is 50-55 kgm^{-2}. As can be seen from these values, productivity of tomato production obtained in unheated greenhouses in Turkey is significantly low when compared to the same productivity in the Netherlands. The main reasons for this outcome are the short production period resulting from high temperature, low temperature in unheated greenhouses, high relative humidity and inadequate modern greenhouse technology.

Heating provides many other benefits besides its positive influence on productivity, earliness and quality. It is much easier to control high humidity, which is the primary cause of plant diseases, in heated greenhouses than in unheated ones. As a result of this, use of pesticides and chemicals threatening human health and the environment is considerably low in heated greenhouses.

In Europe, the highest energy consumption in greenhouse plant production is in the Netherlands due to greenhouse heating. Compared to Spain, in the Netherlands 13 times more energy is consumed to produce one kilogram of tomatoes. In pepper production, energy consumption is 14-17 times higher and in cucumber production it is 9 times higher (Zabeltitz, 2011). However, when compared to the other Mediterranean countries, use of pesticides in producing one kilogram of tomatoes in the Netherlands is very low in heated greenhouses. In the Netherlands, use of pesticides in vegetable production in greenhouses is 31 $kg.ha^{-1}$while in Italy this value is as high as 47 $kg.ha^{-1}$ (Stanghelliniet al. 2003). In Turkey, pesticide consumption of businesses using Bombus bees is78 $kg.ha^{-1}$, and in businesses not using Bombus bees the consumption goes up as high as 357 $kg.ha^{-1}$(Karaman et al. 2006).

Energy consumption and amounts of pesticides used in the production of one kilogram of tomatoes in the Netherlands and different Mediterranean countries and its supply in the Frankfurt wholesale market hall are given in Figure 1. As seen in the figure, the energy required for marketing one kilogram of tomatoes in the Frankfurt wholesale market hall is the highest in the Netherlands (45.9 $MJ.kg^{-1}$). In the case that transfer is made by ship, this value is 14.7 $MJ.kg^{-1}$ in Israel and 2.7 $MJ.kg^{-1}$ in the Canary Islands.On the other hand, as greenhouses in Israel and the Canary Islands are not heated, the amount of pesticides used in producing one kilogram of tomatoes is quite high when compared to the Netherlands. In the Netherlands, 0.024 $g.kg^{-1}$of pesticides are used, but the amount is 0.151 $g.kg^{-1}$ and 0.230 $g.kg^{-1}$' in Israel and the Canary Islands respectively (Zabeltitz, 1997). This issue is highly important in countries with environmental awareness and has great significance regarding human health and the environment.

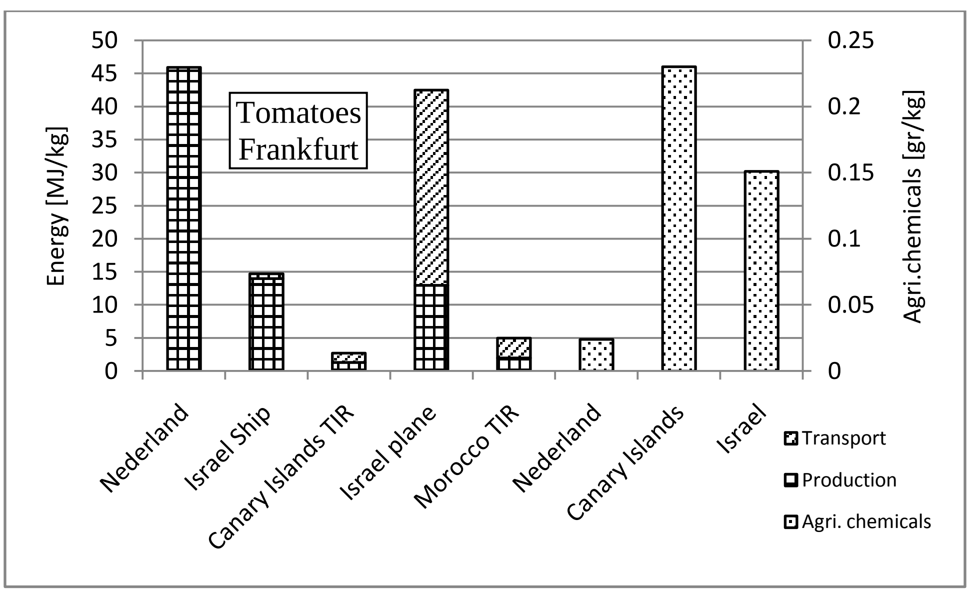

Figure 1. Energy requirements and quantities of pesticides used for tomato production in different countries (Zabeltitz, 1997).

