



MARMARA UNIVERSITY
INSTITUTE FOR GRADUATE STUDIES
IN PURE AND APPLIED SCIENCES



**QUALITY ORIENTED PROCESS
DEVELOPMENT VIA STATISTICAL
ANALYSIS FOR CARBON, WATER, AND
ENERGY FOOTPRINT: AN APPLICATION IN
TEXTILE INDUSTRY**

Mehtap ERDİL

MASTER THESIS
Department of Environmental Engineering

Thesis Supervisor

Prof. Dr. S. Sinan KESKİN

Thesis Co-Supervisor

Assoc. Prof. Dr. Bahar SENNAROĞLU

İSTANBUL, 2017



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STUDIES IN PURE AND APPLIED SCIENCES**

Mehtap ERDİL, a Master of Science student of Marmara University Institute for Graduate Studies in Pure and Applied Sciences, defended her thesis entitled “Quality Oriented Process Development Via Statistical Analysis For Carbon, Water, And Energy Footprint: An Application In Textile Industry”, on 09.08.2017 and has been found to be satisfactory by the jury members.

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ABSTRACT

QUALITY ORIENTED PROCESS DEVELOPMENT VIA STATISTICAL ANALYSIS FOR CARBON, WATER, AND ENERGY FOOTPRINT: AN APPLICATION IN TEXTILE INDUSTRY

Global warming within the last thirty years is an important problem for the world and its relationship with the greenhouse gases is well known. Almost all the industrial activities release carbon dioxide, the most dominant one, into the atmosphere. These emissions are mainly the results of consumption of energy produced from fossil fuels. In addition, water consumption related to industrial activities should also be followed carefully for efficient use of limited fresh water resources of the World. For these reasons, determining carbon, water, and energy footprints in industrial production activities and trying to minimize them by necessary attempt is very important.

In this study, carbon, water, and energy footprint values for each of the production processes have been calculated and Pareto analysis, which is a statistical process control technique, was applied to these values. With the Pareto analysis, main problems related to the production processes have been defined and their reasons have been searched. In addition, an underwear company was included in the statistical analysis and suggestions for reducing footprints within the production processes have been developed. In this context, quality house, quality function deployment of processes and participation to environmentally oriented production have been evaluated by using carbon, water, and energy footprint data.

Keywords: Greenhouse gases, Environmentally oriented production, Footprint, Pareto analysis, Quality house

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Mehtap ERDİL

ÖZET

KARBON, SU VE ENERJİ AYAK İZİNİN İSTATİSTİKSEL ANALİZİ İLE KALİTE ODAKLI SÜREÇ GELİŞTİRİLMESİ: TEKSTİL ENDÜSTRİSİNDE BİR UYGULAMA

Son otuz yıldır gündemde olan küresel ısınma problemi, dünyamız bakımından son derece önemli olup, bunun sera gazları ile ilişkisi çok iyi bilinmektedir. Bu gazlardan etkilisi en baskın olan karbondioksit, hemen hemen tüm endüstriyel faaliyetlerden atmosfere salınmaktadır. Bu emisyonlar büyük oranda fosil yakıtlardan üretilen enerjinin tüketiminden kaynaklanmaktadır. Ayrıca, endüstriyel faaliyetlerden kaynaklanan su tüketiminin de, dünyanın sınırlı tatlı su kaynaklarının verimli kullanılabilmesi bakımından dikkatle izlenmesi gerekmektedir. Bu sebeplerle, endüstriyel üretim faaliyetlerinde karbon, su ve enerji ayak izlerinin belirlenmesi ve bunların minimize edilmesi için gerekli çabanın gösterilmesi son derece önemli ve gereklidir.

Bu çalışmada, bir kumaş üretim tesisindeki iş süreçlerinin herbiri için karbon, su ve enerji ayak izi değerleri hesaplanıp, bu değerlere bir istatistiksel proses kontrol tekniği olan pareto analizi uygulanmıştır. Pareto analizi ile üretim süreçlerindeki temel problemler tanımlanıp, problemlerin sebepleri ortaya çıkarılmaya çalışılmıştır. Ayrıca, istatistiksel çalışmaya bir iç giyim firması da dahil edilmiş ve pareto analizi ile süreçlerdeki ayak izlerinin azaltılmasına yönelik öneriler getirilmiştir. Bu kapsamda, karbon, su ve enerji ayak izleri verilerinden faydalanılarak, kalite evi, iş süreçlerinin kalite fonksiyonu ve çevre odaklı üretime katılım değerlendirilmiştir.

Anahtar kelimeler: Sera gazları, Çevre odaklı üretim, Ayak izi, Pareto analizi, Kalite evi

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Mehtap ERDİL

ABBREVIATIONS

AW	: Absolute weight
AFOLU	: Agriculture, Forestry, and Other Land Use
BP	: British Petroleum
bWF	: Blue water footprint
CO	: Carbon monoxide
CO₂	: Carbon dioxide
CO_{2e}	: Carbon dioxide equivalent
CH₄	: Methane
CF	: Carbon footprint
CF₃ SF₅	: Trifluoromethyl sulphur pentafluoride
CFCs	: Chlor fluorocarbons
CNW	: Customer need weight
ECF	: Energy' carbon footprint
eF	: Ecological Footprint
EF	: Energy footprint
EECF	: Electricity energy' carbon footprint
EEEF	: Electricity energy' energy footprint
EMRA	: Energy Market Regulatory Authority
EPA	: Environmental Protection Agent
FCF	: Carbon footprint in Forklift' transportation
FEF	: Forklift' energy footprint (Forklift use)
FWF	: Fabric' water footprint
GDP	: Gross domestic product
GHGs	: Greenhouse gases
GWF	: Green water footprint
GWP	: Global Warming Potential

gWF : Grey water footprint

ha : hectare

HFCs : Hydrofluorocarbons

HCl FCs : Hydrochlorofluorocarbons

IPPC : International Plant Protection Convention

IPPU : Industrial Processes and Product Use

IR : Improvement ratio

ISO : International Organization for Standardization

IW : Importance weight

LCA : Life Cycle Assessment

LCIA : Life Cycle Impact Assessment

NGECF : Natural gas energy' carbon footprint

NGEEF : Natural gas energy' energy footprint

NF₃ : Nitrogen trifluoride

NH₃ : Ammonia

NMVOCs : Non-methane volatile organic compounds

NO : Nitric oxide

N₂O : Nitrous oxide

NO_x : Nitrogen oxides

OECD : Organisation for Economic Cooperation and Development

QFD : Quality function deployment

PAS : Publicly Available Specification

PFCs : Perfluorocarbons

PTCF : Carbon footprint in product of transportation

PTEF : Product transportation' energy footprint (fabric product transportation)

PWF : Raw wool' water footprint

RMTCF : Carbon footprint in raw material of transportation

RMTEF : Raw material transportation energy footprint (Raw material transportation)

SCF : Service' carbon footprint

SEF : Service' energy footprint (Personnel transportation)

SF₄ : Sulphur tetrafluoride

SF₆ : Sulphur hexafluoride

SCF : Carbon footprint in services' transportation

SO₂ : Sulphur dioxide

TALs : Turkish Apparel Leather

TCF : Transport' carbon footprint

TEP : Tonne equivalent of petrol

UNFCCC : United Nations Framework Convention on Climate Change

WF : Water footprint

WWF : Raw wool'water footprint

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1. INTRODUCTION

In recent years, some research has been performed to determine the energy, carbon, and water footprints in the textile industry. Footprint analyses have resulted in many improvements in the industry. Although related literature review is discussed in detail in Chapter 2, a brief summary is provided in Table 1.1, 1.2, and 1.3 for the footprints (carbon (CF), water (WF), energy (EF)), and Quality Function Deployment (QFD).

Table 1.1 Studies of Multi-Agent Manufacturing solutions about footprints, Pareto analysis, Quality, and QFD (1982-2004)

Scope of the study	Area {Types of footprints (Carbon (CF), Water (WF), Energy (EF)), Pareto analysis, Quality, and Quality Function Deployment (QFD)}	References
Explains quality and quality function deployment tools	Quality	Ishikawa (1982)
Explains the dimensions of quality	Quality	Besterfield (1990)
Explains the main objectives in quality function deployment	Quality	Akao (1990)
Explains the quality and quality function deployment	Quality	Asaka (1990)
Introduction to quality	Quality	Montgomery (2004)

Table 1.2 Studies of Multi-Agent Manufacturing solutions about footprints, Pareto analysis, Quality, and QFD (2006-2012).

Scope of the study	Area {Types of footprints (Carbon (CF), Water (WF), Energy (EF)), Pareto analysis, Quality, and Quality Function Deployment (QFD)}	References
Analyzes effects on water consumption	WF	Chapagain et al. (2006)
Explains the quality and quality control	QFD	Yavuz (2006)
Calculation of emissions related to types of energy and fuel	CF, WF, EF	Pekin (2006)
Case study footprints values	CF, WF, EF	Akıllı et al. (2008)
Optimization of The Product Design Through Quality Function Deployment (QFD) and Analytical Hierarchy Process (AHP): A Case Study In A Ceramic Washbasin	QFD	Yılmaz (2009)
Research on environmental effects of climate change in tourism	CF	Kercher et al. (2010)
Defines Pareto analysis' steps	Pareto analysis	Talib et al. (2010)
Use LCA technique and the technical support for the CF evaluation, Application of Monte Carlo analysis in textile industry	CF	Bevilacqua et al. (2011)
Effects of LCA for shopping bags etc. with carbon footprint	CF	Muthu et al. (2011)
Effects of different energy types and application of a Monte Carlo method	CF, EF	Weber and Clavin (2012)

Table 1.3 Studies of Multi-Agent Manufacturing solutions about footprints, Pareto analysis, Quality, and QFD (2013-2016).

Scope of the study	Area {Types of footprints (Carbon (CF), Water (WF), Energy (EF)), Pareto analysis ,Quality, and Quality Function Deployment (QFD)}	References
CF evaluation at an industrial park with a hybrid approach	CF	Dong et.al (2013)
Use of Logarithmic Mean Divisia Index method on CO ₂ emission and energy consumption	CF, EF	Lin and Moubarak(2013)
Types of carbon footprint	CF	Atabey (2013)
Water footprint evaluation of five textile manufacturers	WF	Chico et.al (2013)
Estimation of carbon footprint	CF	Turanlı (2015)
Carbon footprint in a ship waste water treatment plant	CF	Toröz (2015)
Carbon Footprint and GHGs in the atmosphere.	CF	Subramanian and Muthu (2016)

When the research activities, some of which are provided in Table 1.1, 1.2, and 1.3, are analyzed, it can be seen that there are many studies about footprint concept, pareto analysis and QFD.

1.1. Main Objectives of the thesis

The main objectives of this thesis study can be given as follows:

- To determine energy footprints in fabric textile production processes,
- To determine carbon footprints in fabric textile production processes,
- To determine water footprints in fabric textile production processes,

- To determine footprint (CF,WF, and EF) problems with statistical method (Pareto analysis),
- To evaluate applications of quality function deployment (QFD) in two textile companies in terms of environmentally oriented production.
- To determine options for reducing footprints in order to accomplish environmentally oriented production.

1.2. Scope of the thesis study

Turkish textile industry produces approximately 10% of the country's GDP (TTHD Sektörleri Strateji Belgesi ve Eylem Planı, 2015-2018; Url-68). The selected fabric production company is among the first ten textile companies in Turkey (Url-69).

This study intended to determine carbon, water, and energy footprints for each production process in a fabric manufacturing company. Pareto analysis has been applied to the obtained results for developing suggestions to reduce footprints. Quality Function Deployment (QFD) concept has been used for an environmentally oriented production (clean production) alternative.

Chapter 1 covers research about footprints and QFD and highlights basic findings for the textile industry all over the World.

Chapter 2 covers information about global warming and climate change, energy efficiency, and energy state in Turkey.

Chapter 3 covers information about the greenhouse effect in general and introduces important greenhouse gases.

Chapter 4 explains footprint concept (ecological, carbon, water, and energy) in general and presents literature data.

Chapter 5 covers information about the concepts of quality, quality function deployment, and details about the use of these techniques.

Chapter 6 covers the details of the production processes in the fabric manufacturing plant analyzed in this study.

Chapter 7 presents the footprint calculations in all processes used in the plant together with the application of Pareto analysis and Quality Function Deployment (QFD) evaluation of the footprint results obtained.

Chapter 8 presents results of this study and comes up with some suggestions for future work.



2. GLOBAL WARMING AND CLIMATE CHANGE

Global warming due to greenhouse gases (GHGs) has been an important scientific and political issue during the last two decades. The facts that infrared radiation is trapped by the GHGs and particles in the atmosphere and that the atmospheric carbon dioxide (CO₂) level has increased by some 25% since 1850 mainly due to fossil fuel combustion and land use changes are well accepted (Schneider, 1990; Hartmann, Klein, and Rusticucci, 2013). A certain level of warming effect is a normal part of the Earth's natural variability which is related to interactions among the atmosphere, ocean, and land, as well as variables in the value of solar radiation reaching the earth (Gillis and Justin, 2015; Walker and King, 2010). Global warming and climate change concepts have been developed with the increase of average temperatures during the last century (Gillis and Justin, 2015; Climate Change, 2014) but especially since 1970's (Hartmann, Klein, and Rusticucci, 2013). More energy is stored in oceans and atmosphere since 1970 (EPA, 2013; Borenstein and Seth, 2015) and polar ice sheets started melting as an indication (Rhein and Rintoul, 2013). It has been reported that approximately 95% of global warming is related to increased human activities, thus increased greenhouse gas concentrations (IPCC, 2006; Url-55; National Research Council, 2010; Hartmann, Klein, and Rusticucci, 2013).

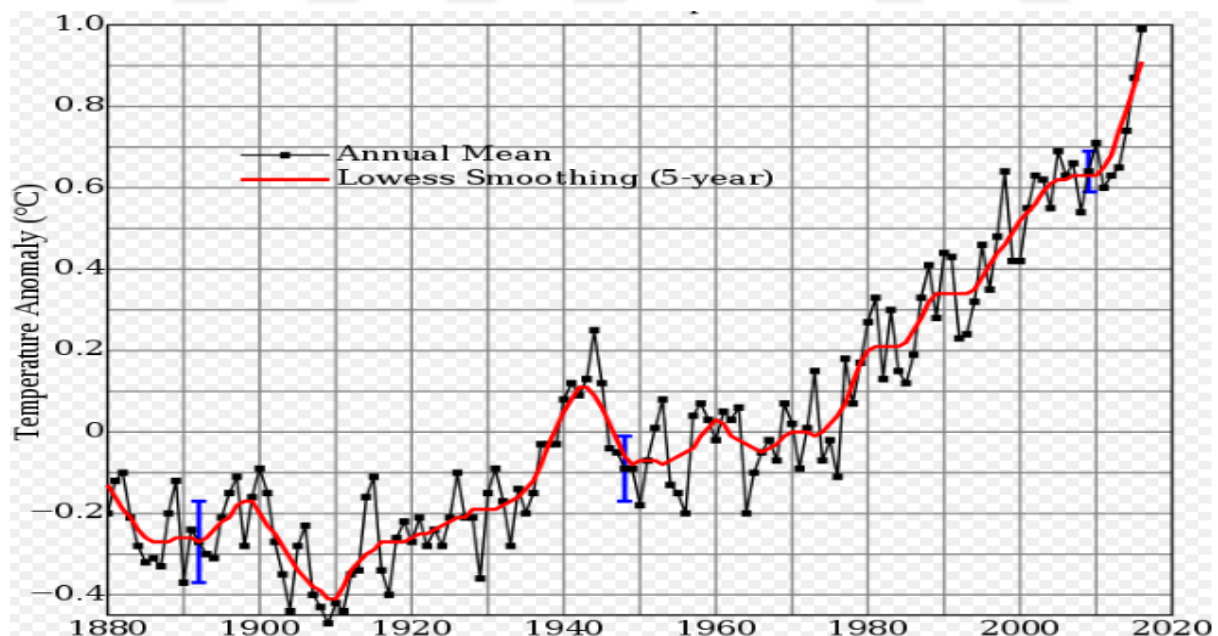


Figure 2.1 Change in temperature related to global warming (Nasa Giss, 1880)

Figure 2.1 shows the global surface temperature anomaly from 1880 to 2016 with respect to the mean between 1951 and 1980. The black line is the global annual and the red line is the five-year lowess smoothing trends. The blue uncertainty columns present a 95% confidence limit (Nasa Giss, 1880; Url-1).

2.1. Kyoto Protocol, United Nations Framework Convention On Climate Change, and Montreal Protocol

Global warming and climate change are serious concerns in recent years and the most significant step towards dealing with this problem has been the Kyoto Protocol. Among the international conferences held about this problem, United Nations Framework Convention on Climate Change (UNFCCC) was a very significant step in 1994 (British Petroleum, 2012).

Table 2.1 shows the classification of countries according to Kyoto Protocol outlines.

Table 2.1 Classification of countries according to Kyoto Protocol (The World Bank, 2012; British Petroleum, 2012)

List A	Countries	Responsibilities
Appendix-I	OECD+AB+PEGSÜ (40 Country)	Emission reduction
Appendix-II	OECD+AB-15 (25 Country)	Technology Transfer and Provide to Supply Finance
Appendix-I External	Other Countries (China, India, Pakistan, Mexico, Brazilia...)	No responsibility
Appendix-B	Appendix-I Countries (38 Countries), Turkey and Belarus external	5% reduction in greenhouse gas emissions between 2008 and 2012

Table 2.2 Classification of countries according to UNFCCC (The World Bank, 2012; British Petroleum, 2012)

Lists	Countries	Responsibilities
Appendix-I	OECD+AB+PEGSÜ 40 Country + Turkey (Specific condition)	Emission Reduction
Appendix-II	OECD+AB-15 (25 Country) Turkey external	Technology Transfer and Provide to Support Finance
Appendix-1 External	OTHER COUNTRIES (China, India, Pakistan, Mexico, Brazilia)	No responsibility

UNFCCC has been accepted by 200 countries and European Community. Kyoto Protocol has been accepted by EU, 182 countries, and 1 economic community. Table 2.3 presents the global warming potential values of greenhouse gases according to UNFCCC and Montreal Protocol (Url-2).

Table 2.3 Global warming potential (GWP) values of greenhouse gases according to UNFCCC and Montreal Protocol (The World Bank, 2012; British Petroleum, 2012)

Greenhouse gases			Global Warming Potential (GWP)
UNFCC	CO ₂	Carbondioxide	1
	CH ₄	Methane	21
	N ₂ O	Nitrous oxide	310
	HFCs	Hydrofluorocarbons	1100-1900
	PFCs	Perfluorocarbons	560-11700
	SF ₆	Sulphurhexafluoride	23900
Montreal Protocol	ClFCs HCFCs	Chlorofluorocarbons and Hydrochlorofluorocarbons	6500-8700

Carbondioxide equivalents are units that show the relative impact of a considered gas. For example, a ton of methane can be considered as 21 tons of CO₂ equivalent (CO_{2e}), and a ton of nitrous oxide can be considered as 310 tons of CO_{2e}. Using a common unit is necessary when making inventories of greenhouse gases or when developing strategies to decrease greenhouse gas emissions as shown in Figure 2.2 (Doll and Baranski, 2011; Url-1; Url-2).

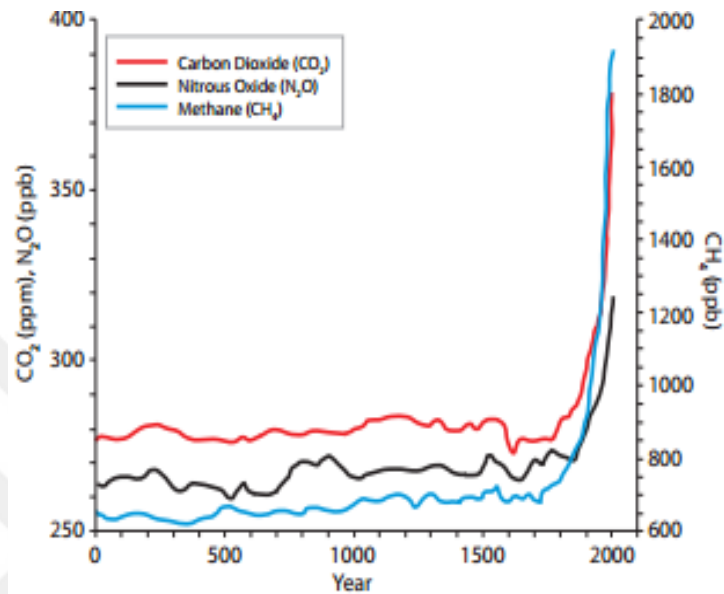


Figure 2.2 Atmospheric concentration of naturally occurring greenhouse gases carbon dioxide, methane and nitrous oxide over the past 2000 years (Doll and Baranski, 2011).

2.2. National Greenhouse gas emission inventory

Inventory development steps are explained as follows (British Petroleum, 2012):

- 1- Data collection,
- 2- Data recording,
- 3- Defining emission factors for forecasts,
- 4- Calculation of emissions,
- 5- Defining sources of emission

2.3. Energy efficiency

Energy efficiency is a concept related to the use of energy more carefully in all of the human related operations (The World Bank, 2012) (Table 2.4).

Table 2.4 Population, Gross domestic product (GDP) / person, amounts of energy production and consumption for countries in 2011 (British Petroleum, 2012; The World Bank, 2012)

Countries	Population (million)	GDP/person (\$/person)	Energy Consumption (Mtep)	Electricity Consumption (TWh)	CO₂ emission (million tonne)
China	1348.1	5445	2613.21	4700.07	8979.14
ABD	313.1	48112	2269.33	4308	6016.61
Russia	142.8	13089	685.63	1051.59	1675.04
India	1242.6	1489	559.10	1006.17	1797.99
Japan	126.5	45903	477.59	1104.18	1307.40
Canada	34.3	50345	330.27	607.59	624.44
Germany	82.1	44060	306.41	614.5	802.82
Brazil	196.7	12594	266.88	501.32	481.89
Korea	48.4	22424	263.01	520.10	738.06
Turkey	74.7	10444	118.80	228.41	323.40
Word	6978.3	10027	12274.62	22018.12	34032.75

2.4. Energy and Carbon Parity

Greenhouse gas emissions in Turkey are given as million tonnes of CO₂e between 1990 and 2014 in Table 2.5 and Table 2.6 by TUIK (TUIK, 2015; Url-3).

Table 2.5 Greenhouse gas emissions (CO₂e) (TUIK, 2015; Url-3)

Million tonnes					
Year	CO ₂	CH ₄	N ₂ O	F-Gases	TOTAL
1990	146.8	43.8	16.5	0.7	207.8
1991	152.3	44.8	16.1	0.9	214.1
1992	158,6	44,7	16.8	0.8	220.8
1993	167.4	44.6	17.8	0,8	230,6
1994	164.6	44.1	15.3	0.7	224.7
1995	178.8	43.9	15.8	0.6	239
1996	194.8	44.2	16.7	1	256.7
1997	208.5	43.4	16.9	1.2	269.9
1998	208.4	43.5	18.7	1.2	271.8
1999	206.4	45	18.9	1.1	271.4
2000	232.5	44.8	18.4	1.0	296.8
2001	217.5	44.0	16.2	1.1	278.8
2002	226.4	42.2	17.1	1.5	287.1
2003	240.9	43.4	17.7	1.7	303.7
2004	253.2	43.0	18.6	2.2	316.9
2005	279.1	44.6	19.0	2.5	345.2
2006	302.2	46.1	20.2	2.7	371.3
2007	333.2	48.5	19.1	2.6	403.4
2008	323.5	49.6	17.3	2.7	393.1
2009	310.6	49.4	19.7	2.9	382.5
2010	320.4	51.4	19.6	3.9	395.3
2011	338.1	53.9	19.5	4.3	415.9
2012	363.1	58.0	21.1	5.2	447.5
2013	355.0	56.2	23.2	4.5	438.8
2014	382.2	57.1	23.3	4.9	467.6

Table 2.6 Greenhouse gas emissions by sectors (equivalent of CO₂) (TUIK, 2015; Url-3)

Million tonnes						
Year	Energy	Industrial processes and product use	Agriculture	Waste	Total	Change compared to 1990 (%)
1990	132.5	23.1	41.2	10.9	207.8	-
1991	136.6	24.4	41.9	11.2	214.1	3.1
1992	142.6	24.7	42.1	11.4	220.8	6.3
1993	150.5	25.5	43.0	11.7	230.6	11.0
1994	147.0	25.5	40.3	11.9	224.7	8.2
1995	160.1	27.0	39.8	12.2	239.0	15.0
1996	175.2	28.0	40.8	12.6	256.7	23.5
1997	188.1	29.6	39.1	13.1	269.9	29.9
1998	187.7	29.8	40.8	13.4	271.8	30.8
1999	187.4	28.7	41.3	13.9	271.4	30.6
2000	214.4	28.4	39.6	14.4	296.8	42.9
2001	198.3	28.6	37.0	14.9	278.8	34.2
2002	206.0	30.0	35.7	15.4	287.1	38.2
2003	219.1	31.6	37.1	15.8	303.7	46.2
2004	229.2	34.3	37.0	16.4	316.9	52.5
2005	252.7	37.8	37.9	16.9	345.2	66.2
2006	275.2	39.8	38.9	17.4	371.3	78.7
2007	306.1	41.1	38.5	17.7	403.4	94.2
2008	295.3	43.5	36.5	17.8	393.1	89.2
2009	280.9	45.8	38.0	17.9	382.5	84.1
2010	286.0	51.8	39.3	18.1	395.3	90.2
2011	298.2	58.2	41.1	18.4	415.9	100.2
2012	321.3	62.4	45.8	18.0	447.5	115.4
2013	310.0	63.2	49.3	16.2	438.8	111.2
2014	339.1	62.8	49.5	16.1	467.6	125.0

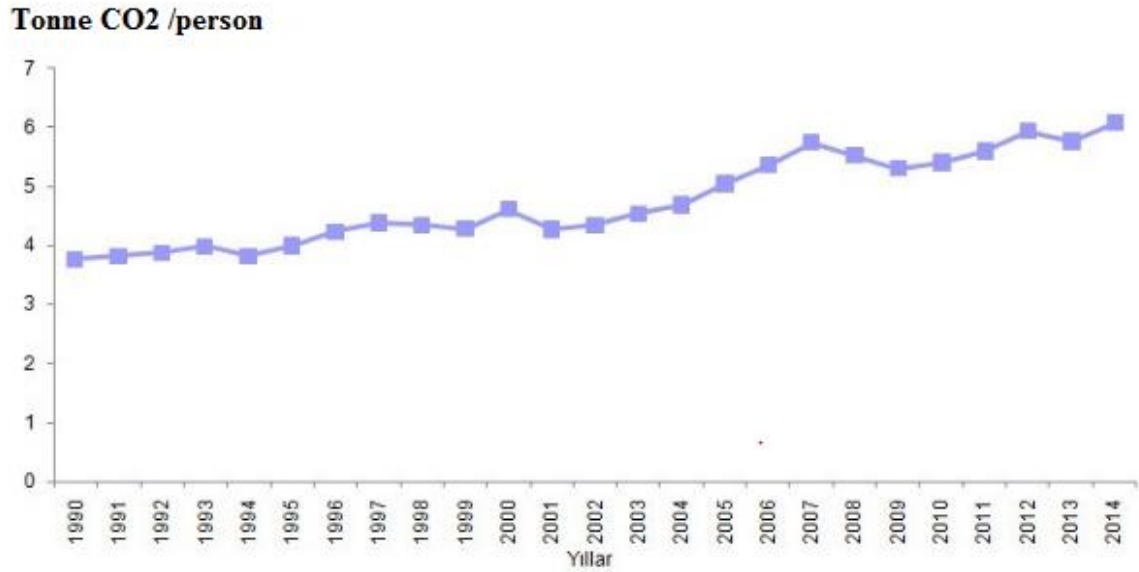


Figure 2.3 Greenhouse gas emissions per capita person between 1990 and 2014 (TUIK, 2015; Url-3)

Consider revising per capita person trend in Figure 2.3 within the same period. Greenhouse gas emissions in the World related to sectors are shown as CO_{2e} between 1990 and 2014 in Table 2.7 (IPCC, 2006; Url-4).

Table 2.7 CO₂ emissions according to sources between 1990 and 2011 (IPCC, 2006; Url-4)

Greenhouse gas sources	Bin tonne	Greenhouse gas sources	Bin tonne
Energy	294781	Industrial processes	49859
A. Fuel consumption	294649	1. Mineral productions	31976
1. Conversion and energy sector	121760	2. Chemical industry	(*)
2. Industrial sector	57253	3. Metal industry	17883
3. Transportation	47675	Waste	54
4. Other sectors	67961	Total	344694
B. Leakage	132		

2.5. The Energy State of Turkey

Figure 2.4 presents the first 20 countries in electricity energy production according to American Energy Information Administration' 2012 data. Turkey's energy consumption is approximately 228 billion kWh and ranked 20 in the list (EUAŞ, 2015; Url-5).

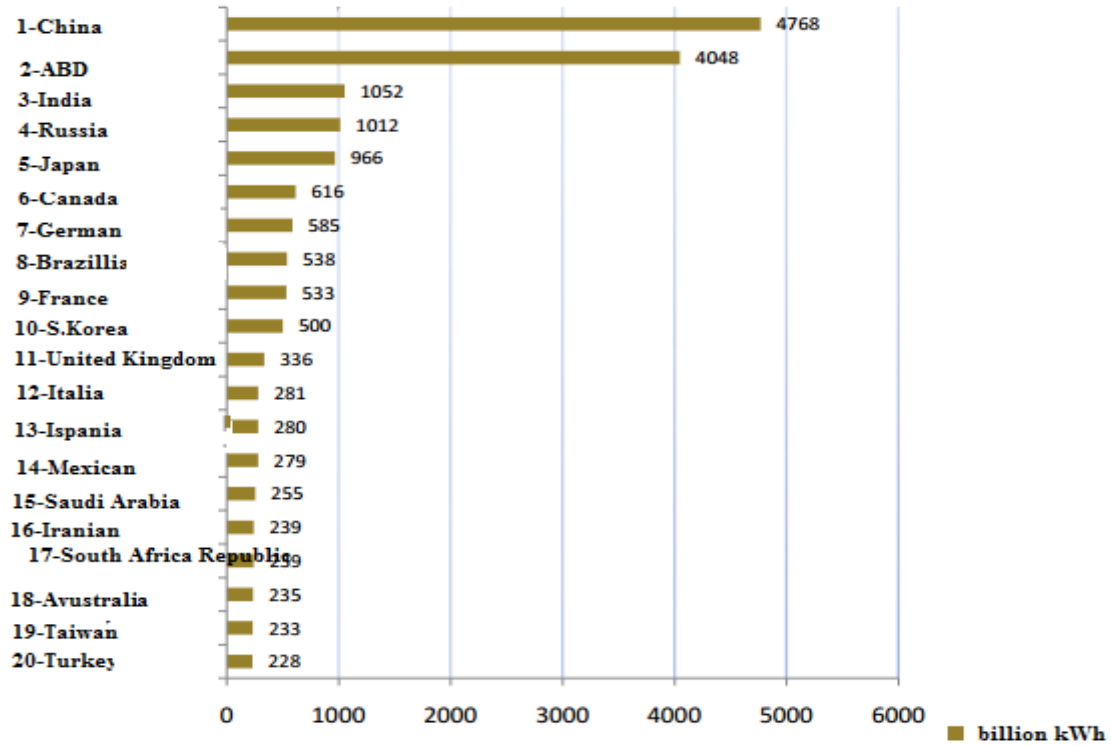


Figure 2.4 The first 20 countries in electricity production (EUAŞ, 2015; Url-5).