In Turkey, fossil energy sources are used to heat greenhouses while in very few greenhouses heating is provided with geothermal energy (Özdemiret al.,2012). The world's fossil energy sources are not endless.Besides, when burned, fossil energy resources emit CO_2, and CO_{2b}emissions depend on the type and quantity of fuel used. CO_{2b}emissions for coal, diesel, propane and natural gas are 80-100 gMJ^{-1}, 75 gMJ^{-1}, 65 gMJ^{-1} and 58 gMJ^{-1} respectively (Kittaset al., 2013). CO_2in the atmosphere increases greenhouse effect. All scientists agree that this will result in global climate change. Today melting polar ice caps and glaciers lead to seal level rises, and disasters resulting from changes in rainfall patterns are not uncommon.

For a sustainable life on earth, it is necessary that industrialized countries decrease the amounts of CO_2 gas emissions into the atmosphere. This will only be possible by using renewable energy sources or decreasing the energy requirement of people. However, this will not be easy as developing countries are striving to reach the standards of developing countries and as the increasing world population continues to contribute as a negative factor.

Table 1shows harmful gas emission values related to fuels used in heating different greenhouse constructions built for tomato production in 10 ha plants in Germany (Elsner, 2010).As it can be seen, using fossil energy resources to heat greenhouses has serious harmful effects on the environment. Alternative energy sources are not very common due to the seasonal irregularities (solar and wind energy) and the need for spacious areas and costly solutions for storing the energy derived from these sources. However,geothermal and biomass energies are increasingly used in greenhouses.

Table 1.Harmful gas emission values related to fuels used in heating different greenhouse constructions built for tomato production in 10 ha plants in Germany (Elsner,et all. 2010)

Covering material	Relative EnergyRequirement	Energy source	Gas emission $kgm^{-2}.a^{-1}$
Single glass	130%	Fuel oil	99
Single glass + thermal curtain	100%	Fuel oil Coal + Fuel oil Waste-to-energy +Fuel oil Waste-to-energy (100%)	76 123 19 5
Double layer plastic Double layer hard plastic Double-glass	90%	Fuel oil Natural gas Wood + natural gas Waste-to-energy + Fuel oil Waste-to-energy (100%)	69 57 20 18 5

This study aims to calculate annual required heat energy, fuel consumption and fuel-related CO_2 emissions in plastic greenhouses constructed in Mediterranean climate conditions, with different specifications such as double layer covering materials, thermal curtains and different heating systems.

Material Method:-

The largest greenhouse areas on the Mediterranean coast are in Antalya (37%). In this study, calculations were madeby taking into consideration the hourly mean climate values of Antalya.

Specifications of Greenhouses:

The study is based on plastic gothic arch greenhouses with plastic covering, which are widely used in Mediterranean countries. As covering material, besides the single layer PE plastic used widely in Turkey, greenhouses with double layer hard plastic (PC) side walls and PE covered roofs have been evaluated.In the calculations, floor area of the greenhouses and surface area of the greenhouse covers have been taken as A_H = 7338 m^2 and A_G = 4800 m^2.The ratio of the cover surface area to the greenhouse floor area (A_H/A_G)is 1,53.

Calculation of heat energy requirement:-

In the study, energy requirement in greenhouses was calculated with equations based on the standards developed by Rath (1992) and DIN 4701 standards, usinghourly mean temperature, wind speed and solar radiation values The total heat transmission coefficient necessary for the calculations was determined by taking into consideration the covering material used in the greenhouse. The total heat requirement coefficient at $4m.s^{-1}$ wind speed was taken as

7,0 $W.m^{-2}.K^{-1}$ for singlelayer, 5,1 $W.m^{-2}.K^{-1}$for double layer PE plastic covering and 4,7$W.m^{-2}.K^{-1}$ for double layer PC (10 mm) covering (Zabeltitz 1986).In the case that both materials are used in different parts of the greenhouse, the total heat transmission coefficient was determined by taking weighted average.It was also taken into consideration that the total heat transmission coefficient changes depending on wind speed.