Total electricity production in Turkey is provided 48.1% by natural gas, 29.2 % from coal, 16.1% by hydraulic, 3.3% by the wind, 1.9% by liquid and asphalt, and 1.4% by waste and geothermal in 2014 (Figure 2.5) (EUAŞ, 2015; Url-5).

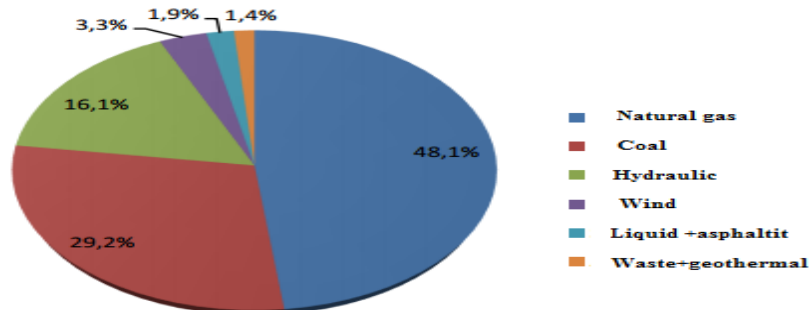


Figure 2.5 Distribution of electricity production in Turkey (EUAŞ, 2015; Url-5)

2.6. Turkey's Greenhouse Gas Emission Trends

Figure 2.6 shows the total greenhouse gas change for countries between 1990 and 2003.

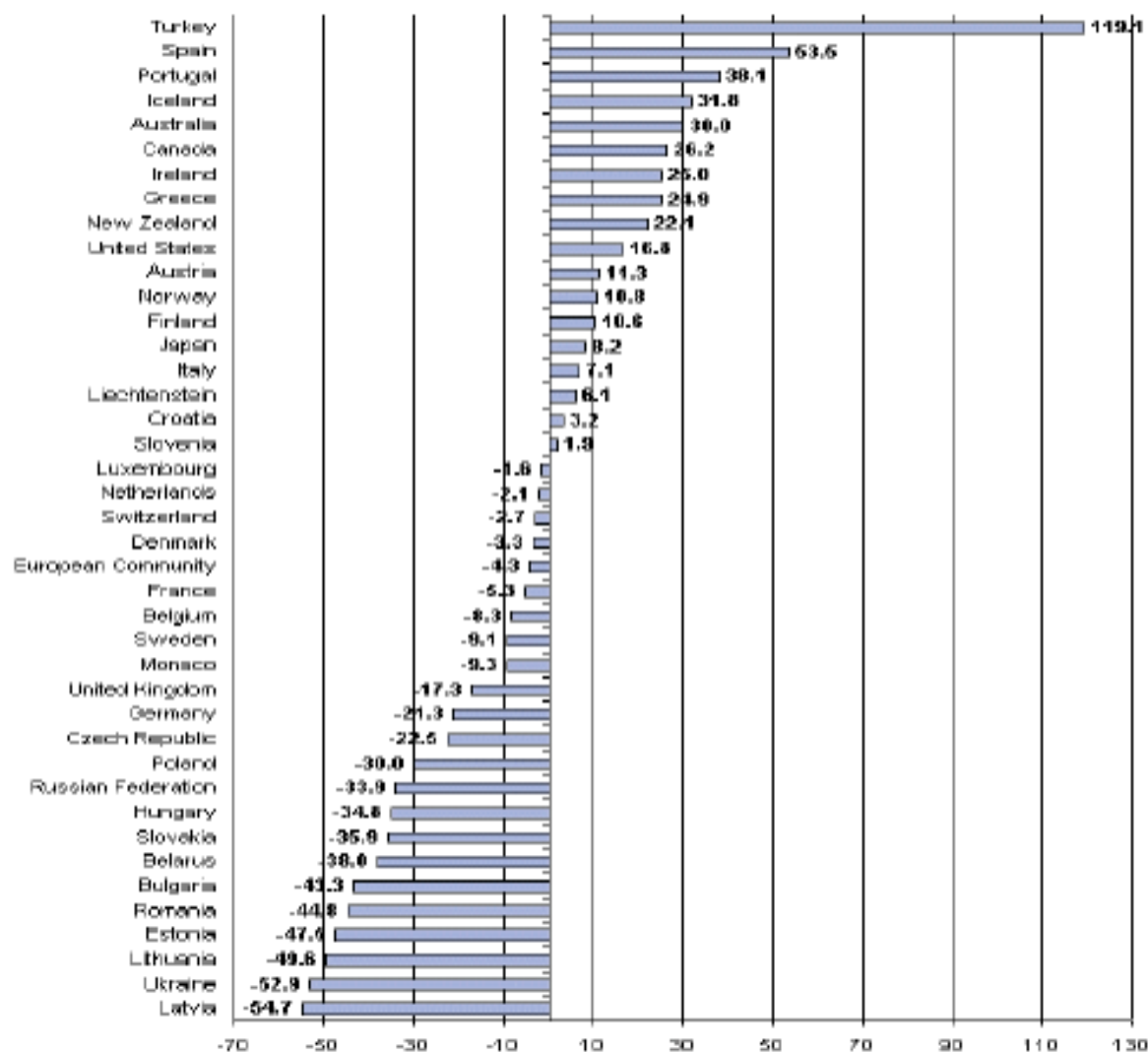


Figure 2.6 Total Greenhouse gas emissions increase for countries (Keskin, 2012)

Table 2.8 shows comparison of Socioeconomic, Energy, and Carbon data indicators for Turkey, OECD Countries, and World in 2008.

Table 2.8 Comparison of Socioeconomic, Energy, and Carbon data Indicators for Turkey, OECD Countries, and the World in 2008 (Keskin, 2012)

INDICATORS		TURKEY	OECD COUNTRIES	WORD
SOCIO ECONOMIC	GDP (Milliard 2000 ABD \$)	375.96	30504	4048200
	Population (million person)	71.08	1190	6688
	GDP per capita person (bin 2000 ABD \$)	5.29	25.63	6.05
ENERGY	Total primer energy supply [MTEP] (million tonne equivalent of petrol)	98.50	5422	12267
	Total energy consumption (Milliard kWh)	170.60	10097	18603
	Primer energy supply per capita person [TEP (tonne equivalent of petrol) /person]	1.39	4.56	1.63
	Electric consumption per capita person (kWh/person)	2400	8486	2782
	Economy' energy density (TEP/bin 2000ABD \$)	0.26	0.18	0.30
CARBON	Total CO ₂ emissions (Million tonne CO ₂)	263.53	12630	29381
	CO ₂ emissions per capita person (tonne CO ₂ /person)	3.71	10.61	4.39
	Economy' carbon density (tonneCO ₂ /bin 2000 ABD \$)	0.70	0.41	0.73
	Energy supply' carbon density (tonne CO ₂ /TEP)	2.68	2.33	2.40

3. GREENHOUSE EFFECT

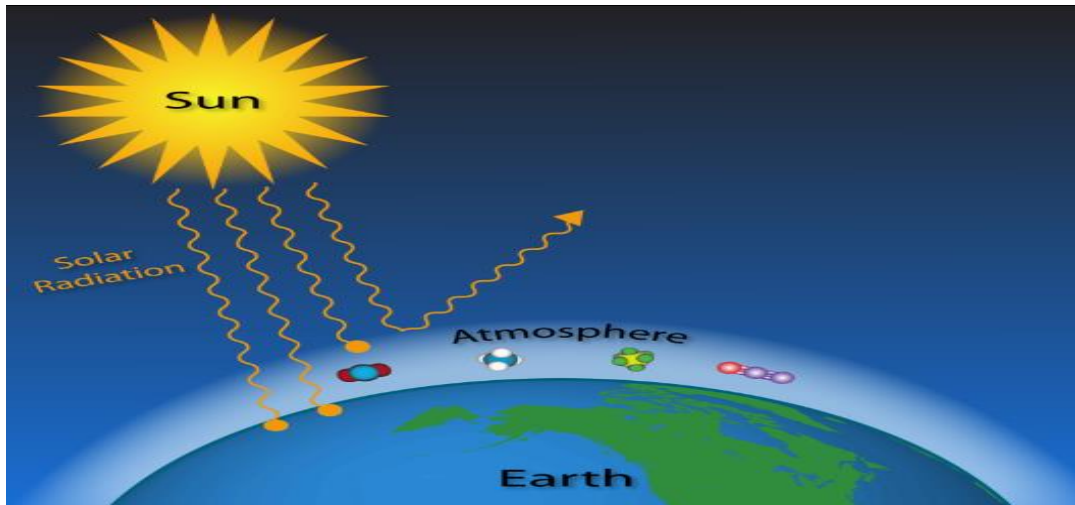


Figure 3.1 Greenhouse gas effect (Url-64)

The Earth's climate depends on the radiative balance of the atmosphere, which in turn relies on the input of solar radiation and the atmospheric abundances of radiative active trace gases (such as greenhouse gases), clouds, and aerosols. Two-thirds is absorbed by the surface and, to a lesser extent, by the Earth's atmosphere to balance the absorbed incoming energy. The energy reached on Earth is the source of life on Earth and some part will radiate back into the atmosphere in longer wavelengths, primarily in the infrared part of the spectrum as shown in Figure 3.1 (Url-62; Url-63; Url-64).

3.1. MAIN GREENHOUSE GASES

The following GHGs are included in IPCC 2006 Guidelines (Url-15; IPCC, 2006):

- **Carbon dioxide (CO₂)**

The chemical formula is CO₂, which is a colourless and odourless gas important to life on Earth. The gas occurs as a chemical compound. It consists of a carbon atom covalently double bonded to two oxygen atoms (Albritton et al., 2001; Gillenwater et al., 2002; Topçu, 2008). Carbon dioxide exists in Earth's atmosphere as a trace gas at a concentration of about 0.04 percent by volume. Natural sources contain volcanoes, hot springs, and geysers, and it is freed from carbonate rocks by dissolution in water and acids (Muslu, 2000; IPCC, 2006; Çevre ve Şehircilik Bakanlığı, 2012). Since the gas is soluble in water, it also arises naturally from groundwater, rivers, and lakes, in icecaps and glaciers in seawater. It is available in deposits of petroleum and natural gas (Dyson, 1977; Energy Institute, 2012; IPCC, 2006; Aydın, 2008).

- **Methane (CH₄)**

The chemical formula is CH₄. The gas is a chemically and radioactively active trace gas that is manufactured from a wide variety of anaerobic (i.e., oxygen deficient) processes and is primarily removed by reaction with hydroxyl radicals (OH) in the troposphere (Pekin, 2006; Gillenwater et al., 2002; Lide and David, 2006). Oxidation of CH₄ by OH in the stratosphere is an important source of stratospheric water (H₂O) where it is a greenhouse gas (Khalil, 1999; Muslu, 2000; Albritton et al., 2001).

- **Nitrous oxide (N₂O)**

Nitrous oxide is recognized as laughing gas, nitrous, nitro or NO_s (Topçu, 2008; EPA, 2014; EPA, 2015; IPCC, 2006). The gas' chemical formula is N₂O. This is a colourless and non-flammable gas (Baird, 1999; Muslu, 2000; Gillenwater et al, 2002).

- **Hydrofluorocarbons (HFC_s)**

Organic compounds that contain fluorine and hydrogen atoms are the most common type of organofluorine compounds(Gillenwater et al., 2002; Topçu, 2008). They are commonly used in air conditioning and as refrigerants in place of the older chlorofluorocarbons. Their atmospheric concentrations and contribution to anthropogenic greenhouse gas emissions are rapidly developing (Pekin, 2006; Topçu,2008; Baird, 1999).

- **PFC_s(Perfluorocarbons)**

Fluorocarbons, sometimes referred to as perfluorocarbons or PFCs, are, strictly speaking, organofluorine compounds with the formula C_xF_y, i.e. they contain only carbon and fluorine, though the terminology is not strictly followed (Pekin, 2006; Topçu, 2008). Compounds with the prefix perfluoro are hydrocarbons, including those with heteroatoms, wherein all C-H bonds have been replaced by C-F bonds. Fluorocarbons and their derivatives are useful fluoropolymers, refrigerants, solvents, and anaesthetics (Baird, 1999; Gillenwater et al., 2002).

- **Sulphur hexafluoride (SF₆)**

The gas is an inorganic, colourless, odourless, non-flammable, extremely potent greenhouse gas, which is an excellent electrical insulator. This gas has an octahedral geometry, consisting of six fluorine atoms attached to a central sulphur atom (Gillenwater et

al., 2002; Topçu, 2008). Typical for a nonpolar gas, it is poorly soluble in water but quite soluble in nonpolar organic solvents. It is generally transported as a liquefied compressed gas. It has a density of 6.12 g/L at sea level conditions, considerably higher than the density of air 1.225 g/L (Baird, 1999; Topçu, 2008).

- **Nitrogen trifluoride (NF₃)**

Nitrogen trifluoride is the inorganic compound with the formula NF₃. This nitrogen-fluorine compound is a colourless, odourless, non-flammable gas. It finds increasing use as an etchant in microelectronics (Sinke, 1967).

- **Trifluoromethyl sulphur pentafluoride (CF₃SF₅)**

This gas is a rare industrial greenhouse gas, first published in 2000 by a group of researchers from Germany, United Kingdom, and the United States. Trifluoromethyl sulphur pentafluoride is considered to be one of the several super greenhouse gases. On a per molecule basis, it is considered to be the most potent greenhouse gas present in Earth's atmosphere. However, the current concentration of Trifluoromethyl sulphur pentafluoride remains at a level that is unlikely to measurably contribute to Earth's warming (Natascha et al., 2014).

3.2. Precursor Gases

The 2006 Guidelines also supported information for the reporting of the following precursors: nitrogen oxides (NO_x), ammonia (NH₃), non-methane volatile organic compounds (NMVOC), carbon monoxide (CO) and sulphur dioxide (SO₂) although methods for estimating emissions of these gases are not taken here (Table 3.1).

Greenhouse gas emission and removal estimates are separated into main sectors, which are groupings of related processes, sources, and sinks:

- Energy
- Industrial Processes and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Waste
- Other (e.g., indirect emissions from nitrogen deposition from non-agriculture sources)

Each sector explains individual categories (e.g., transport) and sub-categories (e.g., cars). Ultimately, countries will construct an inventory from the sub-category level because this is how IPCC methodologies are set out, and total emissions measured by summation. A national

total is calculated by summing up emissions and removals for each gas. An exception is emissions from fuel consumption in ships and aircraft engaged in international transport which is not contained in national total, however, discussed separately. Other gases are explained according to IPCC 2006 Guideline in below (IPCC, 2006):

- **Nitrogen oxides (NO_x)**

The compound connects to NO and NO₂. They occur during burning processes, especially at high temperature. These two compounds are significant trace species in Earth's atmosphere. NO enters with partly oxidised organic species to form NO₂, which photolysed by sunlight to reform NO (Seinfeld et al., 1997; Gillenwater et al., 2002).

- **Ammonia (NH₃)**

Ammonia contains nitrogen and hydrogen and the chemical formula is NH₃. The gas is colourless with a characteristic pungent smell and it is lighter than air. It is demanded significantly for the nutritional needs of terrestrial organisms by serving as a precursor to food and fertilizers (Chisholm et al., 1911).

- **Non-methane volatile organic compound (NMVOCs)**

NMVOCs are a wide variety of chemically different compounds, such as benzene, ethanol, formaldehyde, cyclohexane, 1,1,1-trichloroethane or acetone. They are included in propane, butane, and ethane etc. compounds (Gillenwater et al., 2002).

- **Carbon monoxide (CO)**

Carbon monoxide contains carbon and oxygen atoms. Its molecular weight is 28 g/mole. The gas is colourless, tasteless and odourless. It is toxic to hemoglobin animals when encountered in concentrations above approximately 35 ppm, though it is also produced in normal animal metabolism in low quantities, and is thought to need some normal biological functions (Penney and David, 2000; Gillenwater et al., 2002; Richard, 2012).

- **Sulphur dioxide (SO₂)**

The gas contains one sulphur and two oxygen atoms. Its chemical formula is SO₂. It is a toxic gas with a pungent, irritating smell. It is released naturally by volcanic activity. The gas was used by the Romans in winemaking when they discovered that burning sulphur candles inside empty wine vessels kept them fresh and free from vinegar smell (Url-6).

Table 3.1 Overview of GHG emissions and removals in CO₂ equivalents (TUIK, 2013; Url-3)

(Million tonnes CO₂ equivalent)								
GREENHOUSE GAS EMISSIONS	Years							
	1990	1995	2000	2005	2009	2010	2011	2012
CO ₂ emissions containing net CO ₂ from LULUCF	97.49	126.52	175.55	210.06	243.32	269.00	284.91	297.68
CO ₂ emissions excluding net CO ₂ from LULUCF (Land Use Land Use Change and Forestry)	141.56	174.09	225.61	259.79	299.67	326.85	345.73	357.50
CH ₄	34.05	47.39	53.68	52.55	53.75	57.30	58.05	61.62
N ₂ O	12.22	16.82	17.14	14.67	13.91	14.15	13.73	14.79
HFCs	-	-	0.82	2.38	2.84	4.01	5.31	4.68
PFCs	0.60	0.52	0.52	0.49	0.17	0.31	0.32	0.31
SF ₆	-	-	0.32	0.86	0.80	0.88	0.95	0.97
Total (containing LULUCF)	144.36	191.25	248.03	281.01	314.80	345.65	363.26	380.06
Total (containing LULUCF)	188.43	238.82	298.09	330.74	371.15	403.49	424.09	439.87

3.3. Carbon Cycle

Carbon is a chemical element that is essential for all living creatures. Carbon can have bounds with different elements to form different compounds. Plants and animals contain various carbon compounds, and so are certain minerals. Carbon combines with oxygen to form a gas named carbon dioxide (CO₂). The carbon cycle (Figure 3.2) is very important in nature but it has been changed by human intervention mostly in the last century (Url-8).

The carbon cycle is movement and transmission of carbon through living organisms, the ocean, the atmosphere, rocks, and minerals, and different parts of the Earth. Carbon moves from one place to another through several chemical, physical, geological, and biological processes (Url-7; Url-8; Url-9).

The CO₂ is a colourless, odourless GHG that heats the atmosphere. The GHGs include water vapour, CO₂, methane, NO, and fluorinated gases. It is emitted naturally when dead animals or plants decay and it is needed by plants for photosynthesis. Human activities release CO₂ into the atmosphere mostly by burning fossil fuels (non-renewable sources) such as coal, oil, and natural gas. This special source of CO₂ is the main cause of the climate change. Earth might have been a frozen place without CO₂ and other GHGs. However, human-made activities have resulted in nearly 30% more carbondioxide in the atmosphere within about the last 150 years and earth became a warmer place as a result. Indeed, ice cores show that there is more carbondioxide in the atmosphere than there has been in the last 420000 years (Url-7; Url-8).

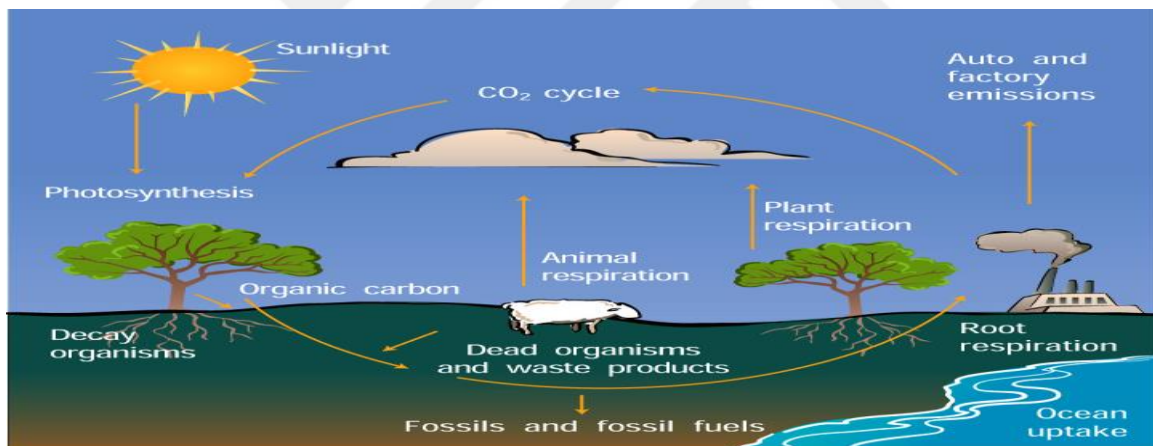


Figure 3.2 Carbon cycle (Url-8)

Decreasing forests that used to absorb CO₂ from the atmosphere and increasing fossil fuel use resulted in increasing CO₂ in the atmosphere. Increasing CO₂ traps more heat released from the Earth and causes temperature increase all over the globe. To deal with this serious problem, some countries started an initiative to control CO₂ emissions by reducing fossil fuel use and signed the Kyoto protocol at 1997 (Url-10; Url-11). Turkey has also signed the Kyoto Protocol for carbon release control.

4. FOOTPRINT CONCEPT

Types of the footprint are shown in Figure 4.1. These footprints are ecological footprint (eF), carbon footprint (CF), water footprint (WF), and energy footprint (EF).

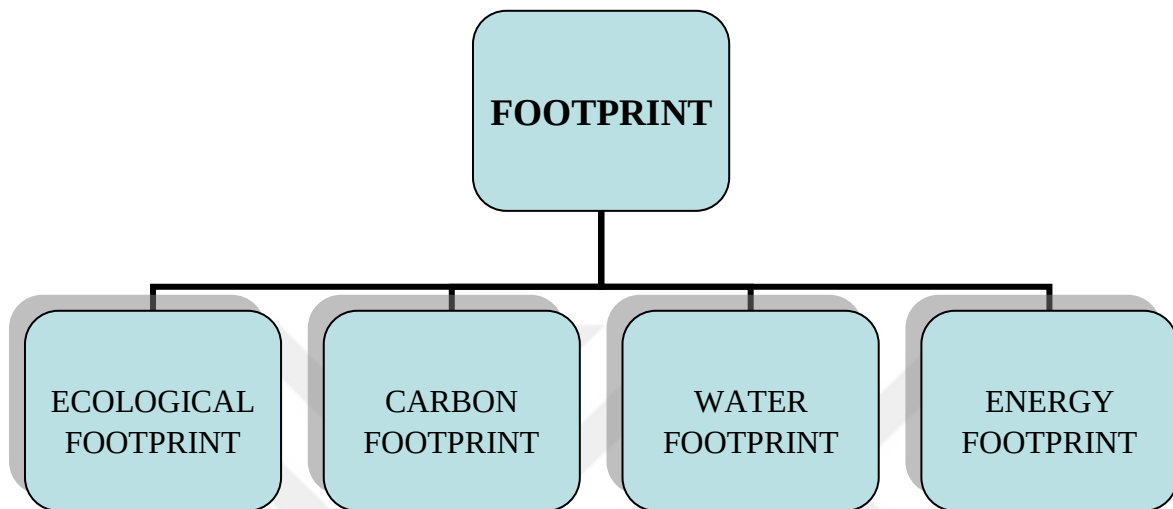


Figure 4.1 Types of footprint

Carbon, water, and energy footprints are very significant concepts for our life since we usually encounter footprints in our daily life (industry, houses, buildings, transportation etc.). We usually encounter with footprint concepts in all human activities. For example, people usually use bus, plane, ship, etc. for transportation and these vehicles release CO₂ and other GHGs into the atmosphere.

4.1. Ecological Footprint (eF)

The footprint concept is a very useful parameter for human activities. The footprint concept was originated from the ecological footprint concept proposed by the scientists Dr. Mathis Wackernagel and Prof. William Rees (Wackernagel et al., 2002; Akıllı et al., 2008; Monfreda et al., 2002). In a study performed in Toronto, footprints for feeding, housing, transportation, and services were found to be 3.0 hectare (ha), 1.4 ha, 1.9 ha, and 1.3 ha, respectively with a total of 7.6 ha per person (Özer, 2002; Wiedmann et al., 2006; Akıllı et al., 2008).

4.2. Carbon footprint (CF)

CF is a measure of the effects that man made activities impose on the ecological state and it has got units of tonnes or kg of CO₂ equivalent. It correlates with the volume of GHGs produced in our daily life through burning fossil fuels for electricity production, heating, transportation, etc. and it is distracted with another term called environmental footprint (Url-12).

According to the United States Environmental Protection Agency's definition (EPA, 2010), CF is the total amount of GHGs released into the atmosphere each year by a person, family, building, organization, or company. This definition contains GHG emissions from direct fuel consumption for heating a home or driving a car. But at the same time, it also contains GHGs that come from product manufacturing or human activities. Grubb and Ellis (2007) explain it as a measure of the amount of CO₂ released from the combustion of fossil fuels (Url-13; Grubb and Ellis, 2007; Subramanian and Muthu, 2016). CF also refers to the GHGs that are released into the environment by using energy. Plants absorb CO₂ from the air. Animals eat plants that contain CO₂. When animals or plants die, CO₂ is released into the atmosphere or soil. If an activity is performed by reducing 1 tons of carbondioxide release, one carbon credit is earned (Url-11). The CF is divided into two parts as follows (Atabey, 2013):

1-Primary carbon footprint: Fossil fuels are sources of direct CO₂ emissions in domestic energy consumption and transportation.

2-Secondary carbon footprint: Indirect emissions during production of goods and services. CO₂ emission has got two different parts. Some CF data are given below (Url-14):

- If you burned 60 gallons of gasoline, 1 ton of CO₂ would be released.
- The average carbon footprint is 28 tons CO₂ / person-year in USA.
- The natural average carbon footprint is approximately 6 tons CO₂ / person-year.
- The global average carbon footprint is approximately 6 tons CO₂ / person-year.
- Banana's CF is 80 g CO₂/kg.
- A bottle of water's CF is 200 g CO₂/kg.
- A new car's CF is 17 tons CO₂/kg.

GHG Protocol, Publicly Available Specification (PAS 2060), International Organization for Standardization (ISO 14064), Kyoto protocol and International Plant Protection Convention (IPPC) procedure are used for calculating footprint. CF is calculated in four step (Url-15):

1. Determine aim,
2. Designate limits,
3. Collect data (inputs) and obtain emission factors,
4. Evaluate results and report footprints,

CF is calculated for the following purposes (Url-10):

- Legal obligation,
- Corporate social responsibility,
- Customer and financier-driven,
- Marketing and corporation image,
- Reduction of emission GHG,
- Emission trade mechanisms.

Calculation method defined in IPPC 2006 Guide was used in this study. GHG inventory for direct and indirect emissions in a company or firm will include the amount of GHG emissions and GHG sinks (Toröz, 2015; IPCC, 2006; Url-34). Tier 1, Tier 2 and Tier 3 methods are used with equations 1, 2 and 3 given below:

Tier-1 (Simple method)

$$\text{Emission} = \text{Consumption of fuel} * \text{Emission factor} * \text{oxidation factor} \quad (1)$$

Emission: Amount of greenhouse gas in types of fuel (kg GHG)

Consumption of fuel: Consumed amount of fuel (kg, L)

Emission factor: SG emission factor with types of fuel (kg gas/TJ)

Oxidation factor=1 (accepted value according to IPCC)

Tier-2 (Active value, specific emission factor in country, and high level)

$$\text{Emission} = \text{Consumption of fuel} * \text{Heating value} * \text{contents of carbon} * \text{oxidation factor} * X_c \quad (2)$$

Emission: Amount of greenhouse gas in types of fuel (kg GHG)

Consumption of fuel: Consumed amount of fuel (kg, L)

Heating value: lower heating value in fuel (kcal)

Contents of carbon: CO₂ and C molecular weight (g/mole) (MW_{CO₂}/MW_C)

X_c: Percent of carbon in fuel (%)

Tier-3 (Comprehensive, complicated, improvement, and specific emission factor in a country)

$$\text{kg CO}_2/\text{kwh} = (860\text{kcal/kwh} * \text{Efficiency} * \text{MW}_{\text{CO}_2}/\text{MW}_C * \text{Percent of carbon in fuel}) / (\text{kcal/kg}) \quad (3)$$

Efficiency=efficiency according to the technology used (%)

Burner conditions, comprehensive burner technology and types of burner technology, care, company conditions, emission control technology and fuel characterization. Calculations follow five stages:

- 1-Determine the consumption of fuel in all compartments,
- 2-Find energy equivalent of the fuel consumption,
- 3-Select carbon emission factors and find amount of total carbon emitted,
- 4-Find nonoxidized amount of carbon to obtain oxidized amount,
- 5-Use oxidized carbon amount to calculate CO₂ emissions.

These stages are explained with equations 4, 5, 6, 7 and 8 below (Atabey, 2013):

According to Tier-1 Method

$$1) \text{ Consumption of energy(TJ)} = \text{Consumption of fuel in kt} * \text{Recycling factor[TJ/kt]} \quad (4)$$

Recycling factor[TJ/kt]

-Gasoline=44.8

-Diesel=43.33

$$2) \text{ Involving carbon (tC)} = \text{Carbon emission factor} * \text{Consumption of energy} \quad (5)$$

Carbon emission factor

-Gasoline= 18.9

-Diesel= 20.2

-Natural gas= 15.3

$$3) \text{ Involving carbon (GgC)} = \text{Involving carbon (tC)} * 10^{-3} \quad (6)$$

$$4) \text{ Carbon emission (GgC)} = \text{Involving carbon (GgC)} * \text{Rate of oxidation carbon} \quad (7)$$

Rate of oxidation carbon

-In liquid fuel= 0.99

-In gaseous fuel= 0.995

$$5) \text{ CO}_2 \text{ emission (GgCO}_2\text{)} = \text{Carbon emission (GgC)} * 44/12 \quad (8)$$

In calculations, activity based and energy-based approaches can be used. In this thesis, CF is calculated with activity based method while energy-based approach is used for transportation CF calculations (Url-16). Tier 1 (simple method) is used for other carbon footprint calculations with equation 1.

a. Activity-based approach (calculation method recommended for use by chemical companies)

Since the vast majority of freight transport operations of the European chemical industry are outsourced, most shippers have no direct access to energy or fuel consumption data. In the absence of such data, shippers can estimate CO₂ emissions of their transport operations by using an activity-based calculation method. The activity-based method uses the Equation 9 given below:

CO₂ emissions = Transport volume by transport mode x average transport distance by transport mode x average CO₂- emission factor per tonne- km by transport mode

$$[\text{Tonnes CO}_2 \text{ emissions} = \text{tonnes} \times \text{km} \times \text{g CO}_2 \text{ per tonne- km} / 1,000,000] \quad (9)$$

b.Energy-based approach (calculation method recommended for use by transport companies)

The easiest and most accurate way for transport companies of calculating their transport emissions is to record energy and/or fuel use and employ standard emission conversion factors to convert energy or fuel values into CO₂ emissions.