The annual heat requirement of the greenhouse was calculated for the hours of the year using equation (1) (Rath, 1992.).

$$Q = \sum_{n=1}^{8760} \left(\left(\left(\vartheta_{i_n} - \vartheta_{i,OH_n} - \Delta\vartheta_{Sp_n} \right) * k'_a \sum A_r * \left(1 - EE_{ES_n} \right) \right) * t_{Si} \right) \qquad (1)$$

In the equation:

Q=Annual heat requirement in the greenhouse [Wh]
ϑ_i=Desired temperature in the greenhouse [^{o}C]
$\vartheta_{i,OH}$=Real inside temperature in the unheated greenhouse [^{o}C]
$\Delta\vartheta_{Sp}$=Temperature rise due to heat energy stored in the greenhouse [^{o}C]
k'_a= Total heat transmission coefficient of the covering material [$Wm^{-2}.K^{-1}$]
EE_{ES}=Savings ratio for energy conservation measure used in the greenhouse [-]
A_r=Greenhouse covering surface area [m^2]
n=Hours of the year
t_{Si}=Time frame in the simulation (1 h)

The real inside temperaturevalues due to solar radiation stored during daytime ($\vartheta_{i,OH}$) and temperature rise due to the heat storage capacity of the unheated greenhouse ($\Delta\vartheta_{Sp}$) in equation (1) are based on Rath's(1992) studies.

As the heat protection method, aluminum containing thermal curtain was considered and company data were used in the calculations. According to the data provided by the producer, the savings ratio (EE_{ES}) of aluminum texture thermal curtains ranges from 35 to 60%. In the calculations, the savings ratio for thermal curtainwas taken as 40% for low aluminum texture in curtain structure.Assuming that the thermal curtain had airtight enclosure, the correction factor was taken as 6.8 (Müller1987, Rath 1992).

Another important factor that influences heat requirement in greenhouses is the type of heating system installed. The most appropriate energy saving heating system in greenhouses is the system in which heating pipes are placed in between plant rows or the vegetation heating system. Therefore, this heating system was considered in the calculations instead of the system placed higher in the greenhouse, and the relative correction factor of this system was taken as 0.86 (Tantau, 1983, Zabeltitz 1986).

Annual fuel consumption and cost calculation:-

The annual heat energy requirement of the greenhouse was calculated for different inside temperature values in the months when heating becomes necessary. In greenhouses, inside temperature values needed by plants show differences at day and night hours.For optimum plant growth in greenhouses, it is desired to have a temperature difference of 5-8^{o}C between night and day (Nisenet al. 1988). For this reason, calculations were based on 4 different temperature regimes: night/day 16/24^{o}C,16/21^{o}C and for energy saving 16/16^{o}C,13/16^{o}C.

Based on the annual heating energy requirement of the greenhouse, annual fuel consumption was calculated using equation (2) (Tantau, 1983).

$$B_y = \frac{Q}{Hu * \eta_t} \qquad (2)$$

In equation 2, Hurepresents the lower heating value of the fuel ($kWh.m^{-3}$, $kWh.kg^{-1}$) while$\eta_t$represents the total efficiency of the heating system. Total efficiency(η_t) is determined in relation with the degree of effectiveness of the annual heating system (η_k) and the losses resulting from the transfer of hot water from the boiler to the greenhouse.In determining total efficiency, the following relation was used (Tantau, 1983).

$$\eta_t = \eta_k * \eta_v \qquad (3)$$

The annual effectiveness value of the heating system (η_k) varies with the boiler used in the heating system. For the (η_k)values, the following values can be taken for the various types of fuel used (Table 2).

Table 2. (η_k)values for different types of fuel.(VDI 2067 Bl. 1, 1979).