Carriers with direct access to fuel consumption data are therefore encouraged to collect all their fuel consumption data. Every liter of fuel consumed will result in a certain amount of CO₂ emissions (Url-16;Url-17). The activity-based method uses the Equations 10 and 11 given below (Url-17):

CO₂ emissions = fuel consumption x fuel emission conversion factor

$$[\text{Tonnes CO-emissions} = \text{liters} \times \text{kg CO}_2 \text{ per liter fuel} / 1,000] \quad (10)$$

$$\text{CO}_2 = \text{fuel consumption (in litres)} \times \text{CO}_2\text{-factor} \quad (11)$$

4.3. Water Footprint (WF)

Water is an irreplaceable resource, covering around two-thirds of Earth's surface, although only one percent is available as usable freshwater. Water consumption and pollution can create water shortage especially in some parts of the World. Increased water use and factors such as climate change make water scarcity a Global problem. Water Footprint (WF), which is consumed amounts of direct and indirect water for manufacturing of products and services (Chapagain et al., 2006; Url-22), is calculated by Equation 12 and some WF values are given below (Url-18; Url-21; Url-22):

$$\text{Total water footprint} = \text{Amount of product (TSE, FAO)} * \text{Variables of water footprint (Water Footprint Network)} \quad (12)$$

1 t-shirt=2700 L, a glass of coffee=140 L, 1 slice of bread=40 L, a glass of milk=255 L, 100 gr of chocolate=2400 L, a pair of jeans=42 L of water

The WF is apportioned among blue, green, and grey (Url-19; Url-20) water parts as explained below:

- The blue water footprint (bWF) refers to consumption of surface and groundwater resources. It is the amount of surface and groundwater used in manufacturing or maintenance of a product. It also contains abstracted water by surface or under ground soil in a catchment area. It can be defined as the volume of water abstracted from

ground or surface water that does not return back to the catchment area from which it was withdrawn. The bWF of a process step is calculated by the Equation 13 as given below:

$$\text{WF}_{\text{proc, blue}} [\text{volume/time}] = \text{Blue Water Evaporation} + \text{Blue Water Incorporation} + \text{Lost Return flow} \quad (13)$$

- The green water footprint (GWF) refers to consumption of rainwater stored in soil (in so far as it does not become run-off). This is significantly relevant to agricultural and forestry activities and it refers to the total rainwater evapotranspiration plus the water incorporated into the harvested crop or wood. The GWF is calculated by the Equation 14 given below:

$$\text{WF}_{\text{proc, green}} [\text{volume/time}] = \text{Greenwater Evaporation} + \text{Green Water Incorporation} \quad (14)$$

- The grey water footprint (gWF) refers to the volume of freshwater polluted. It is the amount of freshwater that is needed to assimilate a load of pollutants based on natural background concentrations and existing ambient water quality standards. The gWF can be calculated by the Equation 15 given below:

$$\text{WF}_{\text{proc, grey}} [\text{volume/time}] = L / (C_{\text{max}} - C_{\text{nat}}) = (\text{Effl} * C_{\text{effl}} - \text{Abstr} * C_{\text{act}}) / (C_{\text{max}} - C_{\text{nat}}) \quad (15)$$

C_{max} = the maximum acceptable concentration [mass/volume]

C_{nat} = natural background concentration [mass/volume]

Abstr = minus the water volume of the abstraction [volume/time]

C_{act} = the actual concentration of the intake water [mass/volume]

C_{effl} = the effluent concentration of the water [mass/volume]

Effl = the effluent volume [volume/time]

L = the pollutant load [mass/time]

$\text{WF}_{\text{proc, grey}}$ = grey water footprint [volume/time]

In order to manufacture 1 kg of finished cotton textile product in the industry, 11000 liters of water is required as a global average. Approximately 2700 liters of water is consumed for one cotton t-shirt that weighs 250 g. Of these 2700 liters, 45% is irrigation water consumed for the cotton plant production, 41% is rainwater evaporated from the cotton field during the growing period, and 14% is the water needed to dilute the wastewater released as a result of chemical compound use in the textile industry. The annual cotton textile manufacturing consumes 210 billion cubic meters of water and contaminates 50 billion cubic meters of water. This is 3.5% of the water needed for global crop production.

4.4. Energy Footprint (EF)

Energy is a critical input parameter for human activities. We use energy for production, transportation, heating, cooling, building, etc facilities. For example, a microwave oven used 96 times per year will consume 96 kWh/year and will result in the emission of 39 kg-CO₂/year (Url-23). Energy sources are categorized as renewable and nonrenewable sources. But nonrenewable energy consumption is dominant as of today due to cost of production and an average family uses 253 kWh of electricity per month .

EF parameter defines the consumed energy per unit product. Energy use will result in Greenhouse gas emissions. In many regions of the World, ecological problems that are both local (such as high rates of urbanization, industrial activities, land use changes, or agricultural practices) and global (such as desertification or deforestation) have considerably decreased the ability of the land to absorb CO₂. More than 65% of total energy need by North American pulp and paper industry is produced from renewable forest biomass. By looking at the entire life cycle, paper product CF value can be separated into three components: GHG emissions, carbon sequestration, and avoided emissions. Each of these components is changed by significant properties that make paper's carbon footprint lower by using renewable source that stores carbon, recyclable material, and renewable energy (Url-9).

4.5. Investigations on Carbon, Water, and Energy Footprint

Bevilacqua et al. (2011) were focused on the use of life cycle assessment (LCA) technique to search the CF of different factors contained in a value chain of the textile industry. They have observed that, the dominant contribution to the greenhouse emissions in the textile industry originates from electrical and thermal energy use in the production and from transportation.

Kercher et al. (2010) investigated ways that modify tour behaviours to cut down environmental effects. They identified four categories of tourists ranging from the regular universal tourist to least active. The regular universal tourist group was most aware of Global warming and climate change, but least willing to alter its tour behaviour. By comparison, less active tourists appeared most willing to travel less. The article concludes that authority interventions may be recommended to a different behavioural variable in travel structures.

Muthu et al.(2011) have studied the carbon footprint of different types of shopping bags (plastic, paper, nonwoven and woven) using life-cycle impact assessment (LCIA) method in two steps. First, they have examined several types of shopping bags in the production step without taking in consideration of their use and disposal. The LCIA was applied by the IPCC 2007 method. The second step was the research of the carbon footprint of these bags considering their usage and disposal. A survey questionnaire applied on several user groups showed that bag use remains very high if no usage and demolition choices were not related to CF, while it is reduced if it was related to CF.

Recently energy produced from shale gas is attracting countries for cutting down Greenhouse gas emissions. Weber and Clavin (2012) have investigated six different energy use alternatives on manufacturing relying on shale and natural gas by a Monte Carlo uncertainty method.

Industrial areas have been supported for sustainable economical development with the following benefits: Communal support and completed industrial actions within planned operation. Dong et al. (2013) have studied to assess CF of one industrial park with mainly chemical and general machinery sectors in China.

Lin and Moubarak (2013) have used Logarithmic Mean Divisia Index method that relates energy consumption and CO₂ emissions to search for alternatives to reduce carbon dioxide emissions. Some other researchers have used methods such as Kuznets and Factor decomposition to search how variables such as energy tolerance and industrial process affect energy consumption and CO₂ emissions.

Chapagain et al. (2006) have analyzed the effects of vaporization of permeate rainwater for cotton growth (green water use), withdrawal of ground or surface water for irrigation or operations (blue water use), and water pollution during growth or operations. The final result was quantified in terms of the dilution volume needed to incorporate the pollution.

Chico et al. (2013) have explained WF evaluation of five textiles used in manufacturing of jeans that contain two different fibres. They observed that highest water consumption stage was cotton fiber manufacturing.

5. QUALITY AND QUALITY FUNCTION DEPLOYMENT

5.1. The Concept of Quality

The term “quality” has many aspects to define and describe. Because of many participants on the subject of quality such as managers, customers, suppliers, etc., it is sometimes difficult to establish a commonly accepted definition and framework for the quality. For example, quality might mean meeting the expectations according to a customer. When a product meets or even exceeds his or her expectations, the customer will possibly regard that product as quality. On the other hand, from the point of view of the manager, a quality product is likely the one, which can be produced at low cost and sold at an adequate price. Thus, the understanding of quality is clearly based on the perception and the position of the associated participants (Besterfield, 1990). Quality is a dynamic concept, which in essence means to exceed the expectations. It involves a continuous development since the expectations of human being tend to increase as those expectations are met. A product regarded as “quality” at the past might now be seen as “ordinary” or even “poor quality”. Therefore, under such rapidly changing conditions organizations must achieve the ability to exceed themselves. Continuous improvement, creativity, and innovation are the basics that give the organizations the ability to cope with the changing, uncertain continuous review and evaluation (Yavuz, 2006). Quality has become one of the most important consumer decision factors in the selection among competing products and services. The phenomenon is widespread, regardless of whether the consumer is an individual, an industrial organization, a retail store, or a military defense program. Consequently, understanding and improving quality is a key factor leading to business success, growth, and an enhanced competitive position. There is a substantial return on investment from improved quality, and from successfully employing quality as an integral part of the overall business strategy (Montgomery, 2004).

5.2. Dimensions of Quality

At this point, it can be useful to mention the different ways quality is viewed. These different components can be gathered under eight dimensions as the following (Montgomery, 2004; Besterfield, 1990):

1-Performance

2-Reliability

3-Features

4-Conformance to Standards

5-Durability

6-Serviceability

7-Perceived Quality

8-Aesthetics

5.3. Quality Function Deployment (QFD)

Dean (1992) views Quality Function Deployment as a system engineering process, which transforms the desires of the customer/user into the language, required at all project levels, to implement a product. It also provides the glue necessary, at all project levels, to tie it all together and to manage it. Finally, it is an excellent method for assuring that the customer obtains high value from product, actually the intended purpose of QFD. Mizuno and Akao (1990) indicate that QFD is far more than has previously been disclosed. It is clearly the mechanism for deploying quality, reliability, cost, and technology throughout the product, the project to bring forth the product, and the enterprise as a whole.

Yoji Akao introduced the concept of QFD in Japan in 1966. In 1972 the concept had demonstrated the power of the approach and in 1978 the first book on the subject was published in Japanese. Unfortunately, for those of us who do not read Japanese, it was not translated into English until 1994. According to Akao, QFD is a method for developing a design quality aimed at satisfying the consumer and then translating the consumer's demand for design targets and major quality assurance points to be used throughout the production phase. QFD is a way to assure the design quality while the product is still in the design stage. As a very important side benefit, Akao points out that, when appropriately applied, QFD has demonstrated the reduction of development time by one-half to one-third (Akao, 1990). The main objective of any manufacturing company is to bring new (and carry over) products to market sooner than the competitors with lower cost and improved quality. The mechanism to do this is called quality function deployment. QFD is an overall concept that provides a means of translating customer requirements into the appropriate technical requirements for each stage of product development and production (i.e. marketing strategies, planning, product design and engineering, prototype evaluation, production process development, production,

sales). In QFD, all operations are driven by the voice of the customer; QFD, therefore, represents a change from manufacturing- process quality control to product-development quality control.

QFD is a structured process, a visual language and a set of interlinked engineering and management charts, which uses the seven management (new) tools. It establishes customer value using the voice of the customer and transforms that value to design, production, and manufacturing process characteristics. The result is a system engineering process with priorities and links to the product development process so that it assures product quality as defined by the customer/user. Additional power derives from use within a concurrent engineering environment (King, B. 1989).

The term QFD states Quality (Meeting Customer Requirements), Function (What must be done-Targeting the consideration), and Deployment (Who will do it, When). The approach was explained in Japan in 1966 by Nishimura and Takayanagi explained by quality diagrams in 1992. The House of Quality is the first matrix in a four-phase QFD process. It's called the House of Quality because of the correlation matrix that is roof-shaped and sits on top of the main body of the matrix. The correlation matrix evaluates how the defined product specifications optimize or sub-optimize each other (Ishikawa, 1982).

Dr. J.M. Juran focused on a quality function as a function that forms quality. Those functions are planning, design, trial, and manufacturing services. QFD is a technical way to convert qualitative user demands into significant parameters to expand the functions forming quality and to expand technics for accomplishing the design quality into subsystems and fundamental parts, and specific elements of producing processes as described by Dr. Yoji Akao, who basically advanced QFD in Japan in 1966. The writer associated this work in quality guarantee and quality control points with function deployment needed in value engineering. QFD helps to convert customer demands (the voice of the customer) into engineering aspects for a manufacturer or employment, prioritizing each manufacturer or employment aspect during together setting evolution benefits for manufacture or employment (Asaka, and Ozeki, 1990; Url-24). The aim of QFD is three goals (Sullivan, 1986):

- 1) It allows us to get higher quality products into the market faster and at a decreasing cost.
- 2) Achieve customer driven manufacturing design.

- 3) It will contribute customer driven manufacturing design or manufacturing improvements.

The benefits we can obtain by accomplishing QFD research are many (Url-24):

- Better understanding of customer needs,
- Enhanced organisation on development projects,
- Enhanced introduction to manufacturing,
- Fewer design variables late in development,
- Fewer production start-up problems,
- Opinion for being deliberate about quality,
- Developed business,
- Documented manufacturing explanation depend on customer requirements.

5.3.1. How to structure a quality diagram?

- 1-Framework a requested quality deployment diagram
- 2-Framework a quality properties deployment diagram
- 3-Mix the above two into a matrix (two-dimensional diagram)
- 4-Show the demand items with symbols such as:

- =Strong relationship
- =Medium relationship
- △ =Weak relationship

A quality diagram is a two-dimensional matrix including a demanded quality diagram mixture with a quality properties deployment diagram. The complex of the two matrices explains the relationship between demanded qualities and quality characteristics.

5.3.2. How to make a quality diagram?

- 1-Collecting demanded quality items and forming the demanded quality deployment diagram,
- 2-Deploying into quality proportions and forming a matrix,
- 3- Obtaining a competitive compression diagram SA,
- 4-Comprising and evaluating the importance of a demanded quality item,
- 5-Re-evaluating the importance of demanded quality items using market information,
- 6-Making decision sales points and assessing (evaluating) the importance of a counterpoint proportion,
- 7-Researching the proportion values of competing products and developing the quality product.

5.3.3. Key Points in the Quality Diagram Application

The key steps in using quality diagrams are summarized below (Akao, 1990):

- 1- Look at critical important items among the customers' demands for quality, use them as quality properties, and research for engineering bottlenecks using them in a quality design diagram.
- 2- Apply the product element relationship diagram to clarify the correlations among product (design) elements (circuits, process, masks etc.).
- 3- Apply on a control rank-salting sheet to arrange the 4M's (man, material, make, method) and search the design (product) difficulty rating necessary for the design.
- 4- Apply on a trouble-prevention sheet and design a trouble-summary. Form T-matrix to analyse quality conformation results and combine the processes.

6. INTRODUCTION OF TEXTILE INDUSTRY

6.1. Textile Industry

It is generally understood that a textile is a fabric made from fibers. However, fibers may either be converted into yarn first and yarns are put together in one of a variety of ways to make fabrics, or the fibres can be converted directly into the fabric. This description includes clothing material such as fur, leather, suede and unsupported plastic sheeting (Vidyasagar, 2000; Miller, 1995; Geijer, 1982).

6.1.1. Textile Industry in the World and Turkey Particularly

From the middle of the nineteenth century onwards, the textile industry has played a key role in early industrialisation process in most countries. This is not surprising, given the combination of a large domestic demand (clothing is a basic necessity) and the early success at mechanising textile production. This was also the case in Turkey and Turkey's textile industry has the biggest share in Turkish foreign trade. Turkey is the sixth largest producer of cotton yarn in the world. Turkey was Europe's number one supplier of ready-to-wear clothes in 1995 (Turkey in Statistics, 1997).

6.1.2. Woolen Fabric Manufacturing in Textile Industry in Turkey

Wool production of Turkey is 4.2 percent of the world wool fiber production and Turkey is an important country in wool production. But the produced wool is not thin enough and for this reason, some import is made (Geijer,1982). Because of the production of fibers that have wool features, increasing use of comfortable and sports garments called casual wear, the need of care for wool, and the price of wool, demand for wool decreased in 1990's (Turkey in Statistics, 1997). But a recent research study showed that over 79% of Turkish consumers know "Wool mark" etiquette and 81% trust it. It is expected that production and consumption will increase parallel to the improvements in the international wool market. There will be an inclination for wool and cellulose fiber mixtures (Turkey in Statistics, 1997; Geijer, 1982; Alkaya and Demirer, 2014).

6.2. Fabric Production

The fabric production flow diagram is shown in Figure 6.1.

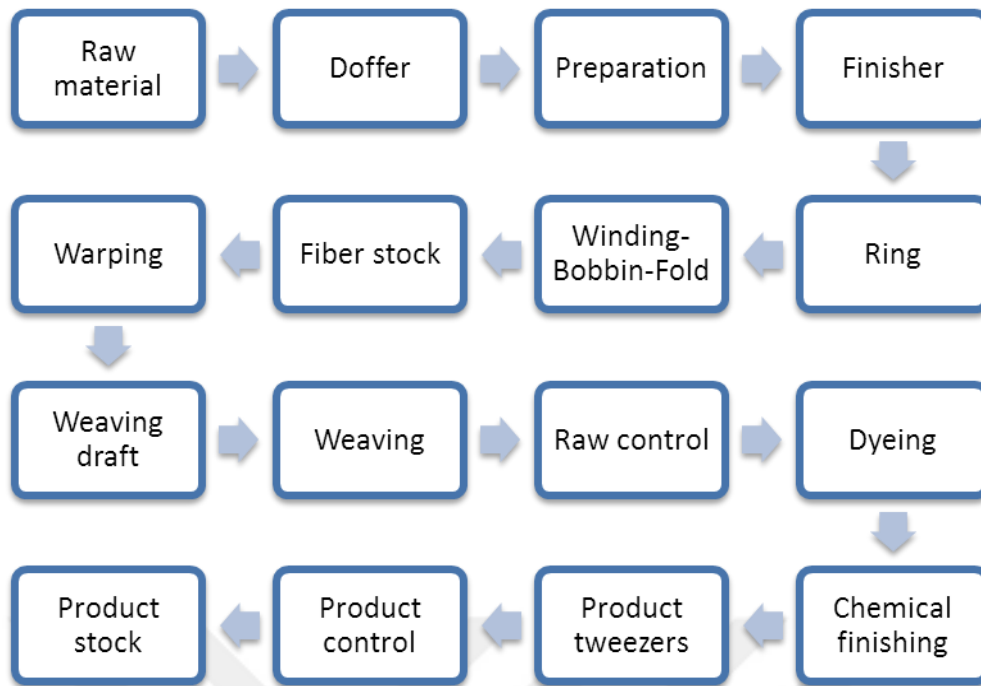


Figure 6.61 Flow diagram of fabric production process

Raw material is polyester and wool in the fabric company examined in this study (Figure 6.2). Fabric production starts with the raw materials. Fiber process, middle processes (doffer, cord machine (finisher), weaving, dyeing), and finishing processes (singeing, and chemical finishing etc.) has been used in the fabric production (Figure 6.3).



Figure 6.2 Raw materials (polyester and wool) (photo taken by the author)

6.2.1. Fabric Production Processes

The layout of the fabric production of the company is given in Figure 6.3.

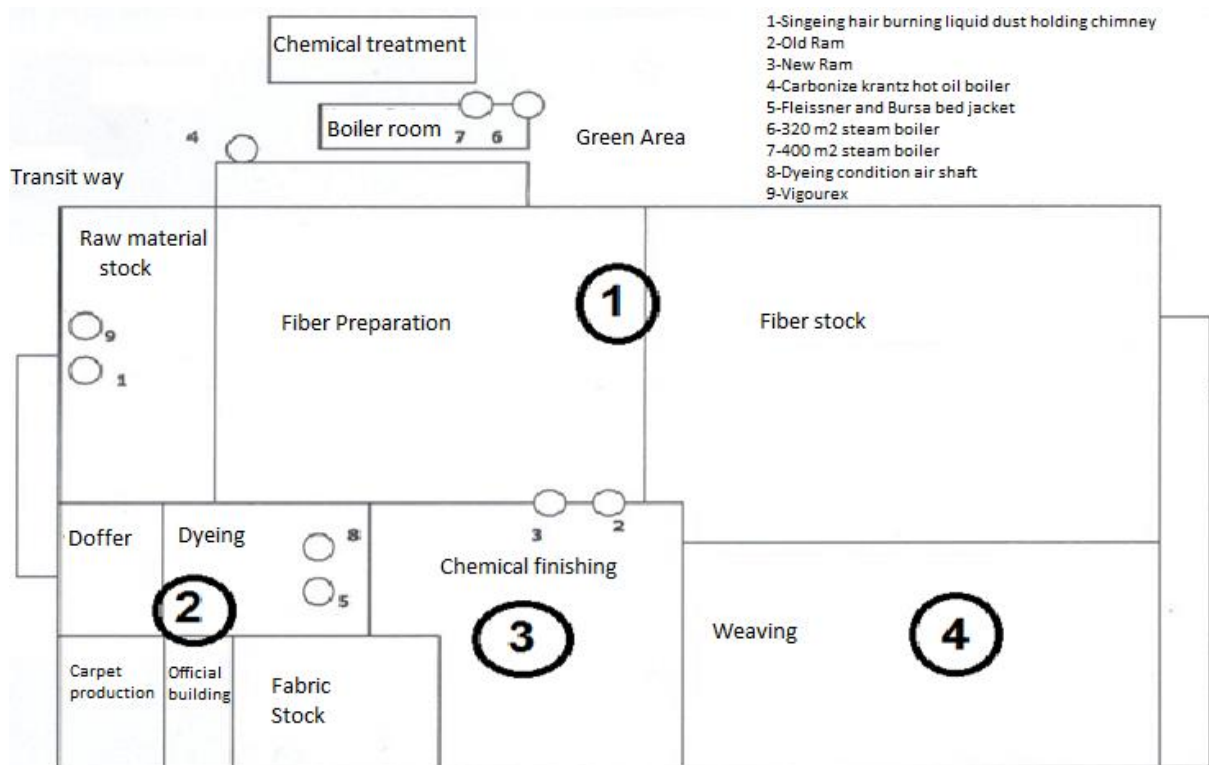


Figure 6.3 Fabric production

6.2.1.1. Fiber Process

Fibers used in the textile industry can be grouped into two categories (Chavan, 2001):

- Natural fibers (cotton, wool, silk, jute etc.)
- Man-made fibers (such as rayon, synthetics, and their blends).

The quality and properties of the fiber or blend of fibers used determine the foundations of the fabric quality and properties. The processes of yarn manufacturing, the formation of fabric structure, and finishing may serve either to enhance or to suppress certain fiber properties but no properties can be created in any type of fiber by any form of the process if the potential is not there. Cotton is the most widely used natural fiber and it is followed by (a good way behind) wool fiber. These two fibers comprise the bulk of natural apparel fiber. Hairs such as mohair, camel, cashmere, alpaca, and vicuna are grouped statistically with wool for convenience, as they only represent a very small percentage. Flax and silk are the only other natural fibers used widely in any significant quantity for clothing and they fall well behind the two major fibers (Potter and Corbman, 1967).

All natural fibers are produced in a range of qualities because of the factors such as variable growing conditions, varieties of plants, breeds of animals, soil properties, climate, and cultivation methods. Each fiber type called in the table possesses certain general

characteristics which distinguish it from the other fibers. The difference between fiber types in different groups is usually wide enough to be obvious to casual examination once the general characteristics are appreciated (e.g. wool and cotton). Differences between fiber types within the same group may not be as obvious, and usually, require more detailed observation and knowledge (e.g. wool and mohair). The use of widely differing amounts of individual fibers can only be satisfactorily explained by relating the practical significance of the fiber qualities and properties to fabric manufacturing processes. The cost of a fabric is always an important factor and it is based on the initial cost of the fiber plus the cost of converting it into a fabric (Hall, 1965).

The processing factors which, together with quality and properties, influence the fabric use value and cost of converting a fiber into fabrics are given below (Potter and Corbman, 1967):

- a) Availability
- b) Adaptability to processing
- c) Versatility

The raw material of fiber will go processes for fabric production as in Figure 6.4. The material will have bobbin form after pulling, scanning and ringing operations. After the control process, the bobbin will be sent to fiber stock.



Figure 6.4 Flow diagram of fiber process of the company

6.2.1.2. Middle Processes

6.2.1.2.1. Doffer

The process is the one that utilizes bobbins, pins or spindles holding spun fiber such as cotton or wool from a spinning frame and replaces them with empty ones. Spinners, doffers, and sweepers have detached responsible for creating spun textiles (Url-2; Hindman, 2009; Zonderman, 1992).

6.2.1.2.2. Cord machine (finisor)

Cord machines use two different structures in fabric manufacturing factories. Those machines are used for the same aim and they have got the same working principle. But the machines' features are different as explained in Figure 6.5 (Url-26).

- 1- Horizontal, pull and wrap part (cord) machine
- 2- Vertical, pull and wrap part (cord) machine

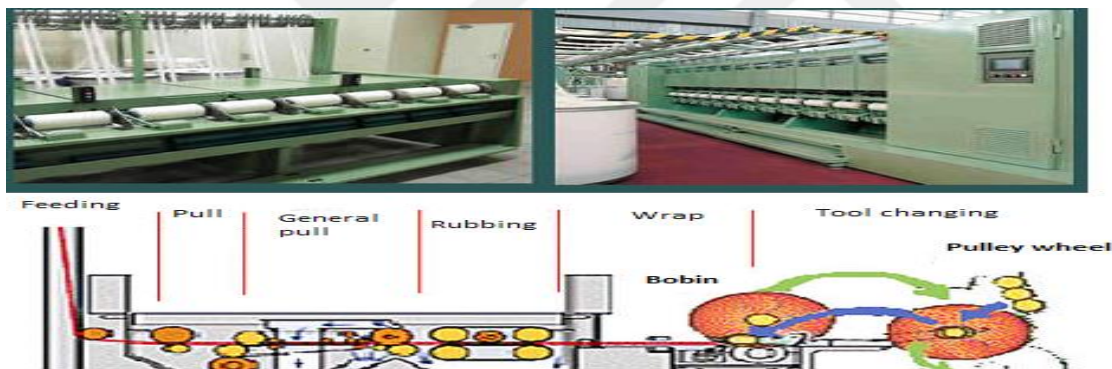


Figure 6.5 Cord machine and machine' parts (Url-26 ; MEB, 2013)

6.2.1.2.3. Weaving Draft, weaving and warping

Fabrics are used for dressing, decoration, and industrial applications. There are three different textile surface processes:

- a) Weaving surfaces,
- b) Knitwear,
- c) Nonwoven surfaces

Longitudinal yarn is warp. Transversal yarn is a weft. These two yarn systems use wadding principle with 90° (Url-27). Most fabrics are made from yarn. Unquestionably the most common structures are woven and knitted fabrics (Wingate, 1981; Hall, 1965). In their

simple form, these include in two series of threads (yarns), warp, and weft, interlaced at right angles to each other to form woven fabric (Figure 6.6).

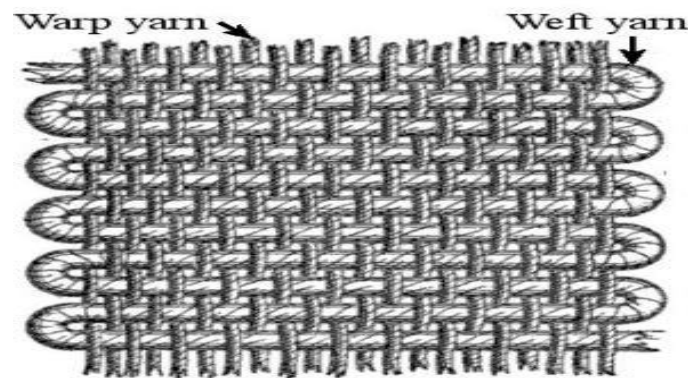


Figure 6.6 Woven fabric (Url-28)

On a weaving loom, rising and falling movement of warp yarns to form a shed are carried out by a patterning mechanism. A predetermined number of warp yarns according to a weaving draft, as required by the design of the fabric to be woven, is raised to form a tunnel called a shed. The weft yarn is passed across the warp yarns through the shed by means of a shuttle or weft carrier and beaten up on the edge of the fabric by means of a reed. The sequence of these operations is repeated for the insertion and interlacing of the weft yarns with the warp yarns resulting in the woven fabric. The weaving draft process can be made by hand or machine (Url-27; Url-29). Figure 6.7 shows the warping machine.



Figure 6.7 Warping machine (photo taken by the author)

Woven structures can vary in density and in interlacing as these properties can result in different appearance and handle, but in their simple forms they represent a very stable material. Woven fabric is produced on a weaving loom or loom. If used industrially the loom is an electrically powered, complex machine. If used domestically, it is a simpler, manually

operated loom. Both types of loom interlace or weave the warp yarns and weft yarns to make the woven fabric. The warp yarns and weft yarns are the two sets of yarns which are required for the manufacture of woven fabrics (Potter et al., 1967).

Knitted fabrics are found in a structure formed by interlocking loops of yarn. This is the type of knitting needles and one ball of yarn. Knitting machines can produce either a flat fabric or tubular fabric depending on the type used. Knitted fabrics are now strenuously rivaling with woven fabrics in many clothing types as improved machines and technologies can manufacture knitted fabrics in complex structures which in some cases are equal to woven fabric stability and in addition, manufacturers and consumers used to handle and use stretchable materials (Wingate,1981).

6.2.1.3. Dyeing

Dyeing or printing appears to have originated several thousand years ago in the Middle East, India, and China. Dyes or colouring matter were initially derived from natural sources such as berries, nuts, fruits, cochineal, indigo, madder, saffron, safflower, wood, and logwood. In 1856, H. Perkin discovered the first synthetic dyes (Hall, A. J.,1965).

The purpose of dyeing is to provide a wide range of coloured fabrics that satisfy the demands of individuals, fashion requirements, etc. Dyes may be classified according to their chemical constitution or alternatively according to a method of application (Potter et al., 1967; Wingate, 1981).

Cotton and viscose fabrics are dyed in temperatures of 60-80 °C while Polyester and nylon fabrics are dyed in temperatures of 105-130 °C. Reactivate dyes, sodium chloride, the liquid of caustic, sodium carbonate, acetic acid, formic acid, ion immobilizer, silicon elastomer finishing or cationic softening chemicals are used in cotton and viscose fabrics' dyeing process (Figure 6.8). Acid dyes, egalization, dispergate, fixator, acetic acid, silicon elastomer finishing or cationic softening finishing chemicals are used in nylon fabrics' dyeing process.



Figure 6.8 Chemical distribution area (photo taken by the author)

This process is very important and has got two components as dyeing and printing. The satisfaction of customers mostly depends on the fashion and attraction of the fabric.

Steps in dyeing process are given below (Potter and Corbman, 1967):

1. Diffusion of the dye from the dyebath to the fiber covering,
2. Adsorption of the dye on the fiber covering,
3. Diffusion of the dye to the fiber,
4. Fixation of the dye on the fiber,



Figure 6.9 Fiber dyeing (photo taken by the author)



Figure 6.10 Fabric dyeing (photo taken by the author)

Dyeing process is used for coloring both fibers and fabrics as in Figure 6.9 and Figure 6.10. If dyeing is applied on fibers, they are placed into ram machine for drying process as in Figure 6.11.



Figure 6.11 Fiber Ram machine (stove) (photo taken by the author)

6.2.1.4. Finish Processes

6.2.1.4.1. Singeing

The process of singeing is applied mainly to cotton goods (cotton, viscose or their mixture of polyester fabrics). The main purpose is to produce a smooth fabric surface by burning off any loose fiber ends and fuzz with natural gas (Figure 6.12) (Hall, A J, 1965; Wingate, 1981).



Figure 6.12 Singeing process (photo taken by the author)

Singeing is called “gaze” process in Turkish. The burning is a dry process. Naps are removed on fabrics (Figure 6.13) to obtain a smooth surface (Turanlı, 2015).

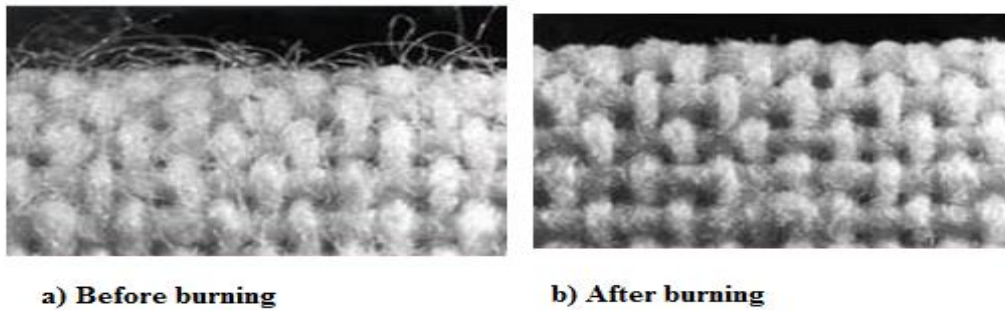


Figure 6.13 Before burning and after burning looks of fabric surfaces (Turanlı, 2015)

6.2.1.4.2. Finishing

Chemical finishing is a complex process. The process will bring out and highlight all the characteristic qualities and properties desired for the fabric. Chemical finishing is called “apreleme” process in Turkish. Chemical finishing processes include mechanical, chemical, thermo-fixation, and coating processes (Figure 6.14). In textile production, finishing requests processes that transform the woven or knitted cloth into the required material. After dyeing process on the yarn or fabric, finishing develops the look, performance or feel of the textile or clothing (Collier, 1970).