Fuel Type	(η_k)
Solid fuels	0.77
Liquid fuels	0.80
Gas fuels	0.81

These values given above are for boilers with heating power ranging from 0.58 and 1.16 MW.Transfer efficiency (η_v) includes losses that occur while hot water is being transferred from the boiler to the greenhouse. This value is taken as 0.97(Tantau, 1983).In the calculations, total efficiency for different boiler types was taken as given in the chart given below (Table 3).

Tablet 3.(η_t)values for different types of fuel.

Fuel Type	(η_t)
Solid fuels	0.75
Liquid fuels	0.78
Gas fuels	0.79

In the calculations natural gas, coal, diesel fuel and fuel oil (radiator fuel) were used as fuel types. Table 4 shows lower heating values, unit prices and efficiency values of some fuel types.

Chart 4. Lower heating values ,unit prices and boiler efficiencies of some fuel types.

Fuel type	Lower heating value of fuel**	Total efficiency %	*Unit price** m^3 ₺$^{-1}$ or kg ₺$^{-1}$*
Natural gas	*9.59*	*79*	*0.93*
Coal (Import)	*8,14*	*75*	*0.36*
Diesel fuel	*11.86*	*78*	*4.42*
Fueloil	*11.28*	*78*	*2.76*

* 2014 Unit Prices.
** kWh.m^{-3} for natural gas, kWhkg^{-1}for other fuels

Annual fuel cost was calculated using equation (4) by taking into consideration the annual fuel requirement.

$$M_y = B_y * C_{f-yak} \quad (4)$$

In the equation:

M_y: Annual fuel cost (₺)
B_y: Annual fuel quantity (m^{3}or kg)
C_{f-yak} : Fuel unit price (₺m^{-3} or₺kg^{-1})

Emission calculation:-

Of the waste gases released as a result of the burning of fuels used in heating systems, 85% is CO_2, while 15% is composed of emissions such as sulphur dioxide (SO_2), carbon monoxide (CO) particulate matter (PM_{10} and PM_{25}) and nitrogen oxide compounds (NO_x). However, as a general approach, calculations were based on CO_2 emission as the other emission values present low percentages. The energy performance directive published on Turkey's Official Gazette of 5 December 2008 and no. 27075, provides the conversion coefficients ($FSEG$) for determining CO_2 quantities resulting from energy consumption, depending on the fuel type used (Table 5).Annual CO_2 emission quantity was calculated for different fuel types using equation (5) by taking into consideration the net heat energy consumption of the greenhouse (Yazıcı, et al. 2012).

$$SEGM_y = B_y * Hu * FSEG \quad (5)$$

In the equation:

$SEGM_y$: Annual CO_2 emission quantity (kg equiv. CO_2)
$FSEG$: CO_2 emission conversion coefficient for fuel type (kg equiv.CO_2kWh^{-1}).

Table 5. FSEG (CO_2) conversion coefficients of fuel types used in calculations (Energy Performance in Buildings Directive. 2008).

Fuel Type	*FSEG (CO_2) Conversion Coefficient (kg equiv. CO_2kWh^{-1})*
Natural gas	*0.234*
Coal (Lignite)	*0.433*
Fuel oil	*0.330*
Other fossil fuels, diesel fuel	*0.320*

Results:-

In order to get high efficiency from greenhouses, heating becomes necessary when average daily outside temperature falls below 12^{o}C. At temperatures between 7^{o}C and 12^{o}C, heating greenhouses only at night hours is usually sufficient to protect plants against low temperatures (Nisenet al, 1988, Baytorunet al, 1994, 2000). In greenhouseswhich require costly investments and operating expenses, it is recommended to provide the optimum conditions for plants to obtain efficiency and quality. The total annual heat energy requirements in plastic greenhouses in 4 different heating regimes in Antalya climate conditions for different specifications are calculated according to Rath (1992) and given in Table 6. In the calculations, ventilation temperature was taken as 25^{o}C and it was assumed that heating pipes have been placed close to the ground.