Figure 6.14 Chemical finishing (photo taken by the author)

6.2.2. Boiler Room

6.2.2.1. Degasifier



Figure 6.15 Degasifier (photo taken by the author)

In water demineralisation, a degasifier, or degasser, is often needed to remove dissolved carbon dioxide after cation exchange (Url-30). The solubility of CO_2 in pure water is high; approximately 1.5 g/L or more than 30 meq/L at 25°C and atmospheric pressure. When you stir the water and separate it into small droplets in an atmospheric degasser and blow air through the "rain", the gas tends to move into the air since the partial pressure of CO_2 in the air is much lower than the equilibrium pressure. The residual CO_2 after an atmospheric degasser is 0.20 to 0.25 meq/L (typically 10 mg/L of CO_2). Therefore, such

degassers are used when the bicarbonate concentration plus free carbon dioxide in the feed water to divide column demineralisation systems is at least 0.6 to 0.8 meq/L (Figure 6.15).

Although the forced draft degasifiers are the most common type in industrial water treatment, there are other types of degassers as given below (Hussain, 2001):

- Thermal degassers= Accepting to strip oxygen as well as carbon dioxide,
- Vacuum degassers= Processing under a vacuum of 1 to 5 kPa for the removal of oxygen,
- Membrane degassers= Interesting in view of their small size.

6.2.2.2. Condensate tank

The primary points of focus when taking into consideration collection of condensate and return to the steam system is the fuel consumption (Figure 6.16). In plant fuel consumption is reduced by about 1% for every 6°C rise in the boiler feedwater temperature. Turn back condensate also reduces water cost; water treatment cost and decreases the pollution load (Vineeth and Prince, 2013). Condensate is ejaculated through traps from a higher to a lower pressure. As a result of this drop in pressure, some of the condensate will then reevaporate into 'flash steam' (George and Prince, 2013).



Figure 6.16 Condensate tank (photo taken by the author)

6.2.2.3. Hot water boiler



Figure 6.17 Hot water boiler (photo taken by the author)

Water heating is a thermodynamic operation that needs an energy source to heat water above its initial temperature. In industry hot water and steam have many uses (Figure 6.17). In addition, water can be heated in vessels known as water heaters, kettles, cauldrons, pots or coppers (Domingo, 2010).

6.2.3. Treatment

There are two types of treatment in the fabric production company examined in this study and they are explained in the following subsections.

6.2.3.1. Chemical treatment

Wastewater comes into the treatment system in the plant. First, neutralization process is applied to the chemical materials (polyelectrolyte etc.) so that a chemical reaction will happen between an acid and a base. As a result of neutralization, no excess of hydrogen or hydroxide ions will be present in a solution (Figure 6.18). In this process, pH of the neutralized solution depends on the acid strength of the reactants (Stumm and Morgan, 1996; Metcalf and Eddy, 2013).



Figure 6.18 Neutralization (photo taken by the author)

Coagulation process (Figure 6.19) follows the neutralization process. In the water treatment, coagulation appears when a coagulant material is attached to water to destabilize colloidal suspensions. In colloidal suspension, particles will settle very slowly or not at all since the colloidal particles have surface electrical charges that mutually repel each other. Typically a metallic salt with the opposite charge is attached to the water to overcome the repulsive charge and destabilize the suspension. Also, Van der Waals force will force the particles to cling together and form micro flocs. Then, flocculation process involves the addition of polymers that clump the small, destabilized particles together into larger aggregates so that these aggregates can be more easily separated from the water. The flocculation is a physical process (Koohestanian,Hosseini,and Abbasian, 2008).



Figure 6.19 Coagulation-flocculation (photo taken by the author)

Following this, sedimentation process will take place (Figure 6.20). The sedimentation is the tendency of particles in suspension to leave the fluid under the forces such as gravity, centrifugal acceleration or electromagnetism (Coe and Clevenger , 1916).



Figure 6.20 Sedimentation (photo taken by the author)

6.2.3.2. Membrane technology

Membrane technology (Figure 6.21) includes all engineering systems for the transport of substances between two fractions with the help of permeable membranes. In general, mechanical separation processes for separating gaseous or liquid streams need membrane technology (Osada and Nakagawa, 1992).



Figure 6.21 Membrane technology-Reverse osmosis (photo taken by the author)

Membrane separation processes continue without heating and need less energy than conventional thermal separation processes such as distillation, sublimation or crystallization. The separation result in permeate and retentate fractions (Mulder, 1996).

7. APPLICATIONS

7.1. Calculation of Carbon, Water and Energy Footprints

The purpose of this study is to calculate the carbon footprint of a textile (fabric production) factory located in Halkalı district of Küçükçekmece in Istanbul. In order to establish a basis for the study, information about the energy consumption and the types of fuels used in the factory were examined. The information that will be used to calculate the footprints of the factory is presented below:

- Company's 2014 Emission Report,
- Data for the combustion systems used on the machinery whose carbon dioxide emissions are measured and take place in the Emission Report together with the daily working hours and the annual working days of these systems,
- The types of fuels used in the processes and vehicles together with their emission factors,
- Amount of electricity energy consumed in the processes to calculate the carbon footprint of electricity energy in 2015,
- The electricity energy production and their sources by TEİAŞ in 2016,
- Total water consumption,
- Processes where water is consumed and the percentages of water consumed in those processes,
- Number of shifts in the factory,
- Number of round trip bus services and their average speeds used for the transportation of factory workers,
- The amount of fuel consumed in the bus services,
- The daily working hours and the annual working days of the bus services,
- The types and amount of fuel consumed by the forklifts used in the factory.

7.1.1. Calculation of Carbon Footprint

In order to determine carbon footprints in the examined factory, the Tier 1 method defined in the 2006 IPCC Guidelines was used in most of the calculations. However, Tier 3 method in the same Guidelines was used in the calculation of the carbon footprint for the electricity energy produced by TEİAŞ since the details for the energy sources and power plant technologies were available. Process and machinery based data related to energy and fuel consumption will be used for emission calculations through the formulas given below (Pekin, 2006; Atabey, 2013; Turanlı, 2015; IPCC, 2006; Url-34):

Tier-1 (Simple method):

$\text{Emission} = \text{Fuel consumption} \times \text{Emission factor} \times \text{Oxidation factor}$
--

Emission = Amount of greenhouse gas according to the type of fuel (kg CO₂)

Fuel consumption = Amount of fuel consumption (kg fuel, lt fuel)

Emission factor = Amount of CO₂ emission according to the type of fuel (kg CO₂/kg fuel)

Oxidation factor = 1 (IPCC accepted value)

Tier-2 (Activity value, specific emission factor in a country, and high level):

1. alternative

Emission = Fuel consumption × Emission factor × Oxidation factor

Oxidation factor = 1 (IPCC accepted value)

Emission = Fuel consumption × Emission factor

Emission factor = $C \times (MW_{CO_2} / MW_C)$, where $MW_{CO_2} = 44$ and $MW_C = 12$

$\text{Emission} = \text{Consumption of fuel} \times C \times (44/12)$
--

Emission = Amount of greenhouse gas according to the type of fuel (kg CO₂)

Fuel consumption = Amount of fuel consumption (kg fuel, lt fuel)

MW = Molecular weights of CO₂ and C (kg CO₂/mole ve kg C /mole)

C = Carbon content of fuel (kg C/ kg yakıt)

2. alternative

Emission = Fuel consumption×Emission factor×Oxidation factor

Oxidation factor = 1 (IPCC accepted value)

Emission = Fuel consumption×Emission factor

Emission factor = $C \times (MW_{CO_2}/MW_C)$, where $MW_{CO_2}=44$ and $MW_C=12$

Fuel Consumption = Energy consumption / Calorific value

$\text{Emission} = (\text{Energy consumption} / \text{Calorific value}) \times C \times (44/12)$
--

Emission = Amount of greenhouse gas according to the type of fuel (kg CO₂)

Energy consumption = Amount of energy consumption (kcal)

Calorific value = Fuel calorific value (kcal/kg fuel)

Fuel consumption = Amount of fuel consumed (kg fuel, lt fuel)

MW = Molecular weights of CO₂ and C (kg CO₂/mole ve kg C /mole)

C = Carbon content of fuel (kg C/ kg fuel)

Tier-3 (Comprehensive, complicated, improvement and specific emission factor in a country)

Conditions and technologies of burners, equipment care, company condition, emission control technology and fuel characteristics are considered in calculations.

Emission = Fuel consumption×Emission factor×Oxidation factor

Oxidation factor = 1 (IPCC accepted value)

Emission = Fuel consumption×Emission factor

Emission factor = $C \times (MW_{CO_2}/MW_C)$, where $MW_{CO_2}=44$ and $MW_C=12$

Fuel consumption = [Energy consumption / (Calorific value×Efficiency)]

$$\text{Emission} = [\text{Energy consumption} / (\text{Calorific value} \times \text{Efficiency})] \times C \times (44/12)$$

Emission = Amount of greenhouse gas according to the type of fuel (kg CO₂)

Energy consumption = Amount of energy consumption (kcal)

Calorific value = Fuel calorific value (kcal/kg fuel)

Fuel consumption = Amount of fuel consumed (kg fuel, lt fuel)

Efficiency = Efficiency according to the technology used (%)

C = Carbon content of fuel (kg C/ kg yakıt)

MW = Molecular weights of CO₂ and C (kg CO₂/mole ve kg C /mole)

Emission Factor Related to Electricity Energy Consumption

$$\text{Emission factor} = [(860 \text{ kcal} / \text{kWh}) / (\text{Calorific value} \times \text{Efficiency})] \times C \times (44/12)$$

Emission factor = Amount of greenhouse gas released (kg CO₂/ kWh electric)

Calorific value = Fuel calorific value (kcal/kg fuel)

Efficiency = Efficiency according to the technology used (%)

C = Carbon content of fuel (kg C/ kg yakıt)

MW = Molecular weights of CO₂ and C (kg CO₂/mole ve kg C /mole)

1 kWh = 860 kcal

7.1.1.1. Energy's carbon footprint (ECF)

Energy sources used in the fabric factory are natural gas, electricity and combined energy. Energy consumption calculations are based on annual nominal power. The carbon footprint account is explained below according to consumed energy types:

7.1.1.1.1. Natural gas energy's carbon footprint (NGECF)

The calculation is based on the amounts of energy consumed in the combustion systems and combustion process in the 2014 emission report. Firms prepare emission reports in every 2 years.

Equations 16 and 17 are used in the calculation of the carbon footprint:

$$\text{Consumed natural gas energy [kWh/year]} = \text{Nominal Power of the process unit [kW]} \times \text{Daily work time [h/day]} \times \text{Annual work days [day/year]} \quad (16)$$

$$\text{Carbon Footprint (CF) [kg CO}_2\text{/year]} = \text{Consumed natural gas energy [kWh/year]} \times \text{Natural gas emission factor [kg CO}_2\text{/kWh]} \quad (17)$$

The amount of natural gas consumed annually for the unit of the process combustion system is given as an example calculation below. Other calculations are done similarly.

$$\text{Consumed natural gas energy [kWh/year]} = 430 \text{ kW} \times 6 \text{ h/day} \times 140 \text{ day/year}$$

$$\text{Consumed natural gas energy [kWh/year]} = 361200 \text{ kWh/year}$$

The annual amount of natural gas consumed for the singeing burning process was found to be 36,1200 kWh. The carbon footprint of the natural gas energy consumed in the singeing burning process was calculated by Equation 17 as 66822 kg CO₂, by choosing the natural gas emission factor from Table 7.2 where carbon emission factors are included.

$$\text{NGECF [kgCO}_2\text{/year]} = 361200 \text{ kWh/year} \times 0.185 \text{ kg CO}_2\text{/kWh} = 66822 \text{ kg CO}_2\text{/year or}$$

$$\text{NGECF [kgCO}_2\text{/kg fabric]} = 66822 \text{ kg CO}_2 / 475000 \text{ kg fabric} = 0.14 \text{ kg CO}_2 / \text{kg fabric}$$

In combustion and combustion process systems, the total consumed natural gas energy is calculated as 18825600 kWh. The carbon footprint of the singeing burning process is given as 66822 kg CO₂ or 0.14 kg CO₂/kg fabric in the sample calculation and the carbon footprint of the total natural gas energy used in all processes is found as 3482736 kg CO₂ or 7.33 kg CO₂ for 475000 kg fabric production and the values calculated for the other processes are given in Table 7.1.

Table 7.1 Carbon Footprint (NGECF) from natural gas consumption in 2015

SYSTEMS	MACHINES	Nominal power [kW]	Daily work time [h/day]	Annual work days (day/year)	Consumed natural gas energy (kWh/year)	NGECF [kgCO ₂ /year]	NGECF[kgCO ₂ /kg fabric]
PROCESS COMBUSTION SYSTEMS	Singeing hair burn-liquid dust holding chimney	430	6	140	361200	66822	0.14
	Old ram chimney	3480	4	120	1670400	309024	0.65
	New Ram chimney 1	3480	5	100	1740000	321900	0.67
	New Ram chimney 2	3480	5	100	1740000	321900	0.67
COMBUSTION SYSTEMS	Old evaporate boiler 320m ² chimney	10000	4	120	4800000	888000	1.86
	New evaporate boiler 400m ² chimney	12900	6	110	8514000	1575090	3.31
TOTAL		33770	30	690	18825600	3482736	7.33

Table 7.2 Carbon emission factor (Url-37)

Consumed Energy Type [kWh]	Emission factor [kg CO ₂ /kWh]
Electricity	0.523
Natural gas	0.185
Burning oil (for heating)	0.245

7.1.1.1.2. Electric energy'carbon footprint (EECF)

Equation (18) is used in the calculation of the carbon footprint of the consumed electric energy.

$$\text{EECF [kg CO}_2\text{/year]} = \text{Consumed electric energy [kWh/year]} \times \text{Electric energy emission factor [kg CO}_2\text{/kWh]} \quad (18)$$

All calculated data are shown in Table 7.3, but only the carbon footprint resulting from the electric energy consumed in the finishing process is calculated as an example. In the calculation, the value given in Table 7.2 is used as the emission factor.

$$\begin{aligned} \text{EECF[kg CO}_2\text{/year]} &= 3519670 \text{ kWh/year} \times 0.523 \text{ kg CO}_2\text{/kWh} = 1840787 \text{ kgCO}_2\text{/year} \text{ or} \\ \text{EECF[kg CO}_2\text{/kg fabric]} &= 1840787 \text{ kgCO}_2 / 475000 \text{ kg fabric} = 3.87 \text{ kg CO}_2\text{/kg fabric} \end{aligned}$$

In 2015, the carbon footprint of electricity in the finishing process was calculated as 1840787 kg CO₂ or 3.87 kg CO₂ and the carbon footprint of total electricity energy as 10698352 kg CO₂ or 22.52 kg CO₂ for 475000 kg fabric production .

Table 7. 3 Carbon Footprint (EECF) from electricity energy consumption in 2015

Electricity consuming units	Consumed electricity energy [kWh/year]	EECF [kg CO ₂ /year]	EECF [kgCO ₂ /kg fabric]
Chemical finishing	3519670	1840787	3.87
Finish new stove	582305	304545	0.64
Finish old stove	407232	212982	0.44
Dyeing	2444526	1278487	2.69
Warping	436758	228424	0.48
Boiler room	1344420	703132	1.48
Climate parts	5167680	2702697	5.68
Compressor	718200	375619	0.79
Doffer room	721014	377090	0.79
Offices+Treatment	5113935	2674588	5.63
TOTAL	20455740	10698352	22.52

According to all the energy types consumed, the total energy carbon footprint value (ECF) is equal to the carbon footprint value of the electricity consumed by the carbon footprint of the consumed natural gas energy. This value is shown by equation (19), and the carbon footprint of the total annual energy consumed is calculated as 14181088 kg CO₂ or 29.85 kg CO₂ for 475000 kg fabric production.

$$ECF = NGE CF + EECF \quad (19)$$

$$ECF = 3482736 + 10698352 = 14181088 \text{ kg CO}_2/\text{year or}$$

$$ECF = 7.33 + 22.52 = 29.85 \text{ kg CO}_2/\text{kg fabric}$$

7.1.1.1.2.1. CO₂ emissions calculation per unit of electricity consumption in Turkey

For the calculation of electricity consumption-related CO₂ emissions, an emission factor based on Turkey's conditions can be reached by taking into account national electricity generation resources and technologies instead of the IPCC data in Table 7.2, which were used in the above calculations. The data pertaining to the electricity generation, consumption, energy source, thermal value, transmission and distribution loss, and the like were obtained from TEİAŞ (Turkish Electricity Transmission Company) statistics web page. The emission amount per unit electricity consumption (kg CO₂/kWh electricity) was calculated using the information given in Table 7.4 and efficiency information given in Table 7.5. In 2015, Turkey's electricity generation totalled 259,690 GWh, whereas its electricity consumption was 264,137 GWh.

The country's electricity generation breakdown was as such the same year: 73,872.6 GWh from coal (hard+import+lignite+asphalt); 98,193.4 GWh from natural gas+LNG; 4,831.8 GWh from renewable energy (waste+geo); 4,243.2 GWh from other-1 energy resources (fuel oil, diesel oil, naphtha) and 94.1 GWh from other-2 energy resources (multi fuel+solid+liquid). The total electricity generation stood at 259,690 GWh. Turkey imported 2,965 GWh of electricity while exporting 7,411 GWh of it. Therefore, Turkey's total electricity consumption added up to 264,137 GWh. The country acquired 68.6 percent of electricity generated from thermal power plants. Thermal power plants emit more carbon emissions than other power plants. Coal, natural gas+LNG, renewable waste, other-1 and other-2 energy groups are addressed as thermal resources in the evaluation of thermal power plants in Turkey. A study was conducted on the efficiencies of thermal power plants in Turkey. The CO₂ emission amount per unit energy production was calculated based on the average yield values of the fuels used in thermal power plants. The amount of CO₂ emission corresponding to the generation of one kWh electric energy was calculated according to Equation 20 below and the results obtained are given in Table 7.5.

$$\text{Consumed electricity energy emission factor [kgCO}_2\text{/kWh electricity]} = \{860\text{kcal/kWh}/(\text{Calorific value} \times \text{Efficiency})\} \times C \times (44/12) \quad (20)$$

Table 7.4 Distribution of electricity generated according to primary sources in Turkey (TEİAŞ, 2015; Url-31)

Production resources	Production in 2015 [GWh]	Contribution available for consumption [%]	Contribution available for production [%]
Coal (Hard+Import+lignite+asphalt)	73872.6	28	28.4
Natural gas+LNG	98193.4	37.18	37.8
Hydraulic	66903.2	25.33	25.8
Wind	11552.1	4.37	4.4
Renewable waste+geo	4831.8	1.83	1.9
Other 1 (Fuel oil+Diesel oil+ Naphtha)	4243.2	1.61	1.6
Other 2 (Multi-fuel+solid+liquid)	94.1	0.04	0
Total production in Turkey	259690.4	98.32	100
Import	2964.6	1.12	0
Given total consumption in Turkey	262655	99.44	0
Exports	7411.1	2.81	0
Total consumption in Turkey	264136.8	100	0

In Table 7.5, the data for each fuel type used in thermal power plants in Turkey was taken as a base. The amount of carbon dioxide emission per unit electric energy production was calculated with the use of Equation 20. Example calculation for hard coal is given below:

$$\text{Emission factor [kgCO}_2\text{/kWh]} = \{860 \text{ kcal/kWh}/(\text{Calorific value} \times \text{Efficiency})\} \times C \times (44/12)$$

$$= \{(860\text{kcal/kWh})/(6000 \times 0.34)\} \times 0.73 \times 3.667$$

$$= 1.13 \text{ kg CO}_2\text{/kWh}$$

Table 7.5 The amounts of CO₂ per unit of energy production in thermal power plants in Turkey (Kıncay and Ozturk, 2003; IPCC, 2006; Keskinel, 2006; Oktay, 2009; EUAŞ, 2011; Aslanoğlu and Köksal, 2012; Url-56)

Types of fuel	Efficiency	C	kcal/kg	kcal/kWh	CO ₂ /C	kg CO ₂ /kWh
Hard coal + Asphalt + Import coal	0.34	0.73	6000	860	3.667	1.13
Lignite	0.33	0.45	2500	860	3.667	1.72
Natural gas	0.55	0.75	8250	860	3.667	0.52
Fuel oil	0.37	0.8	9600	860	3.667	0.71

Table 7.6 The amount of CO₂ released to generate electricity kWh depending on the energy source (Aylık Enerji İstatistikleri (EİGM), 2016; Url-33)

Sources of energy	Production [%]	kg CO ₂ /kWh	(Production %×kg CO ₂ /kWh)/100
Hard coal	1	1.13	0.0113
Import coal	16	1.13	0.1808
Asphaltite coal	1	1.13	0.0113
Natural gas	35	0.52	0.182
Lignite	15	1.72	0.258
Fuel oil	1	0.71	0.0071
HES stream	5	0	0
Hesdam	18	0	0
Wind	5	0	0
Geothermal	2	0	0
Biogas	1	0	0
Total	100		0.6505

In Table 7.6, CO₂ emission amount per unit energy production was calculated based on the production percentages of the fuels in thermal power plants. Additionally, we reach greenhouse gas emission value per one kWh electric energy production in Turkey by adding transmission and distribution losses. In 2015, transmission loss stood at 2.21 percent (EPDK, 2015; Url-32). The distribution loss was taken as the value in 2014, which materialized as 13 percent (Url-54). Carbon emissions per unit of electricity generated were calculated as $(0.6505 + 0.0221 + 0.13) 0.8026$ [kg CO₂/kWh] because transmission and distribution losses should also be included in the unit production.

7.1.1.1.2.2. Calculation of Greenhouse Gas Emissions from electricity consumption in the plant

In the textile company examined, we consider revising calculated the greenhouse gas emissions caused by electricity consumption in 2015. The emission factor resulting from electricity consumption (kg CO₂/kWh) was compared to the two different methods (IPCC Tier 1 and country-based Tier 3). The total electrical energy consumption for the plant's administrative units and production units amounts to 20,455,740 [kWh] per year. It consists of production-related process energy consumption, boiler energy consumption, energy consumption due to the lighting of administrative units and energy consumption in the unit treating the production plant's chemical wastewater. The amount of electricity used inside and outside the production process amounted to 15,341,805 [kWh] and 5,113,935 [kWh] per year, respectively. The total calculated 20,455,740 kWh/year value is converted to megawatts as 20,455.7 [MWh/year]. In Table 7.7, greenhouse gas emissions (GHGs) caused by the facility's electricity consumption was calculated in terms of CO₂ emissions with the transformation rates of these gases in relation to their impact on global warming. The emission factors and conversion rates in the calculations were obtained from the IPCC. Accordingly, the total greenhouse gas emissions (CO₂ equivalent) resulting from the plant's electrical energy consumption calculated as 11,991 [ton CO₂/year] using Equation 21.

$$\text{Emission} = \text{Fuel consumption} \times \text{Emission factor} \times \text{Oxidation factor} \quad (21)$$

Emission = Amount of greenhouse gas according to the type of fuel (kg CO₂)

Fuel consumption = Amount of fuel consumed (kg fuel, lt fuel)

Emission factor = GHG emission [tonne GHG/MWh]

Oxidation factor = 1 (IPCC accepted value)

Table 7.7 Calculation of greenhouse gases according to three important greenhouse gases (IPCC, 2006; Url-55).

Greenhouse Gas	Emission factor [tonne/MWh]	Conversion Rate	Total CO ₂ equivalent value [tonne/year]
CO ₂	0.584	1	11946
CH ₄	0.00001135	21	4.88
N ₂ O	0.00000628	310	39.8
Total			11991

The contribution of fluorine and indirect greenhouse gases (hydrofluorocarbons, perfluorocarbons and sulfur hexafluoride) was neglected in the calculation of electricity consumption-related greenhouse gas emissions as they were very small. If the country-specific emission factor (0.8026) is taken into account, the amount of electricity consumption-related greenhouse gas emissions at the plant is found as tons CO₂/year with Equation 21 as shown below.

Total equivalent GHG emission = Electricity consumption × Emission factor × Oxidation factor

$$= 20,455.7 \times \{(0.8026 \times 1) + (0.00001135 \times 21) + (0.00000628 \times 310)\} \times 1$$

$$= 16,462 \text{ ton CO}_2/\text{year}$$

7.1.1.1.3. Calculation of carbon footprint in transportation

The examined plant results in carbon dioxide emissions due to production-related transportation activities. In the calculation of the transportation-related carbon footprint, the following factors were considered; raw materials and products transported, the forklifts used for their transportation within the company, and the transfer of employees to/from the factory by shuttle. In this calculation, transportation-related carbon footprints are examined in four parts:

7.1.1.1.3.1. Calculation of carbon footprint in the raw material of transportation (RMTCF)

One needs to have the following information to calculate the carbon dioxide emissions and carbon footprints that occur in the transportation of raw materials; where raw materials come from, their quantities, types, and numbers of vehicles used in transportation. Wool and polyester come to the fabric factory as raw materials from Argentina, China, and France. Following is an example of the carbon footprint calculation resulting from the shipping of the raw materials; calculation regarding the carbon footprint resulting from the shipment of 150 tons of wool from Argentina. 150 tons of wool from Argentina arrived at the customs on a container ship and then transported to the factory by eight long vehicles. Similarly, 300 tons of wool from China arrived at the customs on a container ship and then transported to the factory by 15 long vehicles. Calculations for shipments from other countries were conducted in a similar fashion. The Equations (22), (23), (24), (25), (26) and (27) were used in the calculation.

In this calculation, the following approach was developed for fuel calculation:

When transporting 40 tons of raw materials/products as cargo to 100 km distance, the trailer truck will consume 32-36 liters of fuel (Url-38). According to this approach, the fuel consumption calculation was done in proportional relation for trucks, one of the vehicles used for transportation of products and raw materials.

The average speed for the maritime shipping was taken as 24 knots, and the calculation was based on a container ship with an average carrying capacity of 8000 TEU. In 1969, Richard F. Gibney, who worked at the office keeping shipbuilding and maritime statistics in England, put forward this terminology to conduct this process for different vessel types and different container sizes easily (Url-44). In container transport, a common dimension standardization is in place for containers. From these dimensional standards, 20-foot and 40-foot containers are most frequently used in today's container transportation. TEU is the abbreviation for Twenty Foot Equivalent Unit, which refers to a 20-foot container. Also, the term TEU indicates the freight shipment capacity of a container terminal. Container ships' TEU capacities define their sizes (Url-45; Url-46; Url-47). Figure 7.1 demonstrates the relation between speed and size capacity of container ships (The Geography of Transport Systems, 2016; Url-39). Based on this graph, the fuel consumption was determined as 225 tons/day due to its relation with the speed and size capacity. One liter of diesel fuel is equal to 820-860 grams. In calculations, an average of 840 grams per liter was taken (Url-40). In this case, the daily amount of fuel consumed on board is 267,857 L.

Consumed fuel in a ship per day [l/day] = {Fuel consumption [ton/day] $\times 10^6$ g/ton} / 840 [g/l
dizel yakıt] (22)

$$= (225 \text{ ton/day} \times 10^6 \text{ g/ton}) / 840 \text{ g/l} = 267,857 \text{ l/day}$$

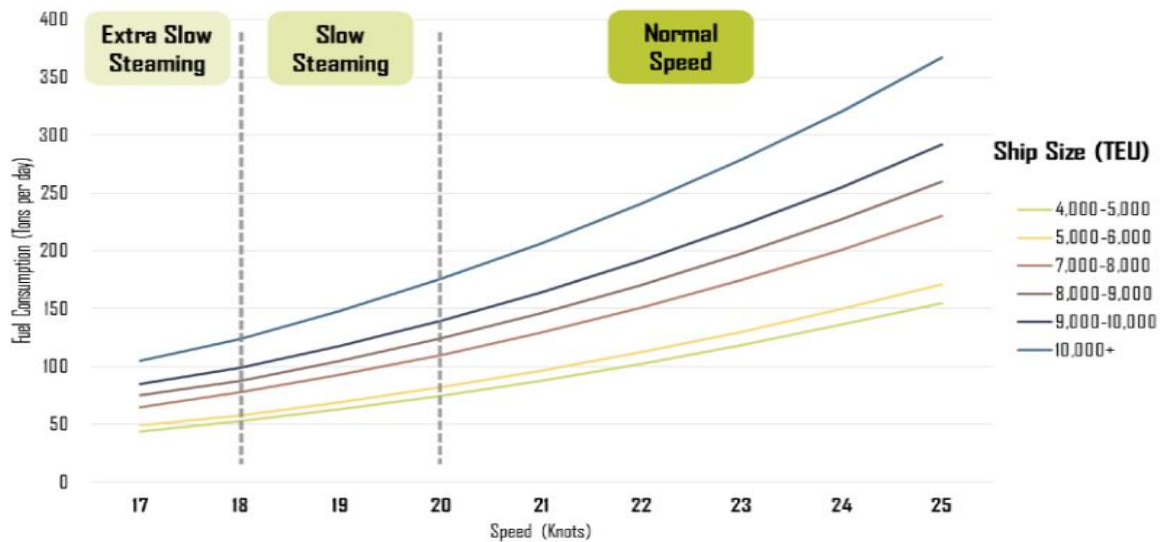


Figure 7.1. Relationship between speed and fuel consumption (The Geography of Transport Systems, 2016; Url-36).

The daily fuel consumption of 225 tons was converted into the liter unit with the Equation 22, and it was calculated as 267,857 liters. The company receives raw materials (wool and polyester) from Argentina, China, and France once a year. We learned from the authorities and literature about the arrival time from Argentina (Ship 1) and China (Ship 2) to Istanbul's customs port by ship. Accordingly, a container ship from Argentina and China arrives at the customs in 20 days and 18 days, respectively (Url-41). Because raw materials are brought in bulk from the two countries once a year, the amount of fuel consumption per year was found with the Equation 23.

$$\text{Ship 1 fuel consumption [l]} = \text{Daily fuel consumption [l/day]} \times \text{Travel duration [days]} \quad (23)$$

$$= 267,857 \text{ [l/day]} \times 20 \text{ days} = 5,357,140 \text{ liters}$$

However, this calculated amount of consumption is the amount of fuel consumed due to the total load carried by ship. This 150-ton load is transferred to the factory by 8 truck trucks. Therefore, the amount of fuel consumed by the ship for the transportation of raw materials was found with Equation 24.

$$\text{Total fuel consumption by ship 1 [liters/8 containers]} = \text{Ship 1 fuel consumption [l]} \times (\text{number of containers carried for the factory} / \text{total number of containers carried}) \quad (24)$$

$$= 5,357,140 * (8/8000) = 5,357 \text{ liters}$$

In this case, the carbon footprint resulting from the transport of wool raw materials from Argentina to Istanbul by a container ship is calculated with the Equation 25. The emission factor is taken from Table 7.8 because the fuel consumed by the truck and ship is diesel.

$$\text{Annual CF for Ship 1 [kg CO}_2\text{]} = \text{Consumed fuel [l]} \times \text{Emission factor [kg CO}_2\text{/l diesel fuel]} \quad (25)$$

$$= 5,357 \text{ [l diesel fuel]} \times 2.9 \text{ [kg CO}_2\text{/l diesel fuel]} = \mathbf{15,535 \text{ kg CO}_2}$$

The wool from arriving at the customs from Argentina was taken to the factory with eight trailer trucks. The amount of fuel consumed by the trucks was calculated with Equation 26:

$$\text{Consumed fuel in trucks [liters]} = \text{Fuel consumption rate [l/100 km]} \times \text{Distance from customs to the factory [km]} \times \text{Number of trucks} \quad (26)$$

$$= (36 \text{ liters/100km}) \times 100\text{km} \times 8 \text{ trucks} = 288 \text{ liters}$$

In this case, eight trailer trucks carrying 150 tons of wool from the customs in Istanbul to the factory consumed 288 liters of fuel. This resulting carbon footprint was calculated with the Equation 27.

$$\text{Annual CF for 8 trucks [kg CO}_2\text{]} = \text{Consumed fuel [l]} \times \text{Emission factor [kg CO}_2\text{/l diesel fuel]} \quad (27)$$

$$= 288 \text{ [l diesel fuel]} \times 2.9 \text{ [kg CO}_2\text{/l diesel fuel]} = \mathbf{835 \text{ kg CO}_2}$$

As a result, the carbon footprint resulting from the transportation of 150 tons of wool from Argentina was found to be (15,535+835) **16,370 [kg of CO₂]**.

Table 7.8 Carbon emission factors according to types of fuel (Cefic, 2011; Url-35).

Types of fuel	kg CO ₂ /liter	kg CO ₂ /kg
Motor Gasoline	2.8	-
Diesel oil	2.9	-
Gas oil	2.9	-
Liquefied Petroleum Gas(LPG)	1.9	-
Compressed Natural Gas(CNG)	-	3.3
Jet Kerosene	-	3.5
Residual Fuel Oil	-	3.5
Biogasoline	1.8	-
Biodiesel	1.9	-

Table 7.9 CF [kg CO₂] in raw materials transportation (RMTCF)

Country of origin	Way of Transport	Number of transportation	Raw material	Raw material [tons]	Distance [km]	References	Type of fuel	Consumed fuel [liters]	RMTCF [kg CO ₂ /year]	RMTCF [kg CO ₂ /kg fabric]
Argentina	Ship	1	Wool	150	12871	Url-48	diesel oil	5357	15535	0.032
	Trailer truck	8			100			288	835	0.001
China	Ship	1	Wool	300	6370	Url-49		9040	26217	0.055
	Trailer truck	15			100			540	1566	0.003
France	Trailer truck	15	Polyester	150	2754	Url-50		14872	43128	0.090
TOTAL		40	Wool+ Polyester	600	22195			30097	87281	0.183

As demonstrated in Table 7.9, the total amount of fuel consumed was 30,097 liters, while the carbon footprint resulting from raw material transportation was found to be 87,281 kg of CO₂ or 0.183 kg CO₂ per year for 475,000 kg of fabric production.

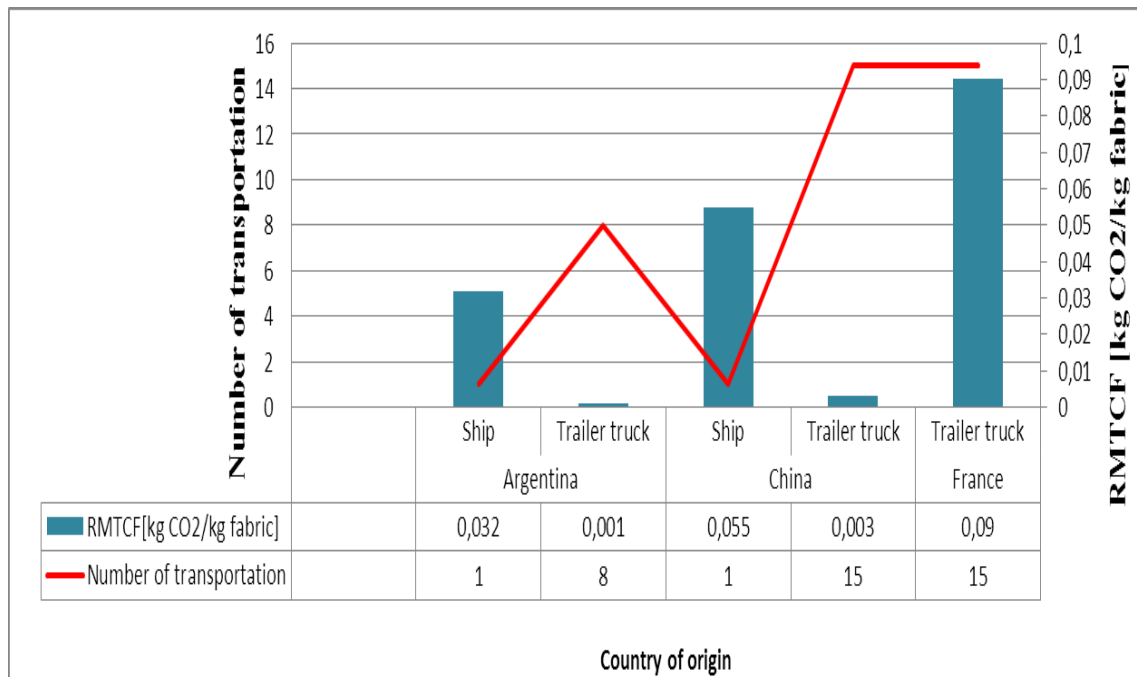


Figure 7.2. CF [kg CO₂] in raw material transportation (RMTCF)

Figure 7.2 shows the distribution of carbon footprint by country in relation to raw material transportation. Fabric production takes place with the raw materials (polyester, wool) brought from Argentina, China and France to the fabric factory. Raw materials from Argentina and China are transported to the fabric factory by ships and then trucks. The annual carbon footprint resulting from the transportation of raw materials from Argentina to the customs by one container ship is 15,535 kg CO₂ or 0.032 kg of CO₂ per the production of 1 kg of fabric, while the annual carbon footprint resulting from its transportation from the customs by eight trucks is 835 kg of CO₂ or 0.001 kg of CO₂ per the production of 1 kg of fabric.

The annual carbon footprint resulting from the transportation of raw materials from China to the customs by one container ship is 26,217 kg CO₂ or 0.055 kg of CO₂ per 1 kg of fabric, while the annual carbon footprint resulting from its transportation from the customs by eight trucks is 1,566 kg of CO₂ or 0.003 kg of CO₂ per 1 kg of fabric. 15 trucks were used for the transportation of the raw materials originating from France, and the annual carbon footprint was calculated as 43,128 kg of CO₂ or 0.090 kg of CO₂ for per 1 kg of fabric. By comparison, we observe the highest amount of carbon footprint in the transportation of 150 tons of polyester raw material from France to the fabric factory in Istanbul.

7.1.1.1.3.2. Calculation of carbon footprint in the product of transportation (PTCF)

One needs to have the following information to calculate the carbon dioxide emissions and carbon footprints that occur in the transportation of products: where products are headed for, their quantities, types, and numbers of vehicles used in transportation. The fabric produced is transported to Germany, Japan, and France. Following is an example of the carbon footprint calculation resulting from the shipment of products: calculation of the carbon footprint resulting from the shipment of 250 tons of fabric from Germany with 20 trailer trucks. Other calculations were made in a similar fashion. The Equations 28 was used in the calculation in below:

$$\text{Consumed fuel in trucks [liters]} = \text{Fuel consumption rate [l/100 km]} \times \text{Distance from German customs to the factory [km]} \times \text{Number of trucks} \quad (28)$$

$$=(36 \text{ liters/100km}) \times 2324\text{km} \times 20 \text{ trucks} = 16,733 \text{ liters}$$

In this case, 20 trailer trucks carrying 250 tons of fabric from Istanbul to Germany consumed 16,733 liters of fuel. This resulting carbon footprint was calculated with the Equation 29.

$$\text{Annual CF for 20 trucks [kg CO}_2\text{]} = \text{Consumed fuel [l]} \times \text{Emission factor [kg CO}_2\text{/l diesel fuel]} \quad (29)$$

$$= 16,733 \text{ [l diesel fuel]} \times 2.9 \text{ [kg CO}_2\text{/l diesel fuel]} = \mathbf{48,525 \text{ kg CO}_2}$$

$$\text{CF for 20 trucks [kg CO}_2\text{/kg fabric]} = \text{Annual CF for 20 trucks/Annual amounts of product}$$

$$= 48,525 \text{ kg CO}_2 / 475,000\text{kg fabric} = \mathbf{0.102 \text{ kg CO}_2\text{/kg fabric}}$$

As a result, the carbon footprint amount resulting from the transportation of 250 tons of fabric to Germany was found to be 48,525 kg of CO₂. Other calculations were made in the same way. They are provided in Table 7.10. Calculations for Argentina regarding raw material shipment were repeated for product shipments to Japan. Daily fuel consumption for this ship was considered to be 225 tons. Two ships carried out the shipment to Japan, which took place once a year. Two ships departing from Istanbul reached the customs in Japan in 12 days (Url-42). As demonstrated in Table 7.10, the total amount of fuel consumed was 36,741 liters, while the carbon footprint resulting from fabric transportation was found to be 106,457 kg of CO₂ or 0.224 kg CO₂ per year for 1 kg of fabric. The total carbon footprint resulting from the shipment was calculated with Equation 30:

$TTCF [kg CO_2/year] = CF \text{ in raw material transportation (RMTCF)} + CF \text{ in product transportation (PTCF)} \quad (30)$

$TTCF[kg CO_2/year] = 87,281+106,547 = \mathbf{193,828 kg CO_2/year}$ or

$TTCF[kg CO_2/kg fabric] = 0.183+0.224=\mathbf{0.407 kg CO_2/kg fabric}$

The annual carbon footprint resulting from the raw material and product shipment were calculated as 193,828 kg of CO₂ or 0.407 kg of CO₂ for per 1 kg of fabric.

Table 7.10 CF[kg CO₂] in product of transportation (PTCF)

Country of origin	Way of Transport	Number of transportation	Product	Fabric [kg]	Fabric [tonne]	Distance [km]	Reference	Types of fuel	Consumed fuel [liters]	PTCF [kg CO ₂ /year]	PTCF[kgCO ₂ /kg fabric]
Germany	Trailer truck	20	Fabric	250,000	250	2,324	Url-51	diesel oil	16,733	48,525	0.102
Japan	Trailer truck	10		100,000	100	100	Url-52		360	1044	0.002
	Ship	2				8,812			8,036	23,304	0.049
France	Trailer truck	12		125,000	125	2,688	Url-53		11,612	33,675	0.070
TOTAL		44		475,000	475	13,924			36,741	106,547	0.224

Figure 7.3 shows the distribution of carbon footprint by country in relation to product shipment. The fabric produced is transported to Germany, Japan, and France. The annual carbon footprint resulting from the shipment to Germany with 20 trailer trucks was calculated as 48,525 kg of CO₂ or 0.102 kg of CO₂ for per 1 kg of fabric. 10 trailer trucks and 2 ships were used for shipping fabrics to Japan. The annual carbon footprint resulting from the shipment to Japan is as such: 1,044 kg of CO₂ or 0.002 kg of CO₂ per 1 kg of fabric resulting from taking the product to the customs by trailer trucks, and 23,304 kg of CO₂ or 0.049 kg of

CO₂ per 1 kg of fabric resulting from its shipment from the customs to the customs in Japan by two ships. 12 trucks were used for the transportation of the products to France, and the resulting annual carbon footprint was calculated as 33,675 kg of CO₂ or 0.070 kg of CO₂ for per 1 kg of fabric. As can be seen in Figure 7.3, the biggest amount of carbon footprint results from the shipment of fabrics to Germany.

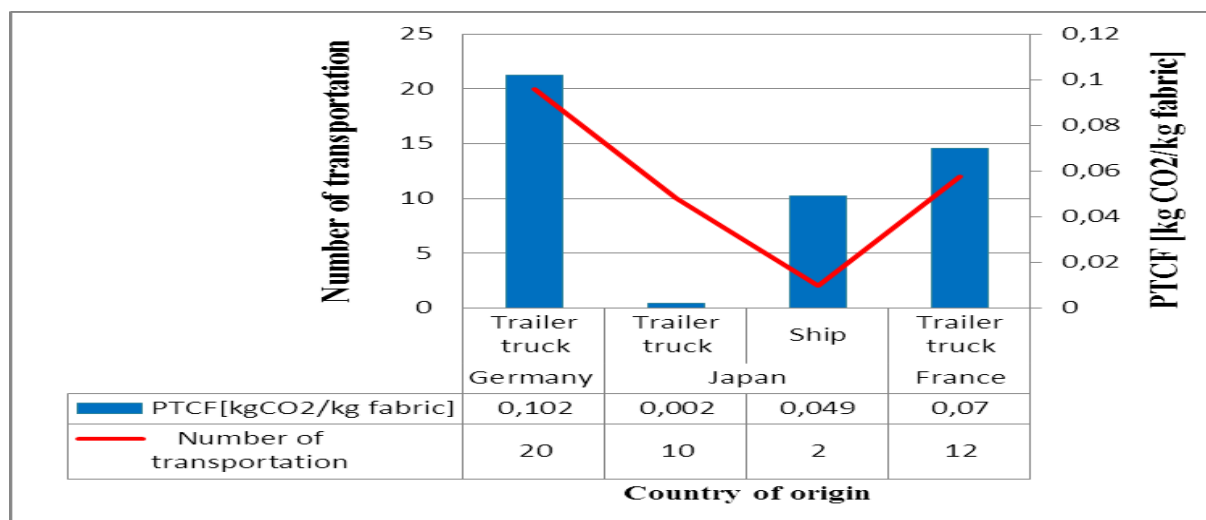


Figure 7.3 CF [kg CO₂/year] in product transportation PTCF

7.1.1.1.3.3. Calculation of carbon footprint in using forklift of transportaion (FCF)

The carbon footprint resulting from forklift use was calculated with the use of Equations 31 and 32:

$$\begin{aligned}
 \text{Consumed fuel in forklift [liters]} &= \text{Consumed fuel in forklift [tonne]} \times 1000 \text{ kg/tonne} \times \\
 &\quad 1.2195 \text{ [l/kg]} \quad (31) \\
 &= 20 \text{ tonne} \times 1000 \text{ kg/tonne} \times 1.2195 \text{ l/kg} \\
 &= 24,390 \text{ liters}
 \end{aligned}$$

The forklift uses diesel fuel type. The diesel fuel's emission factor was taken from Table 7.8, and then the forklift's carbon footprint was calculated and provided in Table 7.11.

$$\begin{aligned}
 \text{FCF [kg CO}_2\text{]} &= \text{Consumed fuel in forklift [liters]} \times \text{Emission factor [kg CO}_2\text{/liters]} \quad (32) \\
 &= 24,390 \text{ [l]} \times 2.9 \text{ [kg CO}_2\text{/l]} = 70,732 \text{ kg CO}_2\text{/year or } 70,732 \text{ kg CO}_2\text{/475,000kg fabric}
 \end{aligned}$$

Table 7.11 Forklift's carbon footprint (FCF) in 2015

Machine	Consumed fuel [tonne]	Consumed fuel [kg]	Consumed fuel [liters]	FCF [kg CO ₂]	FCF [kg CO ₂ /kg fabric]
Forklift	20	20,000	24,390	70,732	0.148

7.1.1.1.3.4. Calculation of carbon footprint in personnel services of transportation (SCF)

We found an annual number of working days by using Equation 33 excluding Sundays (52 days) as off weekend days as well as official and religious holidays (17 days).

$$\text{Annual number of working day for services} = 365 - 52 - 17 = 296 \text{ day} \quad (33)$$

We took into account the two-round trips of the 45 staff shuttles operating in two shifts. A minibus's average fuel consumption is 9 liters per 100 km (Url-43). The daily average one-way distance of a shuttle is 35 km. The annual fuel consumption was calculated using Equation 34:

$$\begin{aligned} \text{Consumed fuel in services (liters/year)} &= \text{Number of services} \times \text{Number of shift} \times \text{Repeat of} \\ &\quad \text{travel} \times \text{Average travel distance in a day [km/day]} \times \text{Work days in a year [day/year]} \times \\ &\quad \text{Consumed diesel in 100 km [liters/100km]} \quad (34) \\ &= 45 \times 2 \times 2 \times 35 \text{ [km/day]} \times 296 \text{ [day/year]} \times 9 \text{ liters/100km} \\ &= 167,832 \text{ liters/year} \end{aligned}$$

As shuttles use diesel as fuel, the carbon footprint resulting from their annual fuel consumption was found using Equation 35 and the emission factor in Table 7.8:

$$\text{SCF [kg CO}_2\text{/year]} = \text{Consumed fuel in [liters/year]} \times \text{Emission factor (kg CO}_2\text{/liters)} \quad (35)$$

$$\text{SCF [kg CO}_2\text{/year]} = 167,832 \text{ [l/year]} \times 2.9 \text{ [kg CO}_2\text{/l]} = 486,713 \text{ kg CO}_2\text{/year or}$$

$$\text{SCF} = 486,713 \text{ kg CO}_2 / 475,000 \text{ kg fabric} = 1.024 \text{ kg CO}_2\text{/kg fabric}$$

The annual fuel consumption of the 45 staff shuttles serving the plant is 167,832 L. The staff's annual fabric production is 475,000 kg. The annual carbon footprint for 475,000 kg of fabric produced after the annual fuel consumption of these shuttles used for the transportation of the staff amounts 486,713 kg of CO₂ per year or 1.024 kg of CO₂ per 1 kg of fabric.

As a result, the emission values of all the resources emitting carbon dioxide in the examined plant were compared in Table 7.12 and Figure 7.4.

Table 7.12 Carbon footprints according to sources

Sources	CF [kg CO ₂ /year]	CF [kg CO ₂ /kg fabric]
NGECF	3,482,736	7.33
EECF	10,698,352	22.52
RMTCF	87,281	0.183
PTCF	106,547	0.224
FCF	70,732	0.148
SCF	486,713	1.024
TOTAL	14,932,361	31.4

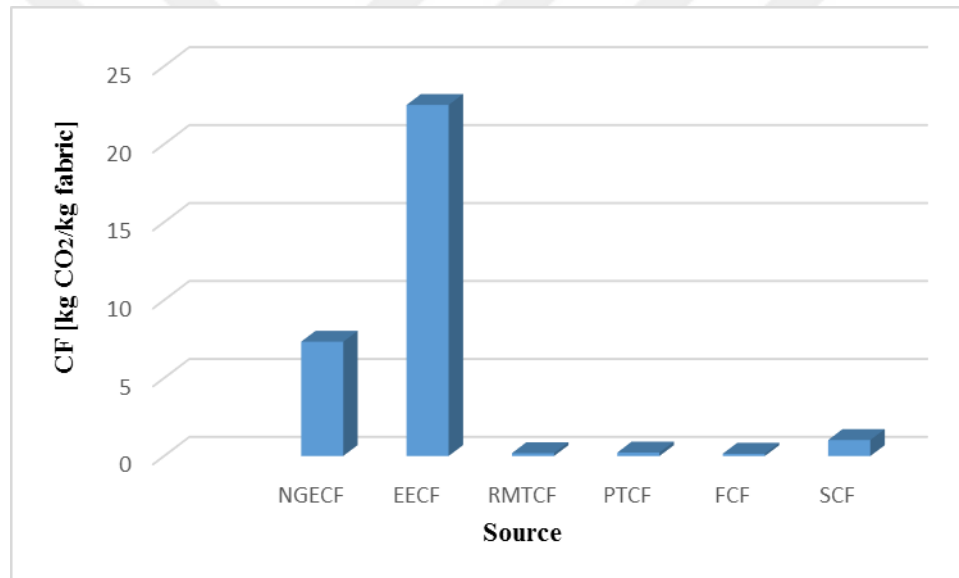


Figure 7.4 Relationships between sources and carbon footprints

As shown in Figure 7.4, the carbon footprint of electric energy ranks the highest. This is followed by the carbon footprint of emissions caused by natural gas consumption. Accordingly, improvements to reduce consumption of these two energy sources will provide the best environmental and economic benefit. We can think of keeping machine maintenance and productivity at an optimum level, saving electricity as much as possible and producing at least part of the electricity from renewable energy resources including the sun and the wind to make improvements in this regard.

7.1.1.1.4. Calculation of carbon footprint due to raw fiber production

The carbon footprint resulting from the production of wool and polyester fiber raw materials (raw material inputs in the factory) in the countries of origin were taken as 20.8 [kg CO₂/kg fiber] and 5.4 [kg CO₂/kg fiber], respectively (Thomas et al, 2012). Considering that the factory uses 450 tons of wool fiber and 150 tons of polyester fiber, the carbon footprint value resulting from the used fiber raw material should be taken as 16.95 [kg CO₂/kg-fiber]. However, 475 tons of product corresponds to the use of 600 tons of fiber raw materials in the factory which means the use of 1.26 kg of fiber per one kilogram of fabric and the corresponding carbon footprint was taken as 21.4 [kg CO₂/kg fabric].

7.1.2. Calculation of Water Footprint

7.1.2.1. Calculation of water consumption in production

Water is used in the dyeing and chemical finishing units. Water consumption decreases thanks to its reuse the treatment unit. Therefore, the wastewater treatment process reduces water footprint. The company's monthly water consumption is given in Table 7.13.

Table 7.13 Water consumption in 2015

Months	Consumed water [m ³]
1	3,956
2	3,741
3	3,214
4	3,010
5	2,207
6	2,313
7	1,574
8	2,805
9	2,275
10	0
11	2,794
12	2,663
Total	30,552
Average (11 months)	2,777

The water consumption percentage values for the production processes are given in Table 7.14.

Table 7.14 Percentages of consumed and treated water in processes in 2015

Process	Fraction [%]
Dyeing	54
Chemical finishing	28
Treatment (recycling)	18

In fact, more water is used in production processes than the purchased amount of 30,552 m³ because 18% of the water is treated and reused in the facility. Therefore, this amount constitutes 82% of the total amount;

$$\text{Total water use in production processes} = 30,552 / 0.82 = 37,259 \text{ m}^3$$

The water amount in all three processes was calculated using Equation (36), and the results are given in Table 7.15.

$$\text{Water in the process [m}^3\text{]} = \text{Total water consumption} \times \text{percentage of water consumption in the processes} \quad (36)$$

$$\text{Water consumption in dyeing process [m}^3\text{]} = 37,259 \times 0.54 = 20,120 \text{ m}^3$$

$$\text{Water consumption in chemical finishing process [m}^3\text{]} = 37,259 \times 0.28 = 10,432 \text{ m}^3$$

$$\text{Treated water for reuse [m}^3\text{]} = 37,259 \times 0.18 = 6,707 \text{ m}^3$$

Table 7.15 Water budget in processes

PROCESSES	Total water volume [m ³]	Fraction [%]	Consumed or treated water [m ³]
Dyeing	37,259	54	20,120
Chemical finishing	37,259	28	10,432
Treatment (Recycling)	37,259	18	6,707

As water is reused after the treatment process, the production stages' total water usage is as much as the amount in the dyeing and chemical finishing stages, and it was calculated with Equation (37).

$$\text{Total consumed water [m}^3\text{]} = \text{Consumed water in all processes} \quad (37)$$

$$\text{Total consumed water [m}^3\text{]} = \text{dyeing process} + \text{chemical finishing process}$$

$$\text{Total consumed water [m}^3\text{]} = 20,120 + 10,432 = 30,552 \text{ m}^3$$

7.1.2.2. Calculation of water footprint due to raw fiber production

The facility receives wool and polyester raw materials processing annually 450 and 150 tons of wool and polyester, respectively. Accordingly, it has an annual 475-ton fabric production. The wool and polyester ratios in the raw material and the wool and polyester amounts in the fabric were calculated using Equation (38) and (39).

$$\text{Fraction of wool (polyester) in raw material} = \text{amount of wool (polyester) used [tone]} / \text{amount of total raw material used [tone]} \quad (38)$$

$$\text{Amount of wool (polyester) in fabric [tone]} = \text{Fraction of wool (polyester) in raw material} \times \text{Total amount of fabric produced} \quad (39)$$

$$\text{Fraction of wool in raw material} = 450 \text{ [tone]} / 600 \text{ [tone]} = 0.75$$

$$\text{Amount of wool in fabric [tone]} = 0.75 \times 475 \text{ [tone]} = 356 \text{ [tone]}$$

$$\text{Fraction of polyester in raw material} = 150 \text{ [tone]} / 600 \text{ [tone]} = 0.25$$

$$\text{Amount of polyester in fabric [tone]} = 0.25 \times 475 \text{ [tone]} = 119 \text{ [tone]}$$

Water footprint values for polyester and wool were obtained from the literature to make a raw material-based water footprint calculation. Accordingly, water footprint values for 1 ton of wool and polyester were determined as 2,237 [m³/ton] and 78 [m³/ton], respectively (WRAP Project Brief, 2011; Url-57). Based on these values, the total water consumption for wool and polyester raw materials in production was calculated using Equations (40) and (41).

$$\text{Water consumption for wool [m}^3\text{]} = \text{Amount of wool used [tone]} \times 2237 \text{ [m}^3\text{/tone]} \quad (40)$$

$$\text{Water consumption for wool [m}^3\text{]} = 450 \text{ [tonne]} \times 2237 \text{ [m}^3\text{/tonne]} = 1006650 \text{ [m}^3\text{]}$$

$$\text{Water consumption for polyester [m}^3\text{]} = \text{Amount of polyester used [tone]} \times 78 \text{ [m}^3\text{/tone]} \quad (41)$$

$$\text{Water consumption for polyester [m}^3\text{]} = 150 \text{ [tonne]} \times 78 \text{ [m}^3\text{/tonne]} = 11,700 \text{ [m}^3\text{]}$$

7.1.2.3. Calculation of total water footprint for fabric production

The total water consumption amount in the firm's fabric production is the sum of the amount consumed in raw materials and fabric production processes.

$$\text{Total water consumption [m}^3\text{]} = \text{Water consumption for wool [m}^3\text{]} + \text{Water consumption for polyester [m}^3\text{]} + \text{Total consumed water in fabric production [m}^3\text{]}$$

$$\text{Total water consumption [m}^3\text{]} = 1,006,650 + 11,700 + 30,552 = 1,048,902 \text{ [m}^3\text{]}$$

The water footprint values for the company's fabric production were calculated with Equation (42), and the obtained values are given in Table 7.16.

$$\text{Water footprint [m}^3 \text{ water/kg fabric]} = \text{Water consumption [m}^3 \text{ water]} / \text{Total fabric production [kg fabric]} \quad (42)$$

$$\text{Water footprint for raw wool (WWF) [m}^3 \text{ water/kg fabric]} = 1,006,650 \text{ [m}^3\text{]} / 475,000 \text{ [kg fabric]}$$

$$\text{Water footprint for raw wool (WWF) [m}^3 \text{ water/kg fabric]} = 2.12 \text{ [m}^3 \text{ water/kg fabric]}$$

$$\text{Water footprint for raw polyester (PWF) [m}^3 \text{ water/kg fabric]} = 11,700 \text{ [m}^3\text{]} / 475,000 \text{ [kg fabric]}$$

$$\text{Water footprint for raw polyester (PWF) [m}^3 \text{ water/kg fabric]} = 0.026 \text{ [m}^3 \text{ water/kg fabric]}$$

$$\text{Water footprint for fabric production (FWF) [m}^3 \text{ water/kg fabric]} = 30,552 \text{ [m}^3\text{]} / 475,000 \text{ [kg fabric]}$$

$$\text{Water footprint for fabric production (FWF) [m}^3 \text{ water/kg fabric]} = 0.064 \text{ [m}^3 \text{ water/kg fabric]}$$

Table 7.16 WF in fabric manufacture in 2015

WWF [m ³ water/kg fabric]	PWF [m ³ water/kg fabric]	FWF [m ³ water/kg fabric]	Total WF [m ³ water/kg fabric]
2.12	0.026	0.064	2.21

7.1.3. Calculation of Energy Footprint

Natural gas and electric energy are used as an energy resource in fabric production. The following information is needed to calculate the amount of energy consumption:

- The amount of electric energy consumed by components such as electric motors, pumps, etc. in the machines used in the production stages of the factory in 2015
- The quantity of natural gas energy consumed in the production stages of the factory in 2015 (Emission report in 2014)
- Daily working hours (hour/day) and an annual number of working days (day/year) of the equipment consuming energy in production stages.

In this study, we calculated the energy quantity consumed annually in production stages as kWh using these values in energy footprint calculation. Energy footprint calculations are explained below:

7.1.3.1. Calculation of consumed natural gas energy' energy footprint (NGEEF)

Based on the company's 2014 emission report, we determined the power values (kW), daily working hours, and annual working days of each component used in the production stages using natural gas energy. The components running on natural gas are steam boilers and process combustion systems. The amount of natural gas consumed annually by one of the boilers is given below as a sample calculation. Other calculations were made in a similar way.

According to the values stated in Energy Market Regulatory Authority' (EMRA) communique, the standard value for the energy amount obtained from one cubic meter of natural gas consumption is regarded as 10.64 kWh (Url-58). The energy footprint values for the steam boilers used in the firm are calculated below with Equations 43 and 44:

$$\text{Consumed natural gas energy [kWh/year]} = \text{Power [kW]} \times \text{Daily work time [h/day]} \times \text{Annual work days [day/year]} \quad (43)$$

$$\text{NGEEF[kWh/kg product]} = \text{Consumed natural gas energy[kWh/year]} / \text{Total product produced [kg product /year]} \quad (44) \text{ or}$$

$$\text{NGEEF[m}^3\text{/kg product]} = \text{Consumed natural gas energy[m}^3\text{/year]} / \text{Total product production [kg product /year]}$$

Consumed natural gas energy [kWh/year] = Power of Old evaporate boiler [kW]×Daily work time [h/day]×Annual work days [day/year]

Consumed natural gas energy [kWh/year] = 10,000 [kW]×4 [h/day]×120 [day/year]

Consumed natural gas energy [kWh/year] = 4,800,000 [kWh/year]

Consumed natural gas energy [m³/year] = 4,800,000 [kWh/year] / 10.64 [kWh/m³]

Consumed natural gas energy [m³/year] = 451,128 [m³/year]

NGEEF [kWh/kg fabric]= 4,800,000 [kWh/year]/475,000[kg fabric/year]=10.11[kWh/kg]

or NGEEF[m³/kg fabric]=451,128 [m³/year]/475,000[kg fabric/year]=0.95[m³/kg fabric]

(for Old evaporate boiler)

Consumed natural gas energy [kWh/year] = Power of New evaporate boiler [kW]×Daily work time [h/day]×Annual work days [day/year]

Consumed natural gas energy [kWh/year] = 12,900 [kW]×6 [h/day]×110 [day/year]

Consumed natural gas energy [kWh/year] = 8,514,000 [kWh/year]

Consumed natural gas energy [m³/year] = 8,514,000 [kWh/year] / 10.64 [kWh/m³]

Consumed natural gas energy [m³/year] = 800,188 [m³/year]

NGEEF [kWh/kg fabric]= 8,514,000[kWh/year]/475,000[kg fabric/year]=17.92[kWh/kg]

or NGEEF[m³/kg fabric]= 800,188[m³/year]/475,000[kg fabric/year]=1.68 [m³/kg fabric]

(for New evaporate boiler)

The energy footprints caused by the process combustion systems are calculated similarly, and the values obtained are given in Table 7.17.