In Antalya climate conditions, the highest heating energy requirement is when inside temperature is maintained at 16/24^{o}Cnight/day (Table 6). The lowest annual heat energy requirement is obtained in greenhouses with thermal curtains and side walls covered with double layerPC (10 mm), at a constant temperature (night/day) of 13/16^{o}C. In greenhouses on the Mediterranean coast, heating in daytime is not necessary as long as the inside temperature is kept at 16^{o}C and below.

Table 6. The total annual heat energy requirements in PE plastic greenhouses (A_H/A_G=1,53) in 4 different heating regimes in Antalya climate conditions for different specifications (KWh.$m^{-2}.a^{-1}$). (Ventilation set temperature 25^{o}C, Heating pipes close to the ground).

Greenhouse Specifications	Total Heating Energy Requirement(kWh.$m^{-2}.a^{-1}$) Night/DayTemperature Values(^{o}C)			
	13/16	16/16	16/21	16/24
Single layer PE plastic on roof and side walls	57,6	118,2	144,6	171,1
Single layer PE plastic on roof, Double layer PC (10 mm) on side walls	53,7	110,7	134,8	158,6
Single layer PE plastic on roof, Double layer PC (10 mm) on side walls, Thermal curtain	38,2	75,4	99,5	123,3

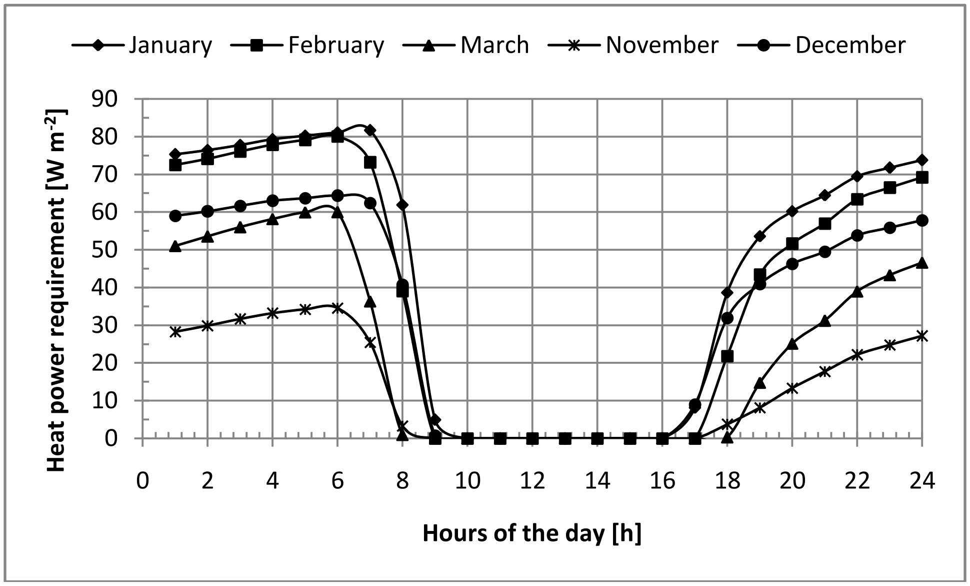

Figure 2.Heat power required in Antalya climate conditions for hours of the day in different months at an inside temperature of 16°C night/day and a ventilation temperatureof 25°C. (Single layer PE plastic)

Heat power requirements in Antalya climate conditions for hours of the day in different months at an inside temperature of 16°C night/day and a ventilation temperature of 25°C are given in Figure 2. As seen from the figure, the highest heat power requirement is during the early morning hours while the greenhouse does not require heating after sunrise.