Table 7.17 Energy footprint (NGEEF) from natural gas consumption

Systems	Machines	Power [kW]	Daily Work Time [h/day]	Annual work days [day/year]	Consumed natural gas energy (kWh/year)	Consumed natural gas energy [m ³ /year]	NGEEF [kWh/kg fabric]	NGEEF [m ³ /kg fabric]
PROCESS COMBUSTION SYSTEMS	Singeing hair burn-liquid dust holding chimney	430	6	140	361,200	33,947	0.76	0.07
	Old ram chimney	3,480	4	120	1,670,400	156,992	3.52	0.33
	New Ram chimney 1	3,480	5	100	1,740,000	163,534	3.66	0.34
	New Ram chimney 2	3,480	5	100	1,740,000	163,534	3.66	0.34
COMBUSTION SYSTEMS	Old evaporate boiler 320m ² chimney	10,000	4	120	4,800,000	451,128	10.11	0.95
	New evaporate boiler 400m ² chimney	12,900	6	110	8,514,000	800,188	17.92	1.68
TOTAL		33,770	30	690	18,825,600	1,769,323	39.6	3.72

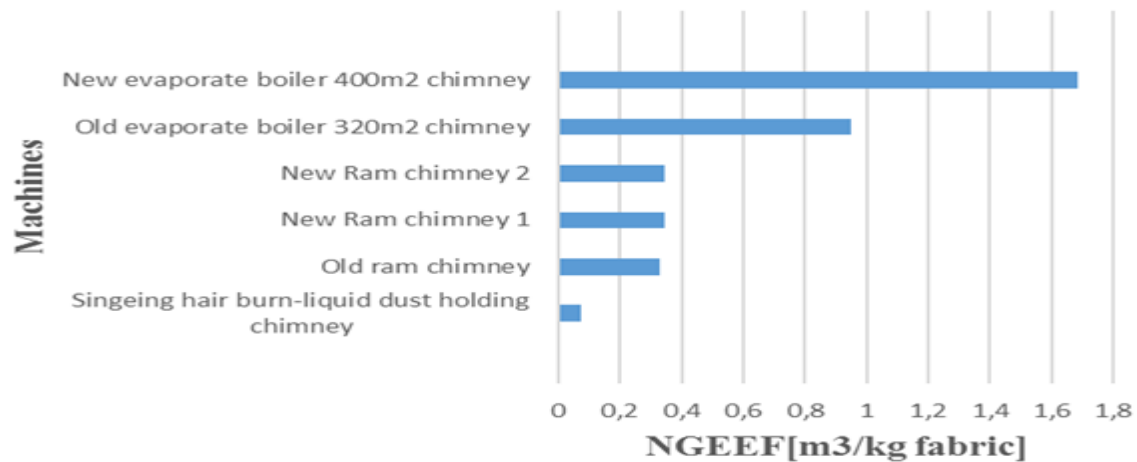


Figure 7.5 NGEEF [m³/kg fabric] in fabric production process

We consider revising created the graphic in Figure 7.5 using the data provided in Table 7.17. As can be seen from this figure, the new steam boiler has the highest natural gas energy footprint. Also, it has 8,514,000 [kWh/year] or equivalent 800,188 [m³/year] values. The firm's process burning systems and steam boiler systems consume a total of 18,825,600 [kWh/year] or 1,769,323 [m³/year] of natural gas to produce 475,000 kg of fabric. Starting with this premise, natural gas energy footprint in the fabric production is $18,825,600 \text{ [kWh/year]} / 475,000 \text{ [kg fabric/year]} = 39.6 \text{ [kWh/kg fabric]}$ or the equivalent of $1,769,323 \text{ [m³/year]} / 475,000 \text{ [kg fabric/year]} = 3.72 \text{ [m³ natural gas/kg fabric]}$.

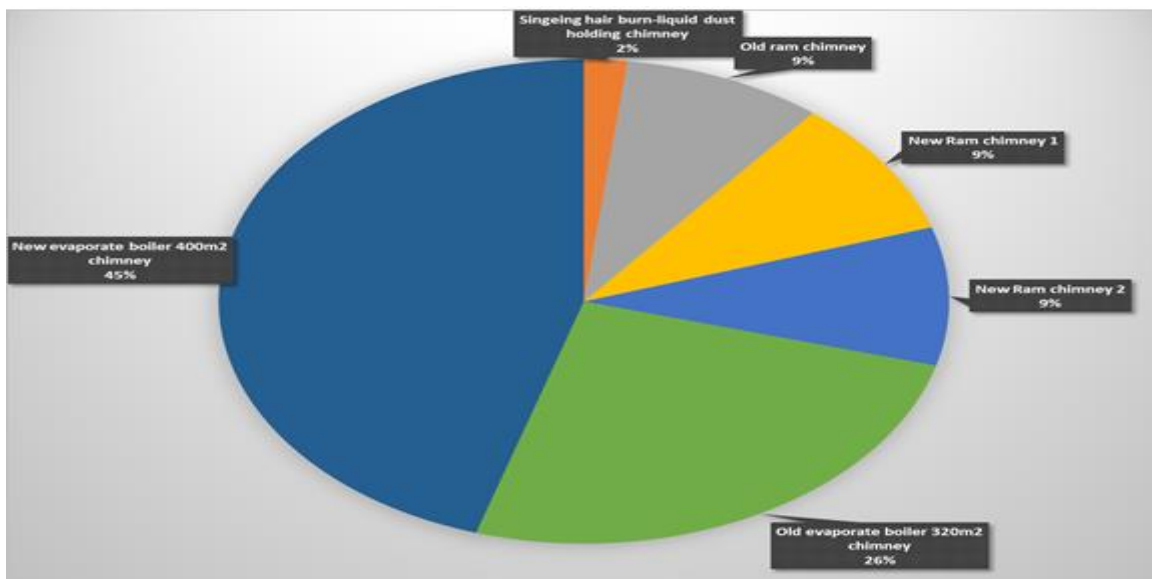


Figure 7.6 NGEEF fractions in fabric production process

Figure 7.6 gives the percentage distribution of the natural gas energy footprint values related to the fabric production according to processes used. Looking at these values, we see that the new steam boiler has the highest value at 45 percent, whereas the gas burning system has the lowest value at 2 percent.

7.1.3.2. Calculation of consumed electricity energy' energy footprint (EEEF)

We determined the number of components of the production stages using electricity energy as well as their power values (kW), daily working hours, and annual working days. The amounts of electric energy consumed by these components were calculated using Equation 45. Energy footprints related to the energy amount consumed in the processes were calculated using Equation 46. Electric energy footprint calculations are shown in detail below only for the air conditioning system. Calculation results for the components in other parts (finishing, new stove, old stove, painting, warp, boiler, compressor, doffer (comb) are shown in tables from Table 7.18 to Table 7.36.

$$\begin{aligned} \text{Consumed electricity energy [kWh/year]} = \{ & \text{Number of components} \times \text{Power of each} \\ & \text{component [kW]} \} \times \text{Daily work time [h/day]} \times \text{Annual work days} \\ & \text{[day/year]} \end{aligned} \quad (45)$$

$$\text{Consumed electricity energy [kWh/year]} = 1 \times 82 \text{ [kW]} \times 24 \text{ [h/day]} \times 280 \text{ [day/year]}$$

$$\text{Consumed electricity energy [kWh/year]} = 551,040 \text{ [kWh/year]} \text{ (for Comber)}$$

$$\text{EEEF[kWh/kg fabric]} = \{ \text{Consumed electricity energy each component[kWh/year]} / \text{Total} \\ \text{product production[kg/year]} \} \quad (46)$$

$$\text{Consumed electricity energy [kWh/year]} = 1 \times 114 \text{ [kW]} \times 24 \text{ [h/day]} \times 280 \text{ [day/year]}$$

$$\text{Consumed electricity energy [kWh/year]} = 766,080 \text{ [kWh/year]} \text{ (for Doffer)}$$

$$\text{Consumed electricity energy [kWh/year]} = 1 \times 99 \text{ [kW]} \times 24 \text{ [h/day]} \times 280 \text{ [day/year]}$$

$$\text{Consumed electricity energy [kWh/year]} = 665,280 \text{ [kWh/year]} \text{ (for Preparation)}$$

$$\text{Consumed electricity energy [kWh/year]} = 1 \times 99 \text{ [kW]} \times 24 \text{ [h/day]} \times 280 \text{ [day/year]}$$

$$\text{Consumed electricity energy [kWh/year]} = 665,280 \text{ [kWh/year]} \text{ (for Ring)}$$

$$\text{Consumed electricity energy [kWh/year]} = 1 \times 152 \text{ [kW]} \times 24 \text{ [h/day]} \times 280 \text{ [day/year]}$$

Consumed electricity energy [kWh/year] = 1,021,440 [kWh/year] **(for Inflection)**

Consumed electricity energy [kWh/year] = $1 \times 223 \text{ [kW]} \times 24 \text{ [h/day]} \times 280 \text{ [day/year]}$

Consumed electricity energy [kWh/year] = 1,498,560 [kWh/year] **(for Weaving)**

Consumed electricity energy in climates [kWh/year] = Consumed electricity energy
(comber+doffer+preparation+ring+inflection+weaving)

Consumed electricity energy in climates [kWh/year] = 551,040 + 766,080 + 665,280
+ 665,280 + 1,021,440 + 1,498,560

Consumed electricity energy in climates [kWh/year] = 5,167,680 [kWh/year]

EEEF in climates [kWh/kg fabric] = $5,167,680 \text{ [kWh/year]} / 475,000 \text{ [kg/year]}$

EEEF in climates [kWh/kg fabric] = 10.9 [kWh/kg fabric]

Table 7.18 EEEF in chemical finishing

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed electric energy [kWh/year]	EEEF [kWh/kgfabric]
FINISH, NEW STOVE	FAN	6	15	22	280	554,400	1.167
	TOP FAN MOTOR	1	11	22	280	67,760	0.143
	IN FRONT FAN MOTOR	2	2,2	22	280	27,104	0.057
	BASIC SANZUMAN	1	35	22	280	215,600	0.454
	BACK FABRIC ADJUSTING	1	0.9	22	280	5,544	0.012
	BACKCYLINDIRICAL GEARBOX	1	11	22	280	67,760	0.143
	IN FRONT FABRIC ADJUSTING	1	0.18	22	280	1,109	0.002
	IMPLEMENTATION GEARBOX MOTOR	1	0.37	22	280	2,279	0.005
FINISH OPEN WASHING	BASIC MOTOR	1	3.6	22	280	22,176	0.047
	PUMP MOTOR	1	3	22	280	18,480	0.039
	SOAP MOTOR	1	0.85	22	280	5,236	0.011
	FABRIC CONTROL MOTOR	2	0.45	22	280	5,544	0.012
FINISH, FLAME	FAN 1	1	5.5	22	280	33,880	0.071
	FAN2	1	3	22	280	18,480	0.039

Table 7.19 EEEF in chemical finishing (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed electricity energy [kWh/year]	EEEF [kWh/kg fabric]
FINISH OPEN	FABRIC OPEN MOTOR	2	0.9	22	280	11,088	0.023
	SPINNING CYLINDIRICAL	1	1	22	280	6,160	0.013
	SCRAMBLER MOTOR	1	0.55	22	280	3,388	0.007
	PASCAL MOTOR	1	1.6	22	280	9,856	0.021
FINISH CONTINUE GRAT	BASIC MOTOR	1	2.2	22	280	13,552	0.029
	PRESSING MOTOR	1	2.2	22	280	13,552	0.029
FINISH CONTINUE PRES	BACK CYLINDIRICAL	1	0.75	22	280	4,620	0.010
	BAND MOTOR	1	0.4	22	280	2,464	0.005
	WATER PUMP MOTOR	1	0.25	22	280	1,540	0.003
	FAN MOTOR	1	1.5	22	280	9,240	0.019
	BASIC MOTOR	1	7.5	22	280	46,200	0.097
	LUBRICANT PUMP MOTOR	1	5.5	22	280	33,880	0.071
	BACK PASCAL	1	0.75	22	280	4,620	0.010
FINISH DECATOR	FAN MOTOR	1	21	22	280	129,360	0.272
	TOP OPEN MOTOR	1	2.2	22	280	13,552	0.029
	BASIC MOTOR	1	14.7	22	280	90,552	0.191
	BACK PASCAL	1	0.95	22	280	5,852	0.012
FINISH CIMI	BASIC MOTOR	1	50	22	280	308,000	0.648
	GEARBOX MOTOR	1	5	22	280	30,800	0.065
	SOAP MOTOR	1	0.75	22	280	4,620	0.010
	FABRIC DISCHARGE MOTOR	1	1.5	22	280	9,240	0.019

Table 7.20 EEEF in chemical finishing (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
FINISH OLD STOVE	LOW DEPRESSING MOTOR	1	0.175	22	280	1,078	0.002
	BASIC MOTOR	1	10	22	280	61,600	0.130
	FAN MOTOR	8	8.3	22	280	409,024	0.861
	FABRIC OPEN MOTOR	2	0.3	22	280	3,696	0.008
	PUMP MOTOR	1	0.75	22	280	4,620	0.010
FINISH TMT KADE	FAN MOTOR	2	4.6	22	280	56,672	0.119
	CAR GEARBOX MOTOR	1	0.65	22	280	4,004	0.008
	CYLINDIRICAL TAMBOURING MOTOR	1	11.6	22	280	71,456	0.150
	CYLINDIRICAL ROTATING MOTOR	1	1.1	22	280	6,776	0.014
	EDGE OPEN MOTOR	1	0.75	22	280	4,620	0.010
	BACK CYLINDIRICAL MOTOR	1	1.5	22	280	9,240	0.019
FINISH SUPER	CYLINDIRICAL MOTOR	1	5.5	22	280	33,880	0.071
	BAND MOTOR	1	4.75	22	280	29,260	0.062
	DECATOR TOP MOTOR	1	12.6	22	280	77,616	0.163
	LUBRICANT PUMP MOTOR	1	5.5	22	280	33,880	0.071
	PASCAL MOTORU	1	0.75	22	280	4,620	0.010
	DECATOR DOWN MOTOR	1	3	22	280	18,480	0.039
	FEEDING MOTOR	1	0.88	22	280	5,421	0.011
	BACK PASCAL MOTOR	1	0.88	22	280	5,421	0.011

Table 7.21 EEEF in chemical finishing (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed electricity energy [kWh/year]	EEEF [kWh/kg fabric]
FINISH NEW SCISSORS	AIR MOTOR	1	15	22	280	92,400	0.195
	MOTOR 1	1	1.1	22	280	6,776	0.014
	MOTOR 2	1	1.5	22	280	9,240	0.019
	MOTOR 3	1	4	22	280	24,640	0.052
	MOTOR 4	1	4	22	280	24,640	0.052
	MOTOR 5	1	1.1	22	280	6,776	0.014
	MOTOR 6	1	1.5	22	280	9,240	0.019
	MOTOR 7	1	1.5	22	280	9,240	0.019
	MOTOR 9	2	0.17	22	280	2,094	0.004
FINISH IRON	BASIC MOTOR	1	20	22	280	123,200	0.259
FINISH OLD SCISSORS	BELOW CYLINDIRICAL MOTOR	1	2.8	22	280	17,248	0.036
	MEDIUM CYLINDIRICAL MOTOR	1	4	22	280	24,640	0.052
	TOP CYLINDIRICAL MOTOR	1	4	22	280	24,640	0.052
	AIR MOTOR	1	18.5	22	280	113,960	0.240
FINISH VAPOUR MACHINE	BACK PASCAL MOTOR	1	0.55	22	280	3,388	0.007
	FAN MOTOR	3	2.5	22	280	46,200	0.097
	BAND MOTOR	1	0.45	22	280	2,772	0.006
	BASIC MOTOR	1	0.55	22	280	3,388	0.007
FINISH PACKING	BASIC RIGHT MOTOR	1	5	22	280	30,800	0.065
	BASIC LEFT MOTOR	1	5	22	280	30,800	0.065
	TRACK MOTOR	1	0.5	22	280	3,080	0.006
	FAN MOTOR	1	0.5	22	280	3,080	0.006

Table 7.22 EEEF in chemical finishing (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
FINISH PACKING SYSTEM	MOTOR	48	0.25	22	280	73,920	0.156
	TRACK MOTOR	1	0.5	22	280	3,080	0.006
	FAN MOTOR	1	0.5	22	280	3,080	0.006
FINISH KGM	VACUUM MOTOR	1	11	22	280	67,760	0.143
	FAN MOTOR	1	0.55	22	280	3,388	0.007
FINISH OBEM	VACUUM MOTOR	1	18.5	22	280	113,960	0.240
	FAN MOTOR	1	0.55	22	280	3,388	0.007
TOTAL						3,519,670	7.410

Table 7.23 EEEF in finish new stove

Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed electricity energy [kWh/year]	EEEF [kWh/kg fabric]
FLAR MOTOR	1	18.5	22	280	113,960	0.240
ENTER OPEN MOTOR	1	0.75	22	280	4,620	0.010
OPENER MOTOR	1	0.37	22	280	2,279	0.005
PRESS MOTOR	2	0.75	22	280	9,240	0.019
EDGE OPENER MOTOR	2	0.18	22	280	2,218	0.005
FEEDING CYLINDIRICAL MOTOR	1	9	22	280	55,440	0.117
MAHLO CYLINDIRICAL MOTOR	1	4	22	280	24,640	0.052
MAHLO CORRECTION MOTOR	1	0.37	22	280	2,279	0.005
PASTAL MOTOR	1	3	22	280	18,480	0.039
ENTER EN OPENER MOTOR	1	0.18	22	280	1,109	0.002
OUTLET EN OPENER MOTOR	1	0.37	22	280	2,279	0.005
MACHINE OPENER MOTOR	2	0.75	22	280	9,240	0.019
COOLING CYLINDIRICAL MOTOR	1	4	22	280	24,640	0.052
BASIC MOTOR	1	22	22	280	135,520	0.285
COOLING MOTOR	2	2.2	22	280	27,104	0.057
FAN MOTOR (Double cycle)	6	0.3	22	280	11,088	0.023
BURNER MOTOR	12	0.55	22	280	40,656	0.086
CHIMNEY MOTOR	1	11	22	280	67,760	0.143
CHIMNEY MOTOR	1	1.5	22	280	9,240	0.019
FABRIC OPENER (DC) MOTOR	2	0.38	22	280	4,682	0.010
OUTLET FEEDING MOTOR	1	2.2	22	280	13,552	0.029
MAHLO OPENER MOTOR	1	0.37	22	280	2,279	0.005
TOTAL					582,305	1.226

Table 7.24 EEEF in finish old stove

Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [kWh/year]	EEEF[kWh/kg fabric]
FLAR MOTOR	1	25	15	280	105,000	0.2211
ENTER OPENER MOTOR	1	0.75	15	280	3,150	0.0066
OPENER MOTOR	1	0.55	15	280	2,310	0.0049
PRINT MOTOR	2	0.37	15	280	3,108	0.0065
BORDER OPENER MOTOR	2	0.18	15	280	1,512	0.0032
IN FRONT OF –BACK FEEDING MOTOR	2	5.5	15	280	46,200	0.0973
ENTER EXHAUSTIVE OPENER MOTOR	1	0.18	15	280	756	0.0016
OUTLET EXHAUSTIVE OPENER MOTOR	1	0.37	15	280	1,554	0.0033
MACHINE INSIDE OPEN MOTOR	2	0.75	15	280	6,300	0.0133
MAIN MOTOR	1	35	15	280	147,000	0.3095
COOLING MOTOR	2	2.2	15	280	18,480	0.0389
FAN MOTOR (double cycle)	6	0.33	15	280	8,316	0.0175
BRULOR MOTOR	12	0.25	15	280	12,600	0.0265
CHIMNEY MOTOR	1	11	15	280	46,200	0.0973
FABRIC OPENER (DC) MOTOR	2	0.38	15	280	3,192	0.0067
MAHLO OPENER MOTOR	1	0.37	15	280	1,554	0.0033
TOTAL					407,232	0.8573

Table 7.25 EEEF in dyeing

Part	Name of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
MINOX 1	BASIC MOTOR	1	37	15	280	155,400	0.327
	PUMP MOTOR	1	3	15	280	12,600	0.027
MINOX 2	BASIC MOTOR	1	37	15	280	155,400	0.327
	PUMP MOTOR	1	3	15	280	12,600	0.027
BOMS BOILER	BASIC MOTOR	2	22	15	280	184,800	0.389
	PUMP MOTOR	1	3	15	280	12,600	0.027
	RESERVE BASIN MIXER MOTOR	1	2.5	15	280	10,500	0.022
ALARKO BOILER	BASIC MOTOR	1	22	15	280	92,400	0.195
	PUMP MOTOR	1	5	15	280	21,000	0.044
BELLINI BOBIN DYE	BASIC MOTOR	1	59	15	280	247,800	0.522
	RESERVE BASIN WATER PUMP	1	6	15	280	25,200	0.053
	PUMP MOTOR	1	5.5	15	280	23,100	0.049
	DYE MIXER MOTOR	1	0.45	15	280	1,890	0.004
SMALL BELLINI DYE	BASIC MOTOR	1	24	15	280	100,800	0.212
	PUMP MOTOR	1	5.5	15	280	23,100	0.049
	RESERVE BASIN WATER PUMP	1	2.2	15	280	9,240	0.019
	DYE MIXER MOTOR	1	0.45	15	280	1,890	0.004

Table 7.26 EEEF in dyeing (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [KWh/year]	EEEF [kWh/kg fabric]
SAMPLE BOBIN DYE	BASIC MOTOR	1	3	15	280	12,600	0.027
	PUMP MOTOR	1	1.5	15	280	6,300	0.013
QUINTETTE BOBIN DYEING	PUMP MOTOR	1	1.5	15	280	6,300	0.013
	BASIC MOTOR	1	4	15	280	16,800	0.035
SANDREVIC 1	MAIN MOTOR	1	22	15	280	92,400	0.195
SANDREVIC 2	BASIC MOTOR	1	20	15	280	84,000	0.177
FIBRILLA PRESS	BELOW BASIC MOTOR	1	1.5	15	280	6,300	0.013
FIBRILLA DRYING STOVE	FLASH FEEDING MOTOR	1	0.55	15	280	2,310	0.005
	FAN MOTOR	2	18.5	15	280	155,400	0.327
	FLASH MOTOR	1	3	15	280	12,600	0.027
	GEARBOX MOTOR	1	2.2	15	280	9,240	0.019
	THUMBLER CONVERTING MOTOR	1	2.2	15	280	9,240	0.019
	FIBRILLA PRINTING PRESS	1	3	15	280	12,600	0.027
BROZZOLI FABRIC DYE	HASBEL MOTOR	6	1.5	15	280	37,800	0.080
	BASIC MOTOR	2	30	15	280	252,000	0.531
	PUMP MOTOR	2	1.5	15	280	12,600	0.027
	FABRIC SUBTRACTION MOTOR	2	1.3	15	280	10,920	0.023
	DYE MIXER MOTOR	1	1.1	15	280	4,620	0.010
BOBIN DRYING	BAND MOTOR	1	0.18	15	280	756	0.002
	FAN MOTOR	2	1.75	15	280	14,700	0.031
	CONVERTING CONTINUE FAN MOTOR	1	2.2	15	280	9,240	0.019
	CONVERTING CONTINUE MOTOR	1	2	15	280	8,400	0.018
	HEAT ADJUSTMENT MOTOR	1	0.55	15	280	2,310	0.005

Table 7.27 EEEF in dyeing (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
BERTA 24 TE	LUBRICANT HYDROLIC MOTOR	1	0.75	15	280	3,150	0.007
	BASIC MOTOR	2	7.5	15	280	63,000	0.133
	BOBIN MASURA CONVERTING MOTOR	1	0.9	15	280	3,780	0.008
OTACLON	BASIC MOTOR	1	11	15	280	46,200	0.097
FIGURE	BASIC MOTOR	1	2	15	280	8,400	0.018
	MIXER MOTOR	2	0.55	15	280	4,620	0.010
THIES 2 KAFA	BASIC MOTOR	1	22	15	280	92,400	0.195
	PUMP MOTOR	1	1,5	15	280	6,300	0.013
	HASBEL MOTOR	2	2.2	15	280	18,480	0.039
THIES 1 KAFA	BASIC MOTOR	1	11	15	280	46,200	0.097
	PUMP MOTOR	1	1.5	15	280	6,300	0.013
	HASBEL MOTORU	1	2.2	15	280	9,240	0.019
SAMPLE FABRIC DYE	HASBEL MOTOR	1	1.3	15	280	5,460	0.011
	PUMP MOTOR	1	1.25	15	280	5,250	0.011
	BASIC MOTOR	1	3	15	280	12,600	0.027
SAMPLE FABRIC DYE SMALL	BASIC MOTOR	1	1.25	15	280	5,250	0.011
	HASBEL MOTOR	1	1.1	15	280	4,620	0.010

Table 7.28 EEEF in dyeing (Continue)

Part	Name of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
ILMA LIZOZ	CONVERTING CONTINUE MOTOR	4	1	15	280	16,800	0.035
	FAN MOTOR	2	10	15	280	84,000	0.177
	THUMBLER CONVERTING MOTOR	1	2	15	280	8,400	0.018
FLEISSNER LIZOZ	FAN MOTOR	2	7.5	15	280	63,000	0.133
	CYLINDIRICAL GEARBOX MOTOR	1	7.5	15	280	31,500	0.066
	CONVERTING CONTINUE MOTOR	3	1.1	15	280	13,860	0.029
SPINNING	AIR MOTOR	1	0.75	15	280	3,150	0.007
	LUBRICANT MOTOR	1	0.55	15	280	2,310	0.005
	BASIC MOTOR	1	2.5	15	280	10,500	0.022
TOTAL						2,444,526	5.146

Table 7.29 EEEF in warping

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
OLD BENINGER	BASIC MOTOR	1	7.5	15	280	31,500	0.066
	PEDAL MOVEMENT MOTOR	1	0.37	15	280	1,554	0.003
	BRAKE MOTOR	1	0.18	15	280	756	0.002
	TURN MOTOR	1	0.13	15	280	546	0.001
	SPORT MOTOR	1	0.13	15	280	546	0.001
	LUBRICANT MOTOR	1	0.73	15	280	3,066	0.006
	LUBRIFACTION MOTOR	1	1.5	15	280	6,300	0.013
HACOBIA 1-2	TAMBOUR MOTOR	2	4	15	280	33,600	0.071
	BASIC MOTOR	2	17	15	280	142,800	0.301
	TREKKING MOTOR	2	0.12	15	280	1,008	0.002
	AIR MOTOR	2	0.42	15	280	3,528	0.007
SUPERTRONIC	BASIC MOTOR	1	13	15	280	54,600	0.115
	WARPING-PACKING	1	13	15	280	54,600	0.115
	COOLING MOTOR	1	0.75	15	280	3,150	0.007
	COMBER OPENER MOTOR	1	0.17	15	280	714	0.002
	AIR MOTOR	2	0.55	15	280	4,620	0.010
	TREKKING MOTOR	1	2.4	15	280	10,080	0.021
	MOTOR	1	0.25	15	280	1,050	0.002
	LUBRICANT MOTOR	1	0.73	15	280	3,066	0.006

Table 7.30 EEEF in warping (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
CONVOLUTION	AIR MOTOR	1	1.1	15	280	4,620	0.010
	MASURA MOTOR	80	0.12	15	280	40,320	0.085
	BAND MOTOR	1	1.1	15	280	4,620	0.010
	TREKKING MOTOR	1	0.15	15	280	630	0.001
	AIR MOTOR	1	0.15	15	280	630	0.001
	STARBOARD MOTOR	1	0.12	15	280	504	0.001
BRUSH	CYLINDIRICAL MOTOR	1	0.75	15	280	3,150	0.007
	BASIC MOTOR	1	3	15	280	12,600	0.027
	AIR MOTOR	1	3	15	280	12,600	0.027
TOTAL						436,758	0.919

Table 7.31 EEEF in boiler room

Part	Name of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
BOILER ROOM	2 numbered boiler feeding pump	1	18.5	15	280	77,700	0.164
	Verticular pump	1	11	15	280	46,200	0.097
	1numbered boiler feeding pump	2	11	15	280	92,400	0.195
	SALT PUMP	1	3	15	280	12,600	0.027
	Raw Water Hydraphor Pumps	3	22	15	280	277,200	0.584
	Soft Water Hydraphor Pumps	3	22	15	280	277,200	0.584
	Degasifier Feeding Pump	2	18	15	280	151,200	0.318
	Raw Water Hydrophore Pump	1	15	16	280	67,200	0.141
	Soft Water Hydrophore Pump	1	15	14	280	58,800	0.124
	Salt Water Pump	1	3	2	280	1,680	0.004
	Degasifier Pump	1	3	8	280	6,720	0.014
	Hardness Test Pump	1	11	24	280	73,920	0.156
	Boiler Burner Fan	1	30	24	280	201,600	0.424
TOTAL						1,344,420	2.830

Table 7.32 EEEF in climates

Part	Unit	Power (kW)	Daily Work Time (hour/day)	Annual Work Day (day/year)	Consumed Electricity Energy (kWh/year)	EEEF [kWh/kg fabric]
COMBER	1	82	24	280	551,040	1.2
DOFFER	1	114	24	280	766,080	1.6
PREPARATION	1	99	24	280	665,280	1.4
RING	1	99	24	280	665,280	1.4
INFLECTION	1	152	24	280	1,021,440	2.2
WEAVING	1	223	24	280	1,498,560	3.2
TOTAL					5,167,680	10.9

Table 7.33 EEEF in compressors

Part	Name of Power Engine	Unit	Power(kW)	Daily Work Time (hour/day)	Annual Work Day (day/year)	Consumed Electricity Energy (kWh/year)	EEEF [kWh/kg fabric]
COMPRESSOR	ECO COMPRESSOR	0.40	45	15	280	189,000	0.40
	INGERSOLL-RAN	1.11	63	15	280	529,200	1.11
TOTAL						718,200	1.51

Table 7.34 EEEF in doffer room

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Days [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
NEW ITALIAN	BASIC MOTOR	1	2.5	15	280	10,500	0.022
	AIR MOTOR	1	2.2	15	280	9,240	0.019
OLD ITALIAN	BASIC MOTOR	1	1.4	15	280	5,880	0.012
	AIR MOTOR	1	0.85	15	280	3,570	0.008
GC 13	BASIC MOTOR	1	8.5	15	280	35,700	0.075
	AIR MOTOR	1	2.5	15	280	10,500	0.022
	TEAM MOTOR	1	0.55	15	280	2,310	0.005
GN 5 PULLING	BASIC MOTOR	1	3	15	280	12,600	0.027
	AIR MOTOR	1	0.75	15	280	3,150	0.007
MENENJOR	BASIC MOTOR	1	15	15	280	63,000	0.133
	AIR MOTOR	1	2.4	15	280	10,080	0.021
	LUBRICANT MOTOR	1	0.55	15	280	2,310	0.005
	BACK CYLINDIRICAL AIR MOTOR	1	0.75	15	280	3,150	0.007
	IN FRONT CYLINDIRICAL AIR MOTOR	1	0.55	15	280	2,310	0.005
GC 13 DUPLEXING	BASIC MOTOR	1	8.5	15	280	35,700	0.075
	AIR MOTORU	1	2.5	15	280	10,500	0.022
	TEAM MOTOR	1	0.55	15	280	2,310	0.005
	LUBRICANT MOTOR	1	0.55	15	280	2,310	0.005
PRESS	LUBRICANT PUMP MOTOR	1	5.5	15	280	23,100	0.049

Table 7.35 EEEF in doffer room (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [h/day]	Annual Work Day [day/year]	Consumed Electricity Energy [KWh/year]	EEEF [kWh/kg fabric]
GC 12 TOPS	BASIC MOTOR	1	6.5	15	280	27,300	0.057
	AIR MOTOR	1	1.5	15	280	6,300	0.013
	LUBRICANT MOTOR	1	0.55	15	280	2,310	0.005
GN 5 TOPS	AIR MOTOR	1	0.75	15	280	3,150	0.007
COMBERS	SAWMILL 1	1	1.5	15	280	6,300	0.013
	SAWMILL 2	1	1.5	15	280	6,300	0.013
	WASTE MORAL 1	1	1	15	280	4,200	0.009
	WASTE MORAL 2	1	0.85	15	280	3,570	0.008
	BASIC MOTOR	1	15	15	280	63,000	0.133
GC15 TOPS PULLING	BASIC MOTOR	1	7,5	15	280	31,500	0.066
	AIR MOTOR	1	2.5	15	280	10,500	0.022
GC15 TWO HEADED	BASIC MOTOR	1	8.5	15	280	35,700	0.075
	AIR MOTOR	1	3	15	280	12,600	0.027
	CYLINDIRICAL AIR ABSORBENT MOTOR	1	0.75	15	280	3,150	0.007
GC15 REGULATOR	BASIC MOTOR	1	8.5	15	280	35,700	0.075
	AIR MOTOR	1	2.4	15	280	10,080	0.021
	CYLINDIRICAL AIR ABSORBENT MOTOR	1	0.75	15	280	3,150	0.007

Table 7.36 EEEF in doffer room (Continue)

Part	Name Of Power Engine	Unit	Power [kW]	Daily Work Time [hour/day]	Annual Work Day [day/year]	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
NEW FINISAR	BASIC MOTOR	1	18.5	15	280	77,700	0.164
	AIR MOTOR	1	9	15	280	37,800	0.080
	M9 MOTOR	1	2	15	280	8,400	0.018
	M11 MOTOR	1	0.37	15	280	1,554	0.003
	M22 MOTOR	1	0.75	15	280	3,150	0.007
	M24 MOTOR	1	0.55	15	280	2,310	0.005
	M25 MOTOR	1	0.5	15	280	2,100	0.004
NSC DOFFER	BASIC MOTOR	1	3.15	15	280	13,230	0.028
	AIR MOTOR	1	1.5	15	280	6,300	0.013
GV20 4 HEADED	BASIC MOTOR	1	11	15	280	46,200	0.097
	AIR MOTOR	1	2.2	15	280	9,240	0.019
TOTAL						721014	1.518

Table 7.37 summarizes the values given on the tables from 7.18-7.36 as well as the total electricity energy consumption values and energy footprint values for different processes. We consider revising created the graphic in Figure 7.7 using the data provided in this table. As can be seen from this figure, the conditioning equipment has the highest energy footprint with the 10.9 [kWh/kg fabric] value. The firm consumes a total of 20,455,740 [kWh/year] electricity energy for the production of 475,000 [kg] of fabric. Starting with this premise, electricity energy footprint in the fabric production is $20,455,740 \text{ [kWh/year]} / 475,000 \text{ [kg fabric/year]} = 43.1 \text{ [kWh/kg fabric]}$.