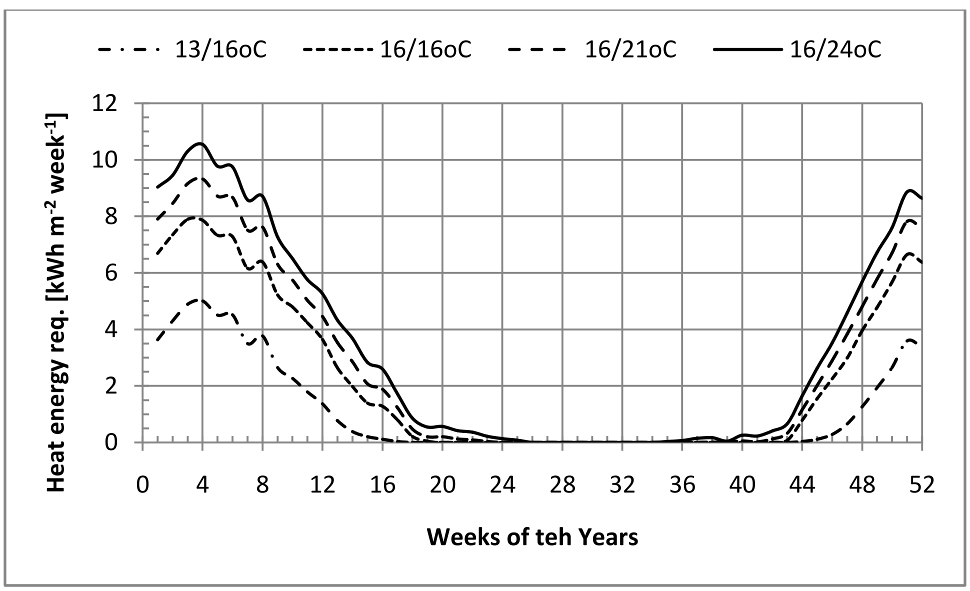

Figure 3. heat energy requirement in greenhouses covered with single layer PE plastic and with vegetation heating system in weeks of the year at different temperature regimes under Antalya climate (kWh.m^{-2}.week^{-1}) (Ventilation temperature 25°C).

In greenhouses, conserving heat energy is as important as heating. It is possible to save 10-20% energy by using multi-layer covering material and isolating the covering surface well (Elsner, 2010). However, the total radiation absolutely necessary for plant growth on the Mediterranean coast is not sufficient (<2.34 kWh.m^{-2}.day^{-1}) in December and January (Baytorunet al. 1994). In the past few years, using single layer covering material on the roof (to get sufficient light) and double layer covering material on the side walls (to save heat)of the greenhouse has become a common practice during these months. The calculations show that compared to greenhouses with single layer PE plastic covered side walls, greenhouses with double layer PC (10 mm) covered sidewalls provide the possibility of saving 8-10% energy. This value varies with the ratio of the area of the side walls to the area of the greenhouse roof.In other words, as the area of the greenhouse increases, energy saved decreases.

Figure 3 shows the heat energy requirement in greenhouses covered with single layer PE plastic, without thermal curtains and with heating pipes close to the ground in weeks of the year under Antalya climate.As seen from the figure, heat energy requirement varies with the desired inside temperature in the greenhouse. In the event that inside temperature is maintained at 13/16^{o}C night/day, required total annual heat energy is 57,6kWh.m^{-2}.a^{-1}. In the given conditions, a total of 20 week heating requirement is seen between weeks 46-52 and 1-14. However, this value ranges between 0 and 5,0 kWh.m^{-2}.week^{-1} and thus quite low. When inside temperature is kept at optimum values required by tomato plants (16/21^{o}C), require annual heat energy for the same greenhouse is 144,6 kWh.m^{-2}.a^{-1}. In this case, there is a total of 27 week heating requirement between weeks 42-52 and 1-18, and the required weekly heating energy ranges from 0 and 9,4 kWh.m^{-2}.week^{-1}.

In greenhouses, thermal curtains are used in order to prevent solar energy stored throughout the day and the heat energy provided with heating from being lost through the covering material at night hours. In the study, calculations were made assuming that the thermal curtain with aluminum texture had airtight enclosure. The study has shown that when compared to the greenhouse covered with single layer PE plastic, the greenhouse with a thermal curtain and side walls covered with double layerPC could provide an energy saving of 36-42%.

In the case that inside temperature is kept at 16/21^{o}C night/day in greenhouses with double layerPC covered side walls, single layer PE plastic covered roof and thermal curtains, fuel costs and CO_2 emission values for different fuel types will be as given in Figure 4.