Table 7.37 Energy footprint (EEEF) from electricity consumption

Process	Consumed Electricity Energy [kWh/year]	EEEF [kWh/kg fabric]
Chemical finishing	3,519,670	7.4
Finish new stove	582,305	1.2
Finish old stove	407,232	0.9
Dyeing	2,444,526	5.1
Warping	436,758	0.9
Boiler room	1,344,420	2.8
Climates	5,167,680	10.9
Compressors	718,200	1.5
Doffer room	721,014	1.5
Offices+treatment	5,113,935	10.8
TOTAL	20,455,740	43.1

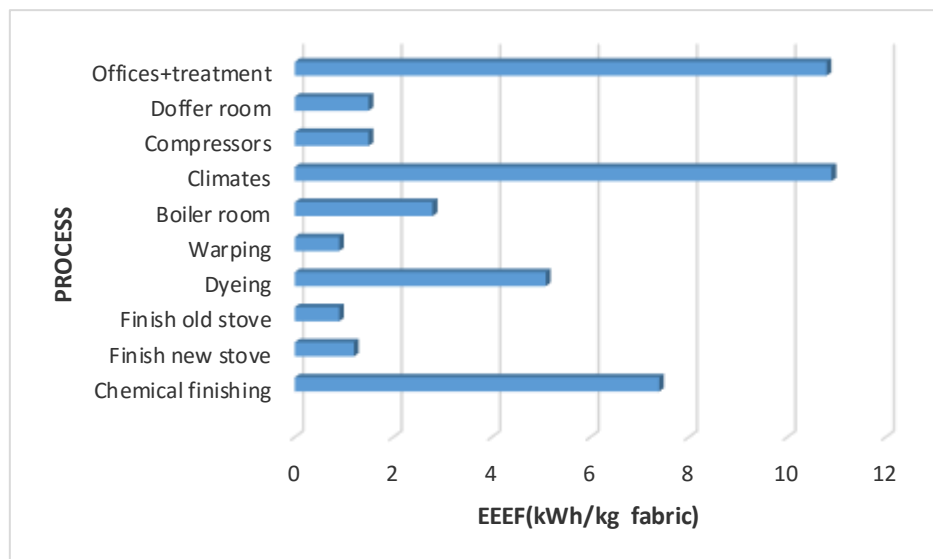


Figure 7.7 EEEF [kWh/kg fabric] in fabric production processes

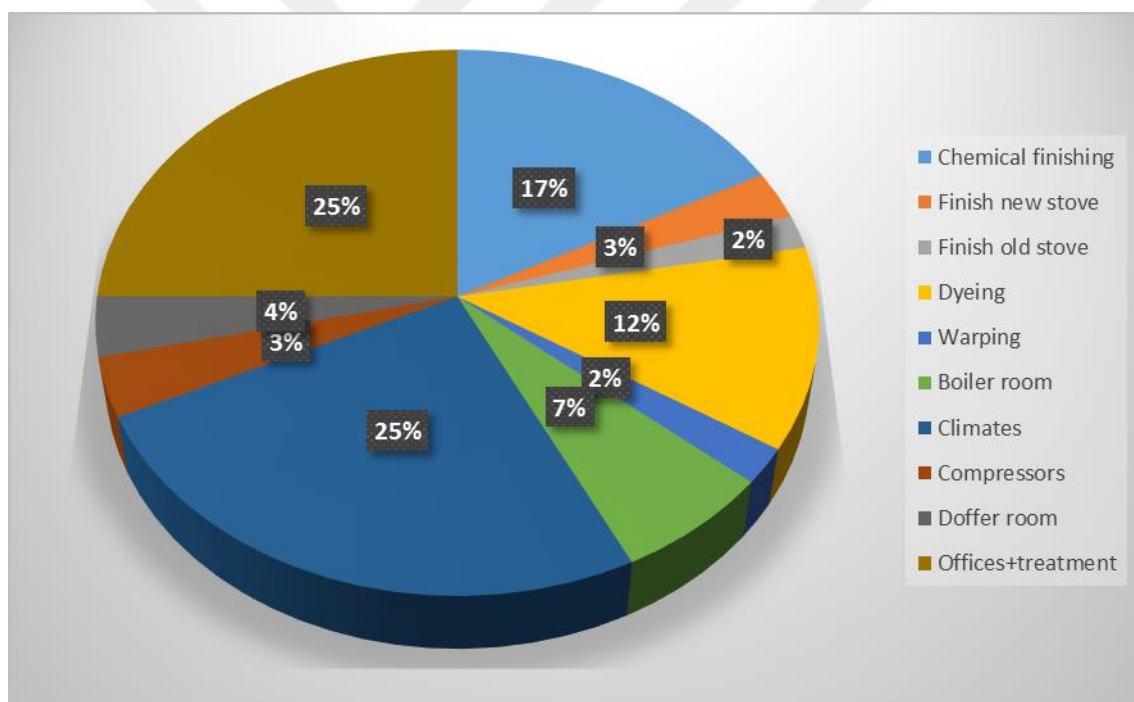


Figure 7. 8 EEEF fractions in fabric production process

Figure 7.8 gives the percentage distribution of the electricity energy footprint values related to the fabric production according to processes used. Looking at these values, we consider revising possibly “ it is clear that see that conditioning equipment has the highest value at 25 percent, whereas the finishing, old stove, and warping system has the lowest value at 2 percent”.

The energy footprint values for all the equipment used in the production stages are given in Table 7.38.

Table 7.38 Energy footprint from all of the equipments' consumption

Machines	NEEF [kWh/kg fabric]	EEEF [kWh/kg fabric]
Singeing hair burn liquid dust holding	0.76	-
Old Ram Chimney (Finish old stove)	3.52	0.9
New Ram Chimney (Finish new stove)	7.32	1.2
Boiler room (Old evaporate boiler 320 m ² chimney + New evaporate boiler 400 m ² chimney)	28.03	2.8
Chemical finishing	-	7.4
Dyeing	-	5.1
Warping	-	0.9
Climate parts	-	10.9
Compressor	-	1.5
Doffer room	-	1.5
Offices+treatment	-	10.8

Table 7.39 Classification of Energy Footprint in fabric production processes (Adapted Jürgen Ströhle Url-59)

Process/Consumer	Energy Sources	Energy Footprint
Singeing hair burn liquid dust holding	Natural gas	Very low
Old Ram Chimney (Finish old stove)	Natural gas, electricity	Middle
New Ram Chimney (Finish new stove)	Natural gas, electricity	High
Boiler room (Old evaporate boiler 320 m ² chimney + New evaporate boiler 400 m ² chimney)	Natural gas, electricity	Very high
Chemical finishing	Electricity	High
Dyeing	Electricity	Middle
Warping	Electricity	Very low
Climate parts	Electricity	High
Compressor	Electricity	Low
Doffer room	Electricity	Low
Offices+treatment	Electricity	High

The calculated energy footprint values were evaluated in Table 7.39 as "very high," "high," "medium," "low," and "very low" in terms of energy efficiency. The boiler room is in the "very high" category in terms of energy footprint and energy consumption. This boiler room included in the "very high" category covers both the old steam boiler and the new steam boiler. The gas process is in the "very low" category in the energy footprint comparison.

7.1.3.3. Calculation of energy footprint due to raw fiber production

The energy footprint resulting from the production of wool and polyester fiber raw materials (raw material inputs in the factory) were taken as 11 kWh fiber (Url-65) and 16.5 [kWh/kg-fiber] (DEPA,1997). Considering that the factory uses 450 tons of wool fiber and 150 tons of polyester fiber, the energy footprint value resulting from the used fiber raw material should be taken as 12.38 [kWh/kg-fiber]. However, 475 tons of product corresponds to the use of 600 tons of fiber raw materials in the factory which means the use of 1.26 kg of fiber per one kilogram of fabric and the corresponding energy footprint was taken as 15.6 [kg kWh/kg fabric].

7.1.4. Calculation of energy footprint in transportation

The examined plant emits carbon dioxide emissions as a result of the production-related transportation activities. In the calculation of the transportation-related energy footprint, the following factors were considered: raw materials and products transported, the forklifts used for their transportation within the company, and the transfer of employees to/from the factory by shuttle. In this calculation, transportation-related energy footprints are examined in four parts:

7.1.4.1. Calculation of energy footprint in the raw material of transportation (RMTEF)

As demonstrated in Table 7.40, the total amount of fuel consumed was 30.097 liters, while the energy footprint resulting from raw material transportation was found to be 0.7 kWh per 1 kg of fabric production. The amount of fuel consumed was calculated with Equation 47 as unit kWh from L. As a result, energy footprint was calculated with the Equation 48.

In this case, the energy footprint resulting from the transport of wool raw materials from France to Istanbul by trailer truck is calculated with the Equation 48 Other calculations were made in a similar fashion. The Equations 47 and 48 were used in the calculation.

Note: $1\text{MJ}=10^6\text{ J}$; 1liter diesel=38.7 MJ/L; $1\text{kWh}= 3,600,000\text{ J}$ (Url-66; Url-67)

$$\text{Consumed fuel [kWh]} = \text{Consumed fuel [L]} * \text{Fuel' calorific value [MJ/L]} \quad (47)$$

$$* [10^6 \text{J}/1 \text{MJ}] * [1 \text{kWh}/3,600,000 \text{J}]$$

$$\text{Consumed fuel [kWh]} = 14,872 \text{ [L]} * 38.7 \text{ [MJ/L]} * [10^6 \text{J}/1 \text{MJ}] * [1 \text{kWh}/3,600,000 \text{J}]$$

$$\text{Consumed fuel [kWh]} = 159,874 \text{ [kWh]}$$

$$\text{EF[kWh/kg fabric]} = \text{Consumed fuel [kWh]} / \text{Total annual product [kg fabric]} \quad (48)$$

$$\text{RMTEF [kWh/kg fabric]} = 159,874 \text{ [kWh]} / 475,000 \text{ [kg fabric]}$$

$$\text{RMTEF [kWh/kg fabric]} = 0.34 \text{ [kWh/kg fabric]}$$

Table 7.40 EF [kWh/kg fabric] in raw materials transportation (RMTEF)

Country of origin	Way of Transport	Number of transportation	Raw material	Raw material[tons]	Type of fuel	Consumed fuel [liters]	Consumed fuel [kWh]	RMTEF[kWh/kg fabric]
Argentina	Ship	1	Wool	150	diesel oil	5,357	57,588	0.12
	Trailer truck	8				288	3,096	0.006
China	Ship	1	Wool	300		9,040	97,180	0.2
	Trailer truck	15				540	5,805	0.012
France	Trailer truck	15	Polyester	150		14,872	159,874	0.34
TOTAL		40	Wool+ Polyester	600		30,097	323,543	0.7

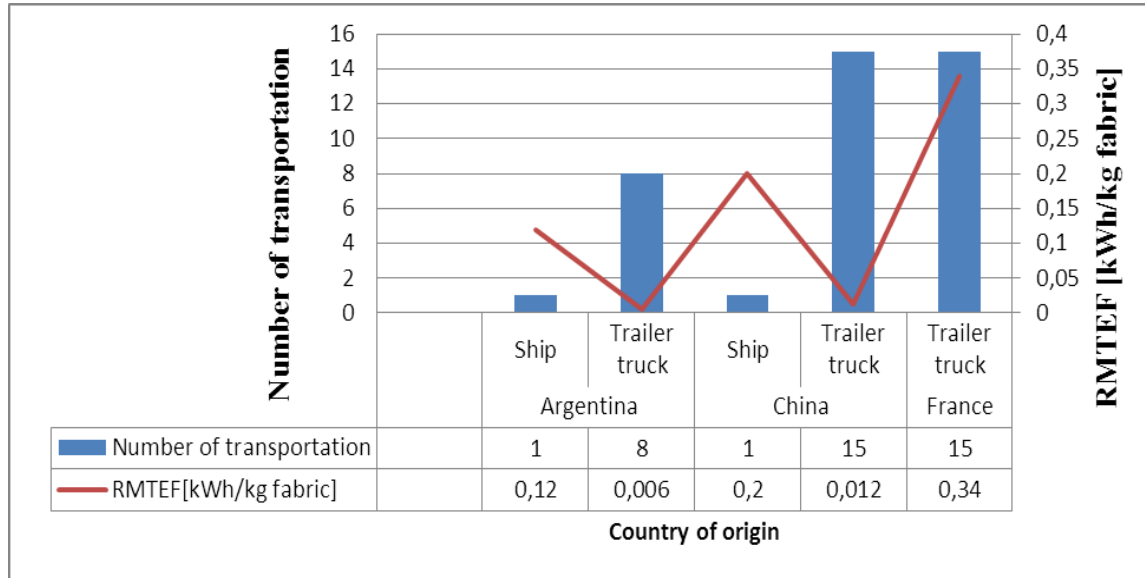


Figure 7. 9 EF [kWh/kg fabric] in raw material transportation (RMTEF)

Figure 7.9 shows the distribution of energy footprint by country in relation to raw material transportation. Fabric production takes place with the raw materials (polyester, wool) brought from Argentina, China and France to the fabric factory. Raw materials from Argentina and China are transported to the fabric factory by ships and then trucks. The annual energy footprint resulting from the transportation of raw materials from Argentina to the customs by one container ship is 0.12 kWh/kg fabric per the production of 1 kg fabric while the annual energy footprint resulting from its transportation from the customs by eight trucks is 0.0065kWh per the production of 1 kg of fabric. The annual energy footprint resulting from the transportation of raw materials from China to the customs by one container ship is 0.204 kWh per 1 kg of fabric, while the annual energy footprint resulting from its transportation from the customs by eight trucks is 0.012 kWh per 1 kg of fabric. 15 trucks were used for the transportation of the raw materials originating from France, and the annual energy footprint was calculated as 0.336 kWh per 1 kg of fabric. By comparison, we observe the highest amount of energy footprint in the transportation of 150 tons of polyester raw material from France to the fabric factory in Istanbul.

7.1.4.2. Calculation of energy footprint in the product of transportation (PTEF)

As demonstrated in Table 7.41, the total amount of fuel consumed was 36741 liters, while the energy footprint resulting from product transportation was found to be 0.8 kWh per kg of fabric production. The amount of fuel consumed was calculated with Equation 47 as unit kWh from L. As a result, energy footprint was calculated with the Equation 48. In this case, the energy footprint resulting from the transport of wool raw materials from Istanbul to Germany by trailer truck is calculated with the Equation 48. Other calculations were made in a similar fashion. The Equations 47 and 48 were used in the calculation.

$$\text{Consumed fuel [kWh]} = \text{Consumed fuel [L]} * \text{Fuel' calorific value [MJ/L]} \\ * [10^6 \text{J/1MJ}] * [1 \text{kWh/3,600,000J}]$$

$$\text{Consumed fuel [kWh]} = 16,733 \text{ [L]} * 38.7 \text{ [MJ/L]} * [10^6 \text{J/1 MJ}] * [1 \text{kWh/3,600,000J}]$$

$$\text{Consumed fuel [kWh]} = 179,880 \text{ [kWh]}$$

$$\text{EF[kWh/kg fabric]} = \text{Consumed fuel [kWh]} / \text{Total annual product [kg fabric]}$$

$$\text{PTEF[kWh/kg fabric]} = 179,880 \text{ [kWh]} / 475,000 \text{ [kg fabric]}$$

$$\text{PTEF[kWh/kg fabric]} = 0.38 \text{ [kWh/kg fabric]}$$

Table 7.41 EF [kWh/kg fabric] in product of transportation (PTEF)

Country of origin	Way of Transport	Number of transportation	Product	Fabric [kg]	Fabric [tonne]	Types of fuel	Consumed fuel [liters]	Consumed fuel [kWh]	PTEF[kWh/kg fabric]
Germany	Trailer truck	20	Fabric	250,000	250	diesel oil	16733	179,880	0.38
Japan	Trailer truck	10		100,000	100		360	3,870	0.008
	Ship	2					8036	86,387	0.18
France	Trailer truck	12		125,000	125		11612	124,829	0.26
TOTAL		44		475,000	475		36741	394,966	0.8

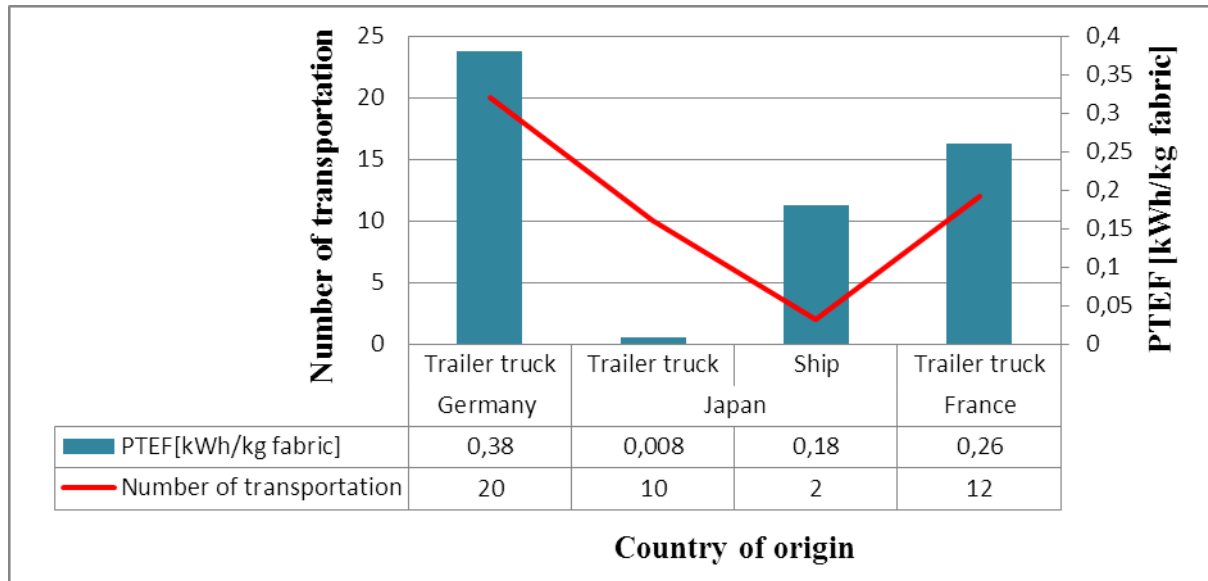


Figure 7.10 EF [kWh/kg fabric] in product of transportation (PTEF)

Figure 7.10 shows the distribution of carbon footprint by country in relation to product shipment. The fabric produced is transported to Germany, Japan, and France. The annual energy footprint resulting from the shipment to Germany with 20 trailer trucks was calculated as 0.378 kWh per 1 kg of fabric. 10 trailer trucks and 2 ships were used for shipping fabrics to Japan. The annual energy footprint resulting from the shipment to Japan is as such: 0.008 kWh per 1 kg of fabric resulting from taking the product to the customs by trailer trucks, and 0.181 kWh per 1 kg of fabric resulting from its shipment from the customs to the customs in Japan by two ships. 12 trucks were used for the transportation of the products to France, and the resulting annual energy footprint was calculated as 0.26kWh per 1 kg of fabric. As can be seen in Figure 7.10, the biggest amount of energy footprint results from the shipment of fabrics to Germany.

7.1.4.3. Calculation of energy footprint in using forklift of transportation (FEF)

The energy footprint resulting from forklift use was calculated with the use of Equations 47 and 48 in below:

$$\text{Consumed fuel in forklift [kWh]} = \text{Consumed fuel [L]} * \text{Fuel' calorific value [MJ/L]} \\ * [10^6\text{J}/1 \text{ MJ}] * [1\text{kWh}/3,600,000\text{J}]$$

$$\text{Consumed fuel in forklift [kWh]} = 24,390[\text{L}] * 38.7 [\text{MJ/L}]$$

$$* [10^6\text{J}/1 \text{ MJ}] * [1\text{kWh}/3,600,000\text{J}] = 262,193 [\text{kWh}]$$

$$\text{EF[kWh/kg fabric]} = \text{Consumed fuel [kWh]} / \text{Total annual product [kg fabric]}$$

$$\text{FEF[kWh/kg fabric]} = 262,193[\text{kWh}] / 475,000 [\text{kg fabric}]$$

$$\text{FEF[kWh/kg fabric]} = 0.6 [\text{kWh/kg fabric}]$$

The forklift's energy footprint was calculated and provided in Table 7.42.

Table 7.42 EF [kWh/kg fabric] in using forklift of transportation (FEF)

Transportation	Consumed fuel [tonne]	Consumed fuel [kg]	Consumed fuel [liters]	Consumed fuel [kWh]	FEF [kWh/kg fabric]
Forklift	20	20,000	24,390	262,193	0.6

7.1.4.4. Calculation of energy footprint in personnel services of transportation (SEF)

The energy footprint resulting from services use was calculated with the use of Equations 47 and 48 in below:

$$\text{Consumed fuel [kWh]} = \text{Consumed fuel [L]} * \text{Fuel' calorific value [MJ/L]}$$

$$* [10^6\text{J}/1 \text{ MJ}] * [1\text{kWh}/3,600,000\text{J}]$$

$$\text{Consumed fuel in services [kWh]} = 167,832 [\text{L}] * 38.7 [\text{MJ/L}] * [10^6\text{J}/1\text{MJ}]$$

$$* [1\text{kWh}/3,600,000\text{J}]$$

$$\text{Consumed fuel in services [kWh]} = 1,804,194 [\text{kWh}]$$

$$\text{EF[kWh/kg fabric]} = \text{Consumed fuel [kWh]} / \text{Total annual product [kg fabric]}$$

$$\text{SEF[kWh/kg fabric]} = 1,804,194 [\text{kWh}] / 475,000 [\text{kg fabric}]$$

$$\text{SEF[kWh/kg fabric]} = 3.8 [\text{kWh/kg fabric}]$$

The annual fuel consumption of the 45 staff shuttles serving the plant is 167,832 liters or 1,804,194 kWh. The staff's annual fabric production is 475,000 kg.

The annual energy footprint for 475,000 kg of fabric produced after the annual fuel consumption of these shuttles used for the transportation of the staff amounts 3.8 kWh per 1 kg of fabric. The services' energy footprint was calculated and provided in Table 7.43.

Table 7.43 EF [kWh/kg fabric] in personnel services of transportation (SEF)

Transportation	Consumed fuel[liters]	Consumed fuel[kWh]	SEF [kWh/kg fabric]
Services	167,832	1,804,194	3.8

7.2. Determination of Problems about Footprints with Pareto Analysis

Pareto Analysis uses the Pareto Principle – also known as the "80/20 Rule". Pareto analysis is a method based on the Pareto law which conditions that 80 percent of problems or effects are occurred by 20 percent of causes (Talib, Rahman and Qureshi, 2010; Url-2). This type of method can be useful in the scoping step of decision making, to define the root attributes of the problem you are trying to address and prioritise them. This method helps to define the top 20% of causes that needs to be addressed to solve the 80% of the problems (Url-60; Url-61). Steps are defined in a Pareto Analysis in below (Talib, Rahman and Qureshi, 2010; Url-60):

1. Collect a list of the causes of problem
2. Accumulate data on the frequency of these causes.

If you have limited data, transfer a relative weighting to each cause. Rank the causes from most to least frequent and compute the cumulative percentage.

3. Draw a horizontal axis showing the several causes, ordered from most to least frequent.
4. Draw a vertical axis

5. Occur a bar chart of the percentage of each cause
6. Occur a line chart of the cumulative percentage of each cause
7. Draw a line from 80% on the Y-axis to the line chart, and then project a line from this intersection to the x-axis. This line separates important causes from the trivial ones.

7.2.1. Application of Pareto analysis for carbon footprint

7.2.1.1. Determination of energy' carbon footprint problem with Pareto analysis

The carbon footprint of the energy was calculated as 29.79 kg CO₂/kg fabric. There was an effort to address the carbon footprint problem in the energy sections with Pareto analysis method, and it was followed by solution-focused recommendations. The carbon footprint values of all the energy sections affecting natural gas, electric and combined energy resources are given in Table 7.44. Rams and stoves are equipment that serves the same purpose. However, these resources are fed by both natural gas and electricity. In Pareto analysis, in the evaluation based on natural gas and electricity, ram chimney is used for natural gas, and finish stove is used for electricity. Because such equipment is energy consuming equipment the names "ram" and "stove" were used for natural gas and electricity, respectively, to determine the degree of importance of carbon footprint. Similarly, the name "evaporate boiler" was used due to the gas consumed in the boiler; and the name "boiler room" was used when addressing electricity consumption.

In Pareto analysis, 80/20 rule was used as a Pareto principle. This method is based on the principle that 80 percent of the effects are caused by 20 percent of the problems. Pareto analysis method steps are applied in sequence, and the problems are identified from bigger to small ones with the 80/20 principle. As the first step of Pareto analysis, carbon footprint sources of energy problems are designated as shown in Table 7.44. Here, a total of 16 energy sections causes energy-related carbon footprints.

Table 7.44 CF data according to energy parts

SERIAL NO	ENERGY PARTS	ECF (kg CO₂/kg fabric)
1	Singeing hair burn-liquid dust holding chimney	0.14
2	Old ram chimney	0.65
3	New Ram chimney 1	0.67
4	New Ram chimney 2	0.67
5	Old evaporate boiler 320m ² chimney	1.86
6	New evaporate boiler 400m ² chimney	3.31
7	Chemical finishing	3.87
8	Finish new stove	0.64
9	Finish old stove	0.44
10	Dyeing	2.69
11	Warping	0.48
12	Boiler room	1.48
13	Climates	5.68
14	Compressor	0.79
15	Doffer room	0.79
16	Offices+treatment	5.63

As the second step, all the parameters causing energy carbon footprint are sorted from bigger to smaller ones as shown in Table 7.45.

Table 7.45 CF data in sorted from high to low

SERIAL NO	ENERGY PARTS	ECF (kg CO ₂ /kg fabric)
13	Climates	5.68
16	Offices+treatment	5.63
7	Chemical finishing	3.87
6	New evaporate boiler 400 m2 chimney	3.31
10	Dyeing	2.69
5	Old evaporate boiler 320 m2 chimney	1.86
12	Boiler room	1.48
15	Doffer room	0.79
14	Compressor	0.79
3	New Ram Chimney 1	0.67
4	New Ram Chimney 2	0.67
2	Old Ram Chimney	0.65
8	Finish new stove	0.64
11	Warping	0.48
9	Finish old stove	0.44
1	Singeing hair burn-liquid dust holding chimney	0.14
TOTAL		29.79

As shown in Table 7.45, the total carbon footprint was found to be 29.79 kg CO₂ based on the sum of all energy sources. Percentages and cumulative percentages of each energy source were calculated. Moreover, percentages and cumulative percentages of the first three energy sources were calculated with Equation 49 as an example as shown below. Percentages and cumulative percentages of other energy sources are calculated in the same way.

Serial No=13 (Climates)

$$\text{Percent} = (\text{CF in process} / \text{total CF in processes}) * 100 \quad (49)$$

$$\text{Percent} = (5.68 / 29.79) * 100 = 19$$

The first cumulative percentage is the same with the first percentage. Other cumulative values are calculated by adding the percentage value of a row to the cumulative value.

$$\text{Cumulative percent} = 19$$

Serial No=16 (Offices+treatment)

$$\text{Percent} = (5.63 / 29.79) * 100 = 19$$

$$\text{Cumulative percent} = 19 + 19 = 38$$

Serial No=7 (Chemical finishing)

$$\text{Percent} = (3.87 / 29.79) * 100 = 13$$

$$\text{Cumulative percent} = 38 + 13 = 51$$

Table 7.46 shows the calculated percentage and cumulative percentage values of energy carbon footprints.

Table 7.46 Percent and cumulative percent of ECF

SERIAL NO	ENERGY PARTS	ECF (kg CO2/kg fabric)	Percent	Cumulative percent
13	Climates	5.68	19.1	19
16	Offices+treatment	5.63	18.9	38
7	Chemical finishing	3.87	13.0	51
6	New evaporate boiler 400 m2 chimney	3.31	11.1	62
10	Dyeing	2.69	9	71
5	Old evaporate boiler 320 m2 chimney	1.86	6.2	77
12	Boiler room	1.48	5	82
15	Doffer room	0.79	2.7	85
14	Compressor	0.79	2.7	87
3	New Ram Chimney 1	0,67	2.2	89.9
4	New Ram Chimney 2	0.67	2.2	92
2	Old Ram Chimney	0.65	2.2	94
8	Finish new stove	0.64	2.1	96
11	Warping	0.48	1.6	98
9	Finish old stove	0,44	1.5	99.5
1	Singeing hair burn-liquid dust holding chimney	0.14	0.5	100
TOTAL		29.79		

A Pareto chart was created with all the data in Table 7.46. This Pareto chart is shown in Figure 7.11 and recommendations were made for sections cumulative percentage values of which are 80 or close to 80.