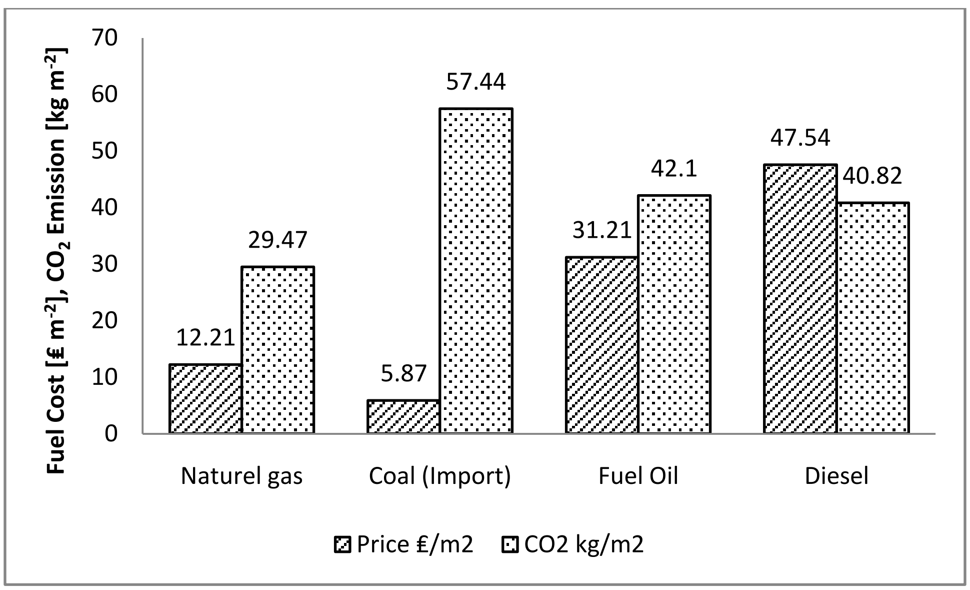

Figure4.Unit heating cost and CO_2 emission related to energy required for unit area in in greenhouses with double layer PC covered side walls and thermal curtains, when inside temperature is kept at 16/21^{o}C night/day.

In Turkey, mostly coal is used to heat greenhouses. This is because there is no sufficient infrastructure for natural gas in areas where greenhouses are built and other alternatives like fuel oil and diesel fuel are costly. Total annual heat energy requirement calculated using equation (1) and the related different fuel quantities and fuel costs required for unit area calculated using equation (2) in plastic greenhouses with and without thermal curtains under different temperature regimes are given in Table 7.

Discussions:-

Using heating in greenhouses has positive influence on plant growth and helps to obtain better quality and high efficiency. In family businesses on the Mediterranean coast, greenhouses are not heated. The main reasons for this practice are that outside temperature values are not lower than 7^{o}C, these family businesses are small scale and the fuel to be used in unit heaters (diesel fuel) is costly. However, in recent years heating in greenhouses has become a widespread practice with modern greenhouses installed as a result of the changing conscious consumption dynamics.

The type of fuel used in heating greenhouses has considerable effect on production costs. With the increasing importance of competition in today's world, the most significant aspect of energy consumption is the cost of the energy source. However, use of fossil fuels has become dangerous as carbon release into the atmosphere leads to environmental disasters. For this reason, carbon release and thus the environmental effect of the type of fuel used are as important, if not more, as the cost. The burning of these fuels release gases into the atmosphere and as their concentrations in the atmosphere increase in time, greenhouse effect occurs. Greenhouse effect contributes to global warming, diminishing of water resources and more importantly to the shortening of our planet's life in a way that we may not even see the day when the world has run out of energy sources.

The primary policy of our country, which imports a large part of its energy needs, should be decreasing energy consumption. Therefore, it is essential to develop methods that will reduce dependence on foreign countries and cause less environmental pollution. Increasing energy efficiency in greenhouse is possible with energy conservation.Besides materials with good thermal insulation, the first precautions to conserve energy in greenhouses are thermal curtains to prevent solar energy stored throughout the day from being lost through the covering material at night hours, automated control of climate factors within the greenhouse and appropriate irrigation systems.

In the study, real heat requirement in plastic greenhouses with different specifications was calculated based on DIN 4701 standards by taking into consideration hourly climate values and costs and CO_2 emissions of different types of fuels were calculated. The calculations showed that required annual heating energy in greenhouses covered with single layer plastic is 171,1 kWh.m^{-2}.a^{-1}, provided that inside temperature is maintained at biologically optimum values of 16/24^{o}C day/night.However, in a greenhouse of the same size, required heat energy drops to 123,3 kWh.m^{-2}.a^{-1} when side walls are insulated with double layer covering and thermal curtains are used for heat conservation during night hours. In other words, with good insulation and thermal curtains, approximately 28% energy can be saved. This will not only reduce production costs but also lead to a significant decrease in CO_2 emissions into the atmosphere.

Also, decreasing inside temperatures of greenhouse to values which plants can tolerate is important for saving energy. In the case that the accepted biologically optimum day time inside temperature for tomato production is dropped from 24^{o}C to 21^{o}C, depending on the technical measures taken in the greenhouse, an average of 15% energy can be saved. Thus, for energy saving in greenhouses, it should be recommended to use sensitive control systems.

As a result of the research conducted, it is determined that the most appropriate fuel, according to the cost, is coal. Again according to the cost, next best alternative is natural gas. Heating oil and fuel-oil are not suitable for heating greenhouses due to their costs (Figure 4- Table 7). According to CO2 emissions, most suitable fuel is natural gas. But due to the lack of natural gas infrastructure in agricultural areas of Turkey greenhouse heating is fuelled by coal.

Table7.Fuel consumption ($m^3.m^{-2}$or $kg.m^{-2}$),fuel costs(₺$.m^{-2}$) and CO_2(kg Eşd. $CO_2.m^{-2}$) emission values in PE plastic greenhouses with different specifications, under different temperature regimes in Antalya climate conditions

Night/Day Temperature (°C)	Heat energy requirement ($kWh.m^2.a^{-1}$)	Fuel quantity ($m^3.m^{-2}$or $kg.m^{-2}$)				Fuel cost(₺$.m^{-2}$)				Emission (kg equiv.$CO_2.m^{-2}$)			
		Natural gas	Coal	Diesel oil	Fuel-Oil	Natural gas	Coal	Diesel oil	Fuel oil	Natural gas	Coal	Diesel oil	Fuel oil
Single layer plastic covering on roof and side walls													
13/16	57,6	7,60	9,43	6,23	6,55	7,07	3,40	27,52	18,07	17,06	33,25	23,63	24,37
16/16	118,2	15,60	19,36	12,78	13,43	14,51	6,97	56,48	37,08	35,01	68,24	48,49	50,01
16/21	144,6	19,09	23,69	15,63	16,43	17,75	8,53	69,09	45,36	42,83	83,48	59,32	61,18
16/24	171,1	22,58	28,03	18,50	19,45	21,00	10,09	81,75	53,67	50,68	98,78	70,19	72,39
Single layer plastic covering on roof and double layer PC (10 mm intervals) on side walls													
13/16	53,7	7,09	8,80	5,80	6,10	6,59	3,17	25,66	16,85	15,91	31,00	22,03	22,72
16/16	110,7	14,61	18,13	11,97	12,58	13,59	6,53	52,89	34,73	32,79	63,91	45,42	46,83
16/21	134,8	17,79	22,08	14,57	15,32	16,55	7,95	64,41	42,29	39,93	77,82	55,30	57,03
16/24	158,6	20,93	25,98	17,14	18,03	19,47	9,35	75,78	49,75	46,98	91,57	65,07	67,10
Single layer plastic covering on roof and double layer PC (10 mm) on side walls + Aluminum containing thermal curtain													
13/16	38,2	5,04	6,26	4,13	4,34	4,69	2,25	18,25	11,98	11,31	22,05	15,67	16,16
16/16	75,4	9,95	12,35	8,15	8,57	9,26	4,45	36,03	23,65	22,33	43,53	30,93	31,90
16/21	99,5	13,13	16,30	10,76	11,31	12,21	5,87	47,54	31,21	29,47	57,44	40,82	42,10
16/24	123,3	16,27	20,20	13,33	14,01	15,14	7,27	58,91	38,68	36,52	71,19	50,58	52,17

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