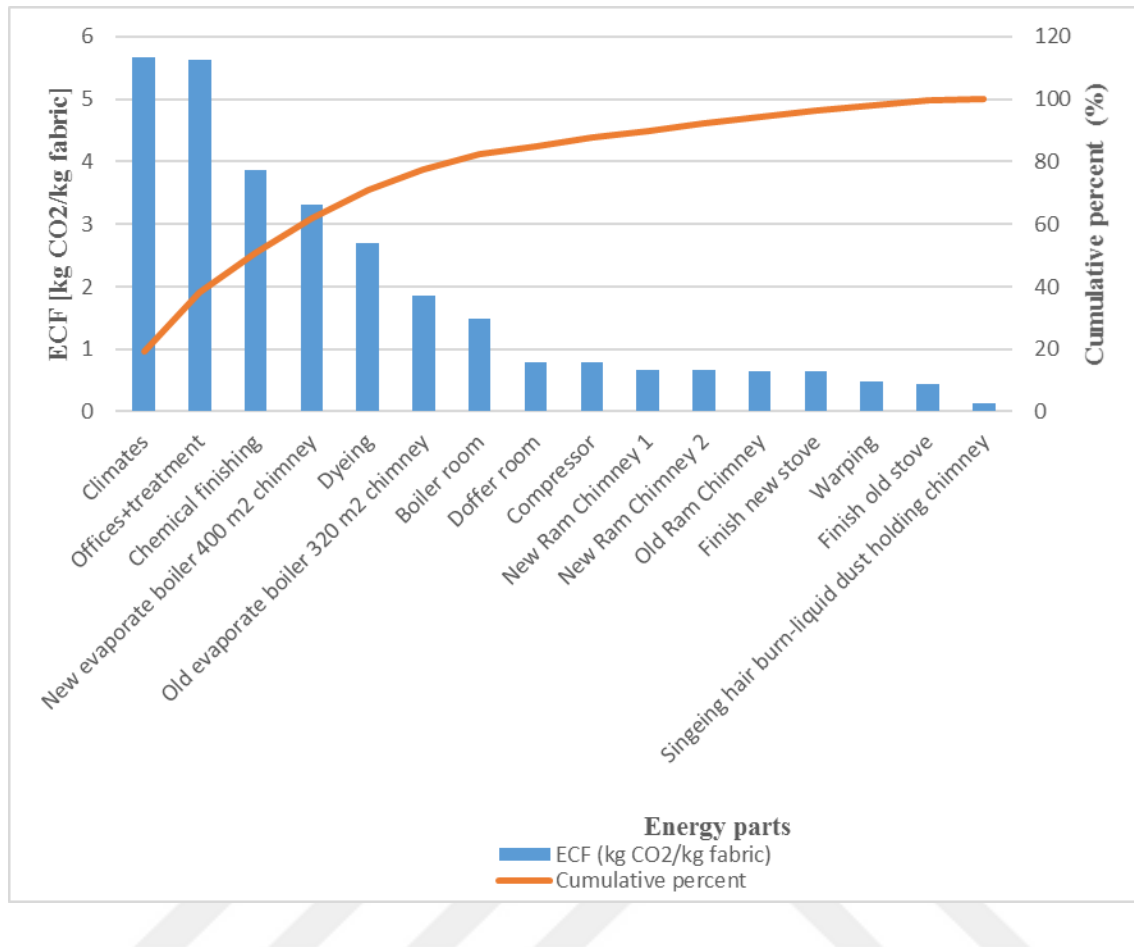


Figure 7.11 Pareto chart about energy' carbon footprint

The carbon footprint of the first six sections of the graph in Figure 7.11 was determined to constitute nearly 80 percent of the carbon footprint and recommendations were made for these sections. The first six energy departments are air conditioning, office treatment, finishing, old-new steam boilers and dyeing respectively. It was suggested that improvements to heat transfer should be made for these first six energy divisions. Also, maintenance of the machines is also important to reduce the carbon footprint.

7.2.1.2. Determination of all of the factors' carbon footprint problem with Pareto analysis

As the first step of Pareto analysis, all the factors causing carbon footprint are numbered as shown in Table 7.47. A total of six factors causing carbon emissions of here. First, the factors causing all carbon emissions are listed in Table 7.47.

Table 7.47 CF data according to common parameters

Serial Number	Factor	Carbon Footprint (kg CO ₂ /kg fabric)
1	NGECF	7.33
2	EECF	22.52
3	RMTCF	0.183
4	PTCF	0.224
5	FCF	0.148
6	SCF	1.024

Table 7.48 enumerates all the parameters causing carbon footprint from bigger to smaller ones.

Table 7.48 CF data in sorted data from high to low

Serial Number	Factor	Carbon Footprint (kg CO ₂ /kg fabric)
2	EECF	22.52
1	NGECF	7.33
6	SCF	1.024
4	PTCF	0.224
3	RMTCF	0.183
5	FCF	0.148
TOTAL		31.4

As shown in Table 7.48, the total carbon footprint was found to be 31.4 kg CO₂ taking into consideration all the factors causing it.

In Pareto analysis, the percentages and the cumulative percentage values of the parameters sorted from larger to smaller are calculated with Equation 50 for the first three parameters, and the other calculations were made in the same way. These percentages and cumulative percentages are shown in Table 7.49.

Serial number=2 (Electric Energy' carbon footprint (EECF))

Percent = (The factor in carbon footprints/Total factors in carbon footprints)*100 (50)

Percent = (22.52/31.4) *100

Percent = 72

Cumulative percent = 72

Serial number=1 (Natural gas energy' carbon footprint (NECF))

Percent = (7.33/31.4) *100

Percent = 23

Cumulative percent= 72+23= 95

Serial number=6 (Service' carbon footprint(SCF))

Percent= (1.024/31.4) * 100=3

Cumulative percent= 95+3= 98

Table 7.49 Factors' percent and cumulative percent

Serial Number	Factor	Carbon Footprint(kg CO ₂ /kg fabric)	Percent(%)	Cumulative percent(%)
2	EECF	22.52	72	72
1	NGECF	7.33	23	95
6	SCF	1.024	3	98
4	PTCF	0.224	0.7	99
3	RMTCF	0.183	0.6	100
5	FCF	0.148	0.5	100
TOTAL		31.4		

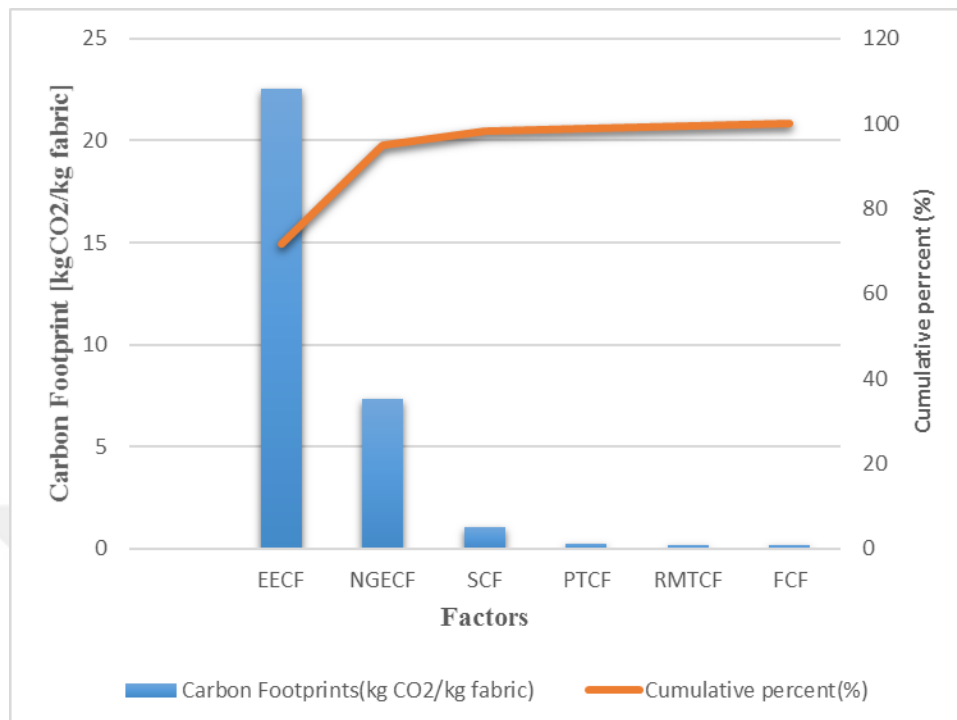


Figure 7.12 Pareto chart about all of the factors' carbon footprint

A Pareto chart was created with all the data in Table 7.49. This Pareto chart is shown in Figure 7.12 and recommendations were made for parameters cumulative percentage values of which are 80 or close to 80.

The first parameter amounting to 80 percent of carbon emissions is electricity. For this first parameter, it is necessary to reduce the use of non-renewable energy resources and make improvements to the energy resource. It was even suggested that the company should lean towards renewable energy resources if the cost is affordable.

7.2.2. Application of Pareto analysis for energy footprint

7.2.2.1. Determination of energy footprint problem with Pareto analysis

The total energy footprint for the processes where energy was consumed was calculated as 83 kWh/kg-fabric. The problem was determined with the use of the Pareto analysis method, i.e. the 80/20 ratio to reduce the energy footprint. Recommendations were made to help improve the problems of energy-consuming sections with 80 percent or figures close to 80 percent.

Table 7.50 EF data according to energy parts

Serial No	Energy part	EF [kWh/kg fabric]
1	Singeing hair burn liquid dust holding	0.8
2	Old Ram (finish old stove) Chimney	4.4
3	New Ram (finish new stove) Chimney	8.5
4	Boiler room	30.8
5	Chemical finishing	7.4
6	Dyeing	5.1
7	Warping	0.9
8	Climates	10.9
9	Compressors	1.5
10	Doffer room	1.5
11	Offices+treatment	10.8

Energy consuming parts are listed in Table 7.50 as the first step of implementing Pareto analysis. As the second step, Table 7.51 shows the sorting of energy footprints in energy consuming sections from larger to smaller values. The total annual energy footprint for the sections where energy was consumed was calculated as 83 kWh/kg fabric.

Table 7.51 EF data in sorted from high to low

Serial No	Energy part	EF [kWh/kg fabric]
4	Boiler room	30.8
8	Climates	10.9
11	Offices+treatment	10.8
3	New Ram (finish new stove) Chimney	8.5
5	Chemical finishing	7.4
6	Dyeing	5.1
2	Old Ram (finish old stove) Chimney	4.4
9	Compressors	1.5
10	Doffer room	1.5
7	Warping	0.9
1	Singeing hair burn liquid dust holding	0.8
TOTAL		82.6

As a third step, percentage and cumulative percentages are calculated. The percentages and cumulative percentages calculated with Equation 51 are described below.

Serial No=4 (Boiler room)

$$\text{Percent} = (\text{EF in the energy parts} / \text{total consumed energy}) * 100 \quad (51)$$

$$\text{Percent} = (30.8 / 82.6) * 100 = 37.3 = \sim 37$$

The first cumulative percentage value is the same with the first percentage value. Other cumulative values are calculated by adding the percentage value of a row to the cumulative value.

$$\text{Cumulative percent} = 37.3$$

Serial No=8 (Climate parts)

$$\text{Percent} = (10.9 / 82.63) * 100 = 13.2$$

$$\text{Cumulative percent} = 37.3 + 13.2 = 50.5 = \sim 51$$

Serial No=11 (Offices+treatment)

$$\text{Percent} = (10.8 / 82.63) * 100 = 13.1 = \sim 13$$

$$\text{Cumulative percent} = 51 + 13 = 64$$

Other percentages and cumulative percentages were calculated in the same way. The percentages and cumulative percentages of the sections are shown in Table 7.52.

Table 7.52 EF percent and cumulative percent

Serial No	Energy part	EF [kWh/kg fabric]	Percent (%)	Cumulative percent(%)
4	Boiler room(Old evaporate 320 m2 +new evaporate boiler 400m2 chimney)	30.83	37.3	37.3
8	Climate parts	10.9	13.2	51
11	Offices+treatment	10.8	13.1	64
3	New Ram (finish new stove) Chimney	8.5	10.3	74
5	Chemical finishing	7.4	9.0	83
6	Dyeing	5.1	6.2	89
2	Old Ram (finish old stove) Chimney	4.4	5.3	94
9	Compressor	1.5	1.8	96
10	Doffer room	1.5	1.8	98
7	Warping	0.9	1.1	99
1	Singeing hair burn liquid dust holding	0.8	0.9	100
TOTAL		82.63		

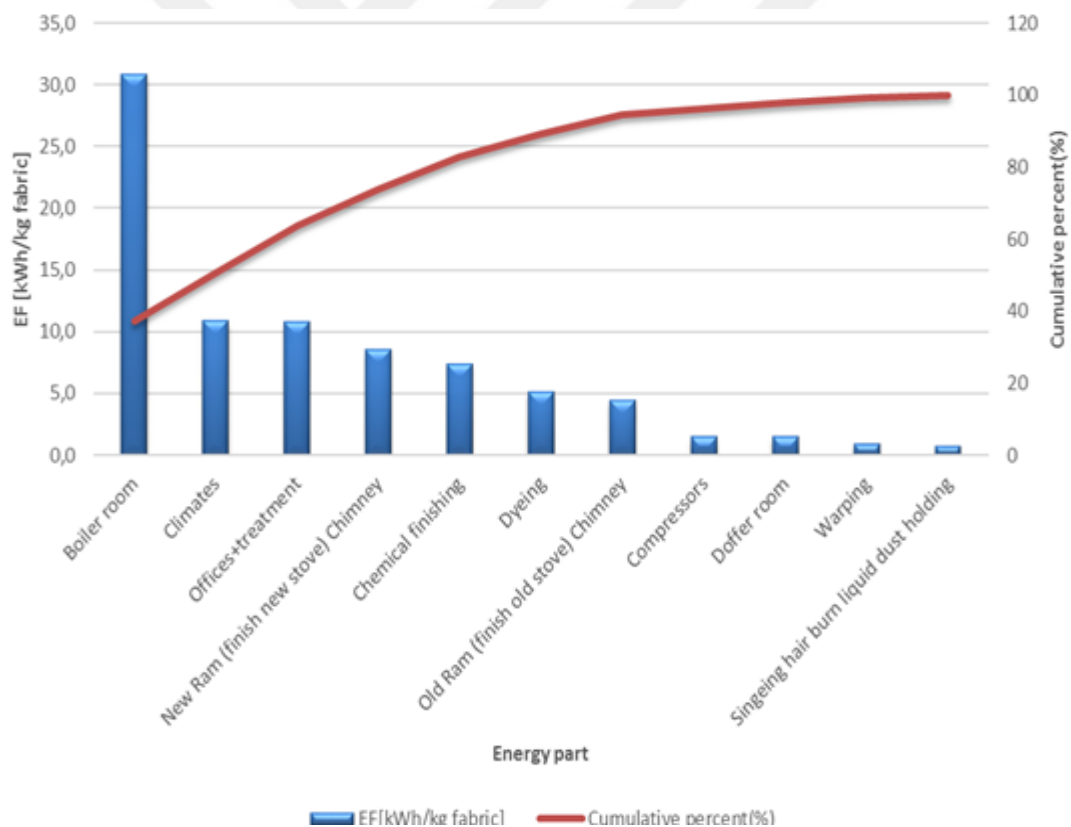


Figure 7.13 Pareto chart about energy footprint

In the last step, Pareto graphic in Figure 7.13 was created with the data provided in Table 7.52. With this chart, improvements must be made to the first five energy sections with an 80 percent cumulative value of a value close to that. It is suggested that improvements be made to these first five energy sections for heat transfer or use surface geothermal heat pump systems in these energy sections.

7.2.2.2. Determination of all of the factors' energy footprint problem with Pareto analysis

As the first step of Pareto analysis, all the factors causing energy footprint are numbered as shown in Table 7.53. A total of six factors causing carbon emissions of here. First, the factors causing all carbon emissions are listed in Table 7.53.

Table 7.53 EF data according to common parameters

Serial Number	Factor	Energy Footprint (kWh /kg fabric)
1	NGEEF	39.6
2	EEEF	43.1
3	RMTEF	0.7
4	PTEF	0.8
5	FEF	0.6
6	SEF	3.8

Table 7.54 enumerates all the parameters causing energy footprint from bigger to smaller ones.

Table 7.54 EF data in sorted data from high to low

Serial Number	Factor	Energy Footprint (kWh /kg fabric)
2	EEEF	43.1
1	NGEEF	39.6
6	SEF	3.8
4	PTEF	0.8
3	RMTEF	0.7
5	FEF	0.6
TOTAL		88.6

As shown in Table 7.54, the total energy footprint was found to be 88.6 kWh/kg fabric taking into consideration all the factors causing it.

In Pareto analysis, the percentages and the cumulative percentage values of the parameters sorted from larger to smaller are calculated with Equation 52 for the first three parameters, and the other calculations were made in the same way. These percentages and cumulative percentages are shown in Table 7.55.

Serial number=2 (Electric Energy' carbon footprint (EECF))

Percent = (The factor in energy footprints/Total factors in energy footprints)*100 (52)

Percent = $(43.1/88.6) * 100$

Percent = 49

Cumulative percent = 49

Serial number=1 (Natural gas energy' energy footprint (NEEF))

Percent = $(39.6/88.6) * 100$

Percent = 44.7

Cumulative percent= $49+44.7=93.7 \approx 94$

Serial number=6 (Service' energy footprint(SEF))

Percent= $(3.8/88.6) * 100=4.3$

Cumulative percent= 94+4.3=98.3=~98

Table 7.55 Factors' percent and cumulative percent

Serial Number	Factor	Energy Footprint (kWh /kg fabric)	Percent (%)	Cumulative percent (%)
2	EEEF	43.1	49	49
1	NGEEF	39.6	44.7	93
6	SEF	3.8	4.3	98
4	PTEF	0.8	0.9	99
3	RMTEF	0.7	0.8	99
5	FEF	0.6	0.7	100
TOTAL		88.6		

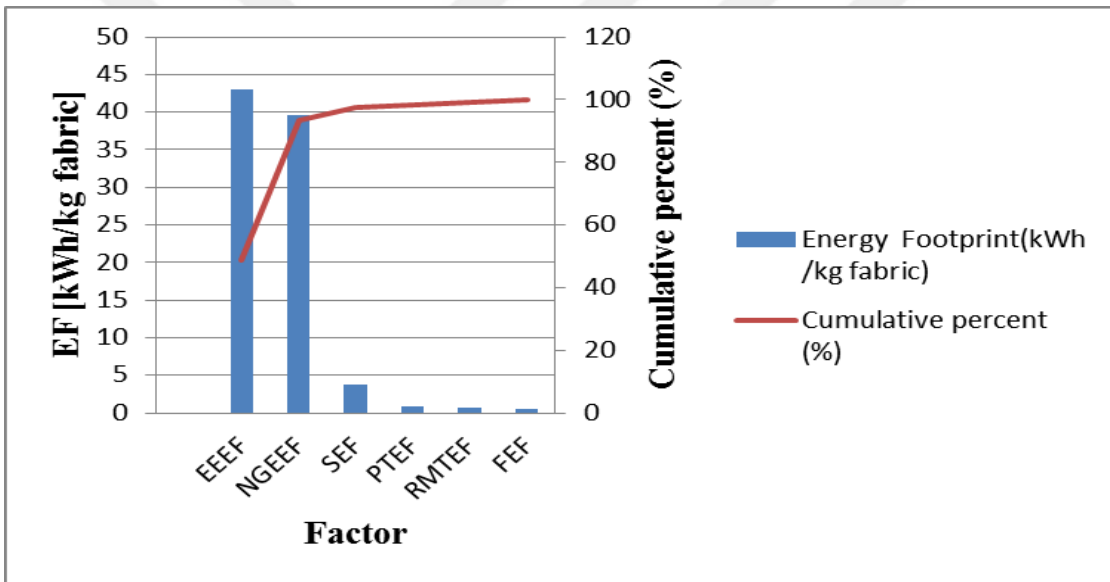


Figure 7.14 Pareto chart about all of the factors' energy footprint

A Pareto chart was created with all the data in Table 7.55. This Pareto chart is shown in Figure 7.14 and recommendations were made for parameters cumulative percentage values of which are 80 or close to 80. The first parameter amounting to 49 percent of energy emissions is electricity. For this first parameter, it is necessary to reduce the use of non-renewable energy resources and make improvements to the energy resource. It was even suggested that the company should lean towards renewable energy resources if the cost is affordable.

7.3. Quality Function Deployment (QFD)

As part of the study, a quality function deployment was applied in a fabric company in Halkalı and an underwear company in Yenibosna. In this application, customer requirements, customer significance level and technical characteristics were determined and scored. A survey was prepared for carbon, water, and energy footprint for environment-focused production to assist in the implementation study and this survey (Appendix-2.1, and Appendix-2.2) was e-mailed to a total of 73 textile companies in Turkey with the help of the Turkish textile industry employers' union. The results of this survey were evaluated on the basis of environment-focused production.

Customer requirements include carbon, water, and energy footprints. Technical characteristics include groupings identified according to the survey on environment-focused production. The technical characteristics which were determined according to the survey questions and answers are shown in Table 7.56 and Table 7.57.

The quality function deployment applied in the two companies are shown in Table 7.58 and Table 7.59.

Table 7.56 Technical characteristics for environmental oriented production

Company Features	Environmental Oriented Production Characteristics	Importance of Water	Importance of Energy
-Commercial title -Number of activity -Location -Number of employees -Working order -Types of manufacture -Raw material supply -Environmental oriented -Export	-Economic scale -Change of process -Machine technology -Using less polluted material equipment -Education - Importance of education -Strategic plan -Environmental oriented research with supplier -Amount of (CF) (kg CO₂/year) -Reduction influence of toxicity -Machines' capacity of using rates	-Amounts of consumption water [m³/ton production] according to types of material/product -Reduction amounts of consuming water research -Treatment research in wastewater -Recovery water and recovery technology -Amounts of annual consuming water, measuring consumption annual water values and record those values	-Research on saving energy -Research on saving energy in future -Amounts of annual consuming energy, measuring consumption annual energy values and record those values

Table 7.57 Technical characteristics for environmental oriented production (Continue)

Company Features	Environmental Oriented Production Characteristics	Importance of Water	Importance of Energy
	-Burn systems technology in fabric -Change of burn system technology in fabric -Measurement of emission -Abroad standard suitable certification -ISO 14001 standard -Documents certificates in domestic and abroad -Some factors importance degree in year	-Amounts of annual consuming water information according to processes	-Amounts of annual consuming energy information according to processes

Table 7.58 Application of QFD in an underwear textile company

Customer Requirements (What)	Importance of customer**/ Technical characteristics (How)*	COMPANY FEATURES*								ENVIRONMENTAL ORIENTED PRODUCTION*																IMPORTANCE OF WATER*						IMPORTANCE OF ENERGY*				General Total			
		a	b	c	cx	d	e	f	g	gx	h	i	ix	k	kx	l	m	n	o	ox	p	r	s	sx	t	u	ux	v	y	z	q	w	x	wx	wy		wz	qx	qy
CF	4	3	9	1	9	9	9	9	9	9	9	9	9	1	1	9	9	9	1	3	9	9	9	9	3	9	3	3	0	0	0	0	0	0	9	9	9	9	
WF	4	3	9	1	9	9	9	1	9	1	9	9	9	9	9	9	9	0	1	9	0	0	0	0	3	9	3	3	9	9	9	9	9	1	1	1	1		
EF	4	3	9	1	9	9	9	1	9	1	9	9	9	9	9	9	9	9	1	9	3	9	9	3	3	9	3	3	1	1	1	1	1	9	9	9	9		
AW		36	108	12	108	108	108	44	108	44	108	108	108	108	76	76	108	108	72	12	84	48	72	72	48	36	108	36	36	40	40	40	40	40	40	76	76	76	2644
CNW (%)		1.4	4.1	0.5	4.1	4.1	4.1	1.7	4.1	1.7	4.1	4.1	4.1	4.1	2.9	2.9	4.1	4.1	2.7	0.5	3.2	1.8	2.7	2.7	1.8	1.4	4.1	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.5	2.9	2.9	2.9	100
Rank		33	1	37	1	1	1	25	1	25	1	1	1	1	14	14	1	1	20	37	13	23	20	20	23	33	1	33	33	27	27	27	27	27	14	14	14	14	38

Note : Strengh of relationships(Yılmaz, 2009): **Importance of customer **1-5**(1-Not important;2-Less important;3-not decide;4- important;5-Very important), **Technical characteristics*** (0- Not correlated;9-Very strong correlate;3-Middle correlate;1-Weak correlate) : (a) Commercial title; (b) Number of activity; (c)Location; (cx) Number of employee; (d) Working order; (e) Types of manufacture; (f) Raw material supply; (g) Environmental oriented; (gx) Export; (h) Economic scale; (i) Change of process; (ix) Machine technology ;(k) Using less pollute material; (kx) Education; (l) Importance of education; (m) Strategic plan; (n)Environmental oriented research with supplier; (o) Amount of (CF) (kg CO2/year); (ox) Reduction influence of toxicity; (p) Machines' capacity of using rates; (r) Burn systems technology in fabric; (s) Features of transport (transport, service etc.); (sx) Change of burn system technology in fabric; (t)Measurement of emission; (u)Abroad standard suitable certification; (ux) ISO 14001 standard; (v) Documents certificates in domestic and abroad; (y) Some factors importance degree in year; (z) Amounts of consumption water [m³/ton production] according to types of material / product; (q) Reduction amounts of consuming water research; (w)Treatment research in wastewater; (x) Recovery water and recovery technology; (wx) Amounts of annual consuming water, measuring consumption annual water values and record those values; (wy) Amounts of annual consuming water information according to processes; (wz) Research on saving energy; (qx) Research on saving energy in future; (qy) Amounts of annual consuming energy, measuring consumption annual energy values and record those values; (qz) Amounts of annual consuming energy information according to process

The scoring and calculation details were explained for the first column only regarding the quality function deployment application in the underwear textile industry as shown in Table 7.55. The scoring and calculations in the other columns were done in the same way with Equations 52 and 53:

Note:

The strength of relationships (Yılmaz, 2009):

Importance to customer **1-5 (1-Not important; 2-Less important; 3-not decide; 4- important; 5-Very important)

Technical characteristics* (0-Not correlated; 9-Very strong correlate; 3-Middle correlate; 1-Weak correlate)

The above score was taken into account and this scoring system was used in the application in these two textile industries.

Also, calculated absolute weight, the weight of the customer requirements and their formulas are explained below:

Absolute weight (AW): multiplying; the importance weight (IW) and improvement ratio (IR) give absolute weights of the customer requirements to us.

The conversion of the degree of importance of counterpart quality characteristics can be denoted by the following equations (52) and (53) in below (Yılmaz, 2009):

$$AW = \sum IW_i * IR_{ij} \quad (52)$$

Where: AW= absolute weight

IW=importance weight

IR= improvement ratio

Total score in which column= Importance to customer in which first line*design requirements in which the first line+Importance to customer in which second line*design requirements in which the second line+Importance to customer in which third line*design requirements in which the third line

Total score in the first column= $4*3+4*3+4*3$

Total score in the first column=36

Customer need weight (CNW) which the absolute weights are collected and each divided by the collect to yield a normalized customer need weight.

$$CNW = AW(1.) / \sum(AW) * 100 \quad (53)$$

(1.customer requirement)

CNW in first column = (Total score in first column/General Total)*100

CNW in first column=(36/2644)*100

CNW in first column=1.4

The scoring and calculations in the other columns were conducted just as above.

Scoring and calculations were done in the textile company according to the relationship between customer requirements and technical characteristics. In the calculations, sorting was conducted from bigger to smaller with the help of the statistical package program based on the weight of customer requirements. As a result of this sorting, 12 technical characteristics were identified with a value of 4.1 percent. These are the 12 priority technical characteristics:

b-Number of activity

cx-Number of employee

d- Working order

e-Types of manufacturing

g- Environmental oriented

h-Economic scale

1- Change of process

1x- Machine technology

k- Using less polluted material

m-Strategic plan

n- Environmental oriented research with the supplier

ux-ISO 14001 standard

The second priority technical characteristic is the 3.2 percent capacity utilization rate of the machines. Following are the recommendations for the company to make improvements in environment-focused production with all the determined technical characteristics:

- The company's number of operations and an adequate number of employees.

- The working order of the company should be adjusted accordingly.

- For environment-focused production, it is necessary to move towards renewable energy resources. However, the firm can carry out environment-focused production by using appropriate renewable energy resources and taking into consideration the cost aspect.

- Process changes can be made to reduce footprints. It is because making a process change is more cost-effective than acquiring a machine with new technology.

- It is very important to use machine technology to carry out different modes of production. However, buying a technology proves costly. For this reason, it is more economical to undertake a process, rather than technology, change, and improvement. This would reduce footprints and enable an environment-focused production.

- The use of fewer pollutant materials is crucial for human health.

- The strategic plan is important for the textile firms to carry out environment-focused production. The textile should prepare its strategic plans for environment-focused production and review it on a regular basis.

- It should also increase its environment-focused activities with suppliers. Doing so would reduce the amount of carbon dioxide released to the environment.

- The ISO 14001 standard is an environmental management system. It is a necessary standard for the fulfilment of all obligations and environment-focused production. This standard should be obtained by all textile companies.

- The machines' capacity utilization rate is a very important characteristic for production. Thus, care must be taken to ensure that activities are conducted according to machine operation capacities. Protective and preventive maintenance should be performed on the machines.

Table 7.59 Application of QFD in a fabric production textile company

Rank	CNW (%)	AW	EF	WF	CF	Customer Requirements (What) Importance of customer**/ Technic characteristics (How)*	COMPANY FEATURES*								ENVIRONMENTAL ORIENTED PRODUCTION CHARACTERISTICS*																IMPORTANCE OF WATER*					IMPORTANCE OF ENERGY*				General Total																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																								
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Note : Strenght of relationships(Yilmaz, 2009): **Importance of customer **1-5**(1-Not important;2-Less important;3-not decide;4- important;5-Very important), **Technical characteristics*** (0-Not correlated;9-Very strong correlate;3-Middle correlate;1-Weak correlate) : (a) Commercial title; (b) Number of activity; (c)Location; (cx) Number of employee; (d) Working order; (e) Types of manufacture; (f) Raw material supply; (g) Environmental oriented; (gx) Export; (h) Economic scale; (i) Change of process; (ix) Machine technology ;(k) Using less pollute material; (kx) Education; (l) Importance of education; (m) Strategic plan; (n)Environmental oriented research with supplier; (o) Amount of (CF) (kg CO2/year); (ox) Reduction influence of toxicity; (p) Machines' capacity of using rates; (r) Burn systems technology in fabric; (s) Features of transport (transport, service etc.); (sx) Change of burn system technology in fabric; (t)Measurement of emission; (u)Abroad standard suitable certification; (ux) ISO 14001 standard; (v) Documents certificates in domestic and abroad; (y) Some factors importance degree in year; (z) Amounts of consumption water [m³/ton production] according to types of material / product; (q) Reduction amounts of consuming water research; (w)Treatment research in wastewater; (x) Recovery water and recovery technology; (wx) Amounts of annual consuming water, measuring consumption annual water values and record those values; (wy) Amounts of annual consuming water information according to processes; (wz) Research on saving energy; (qx) Research on saving energy in future; (qy) Amounts of annual consuming energy, measuring consumption annual energy values and record those values; (qz) Amounts of annual consuming energy information according to process

The scoring and calculation details were explained for the first column only regarding the quality function deployment application in the fabric textile industry as shown in Table 7.56. The scoring and calculations in the other columns were conducted as follows with Equations 52 and 53:

Total score in the first column= $5*9+5*9+5*9$

Total score in the first column=135

$CNW = AW(1.) / \sum(AW) * 100$

(1.customer requirement)

Rate in the first column=(Total score in the first column/General Total)*100

Rate in the first column=(135/2215)*100

Rate in the first column=6.1

The scoring and calculations in the other columns were conducted just as above. Scoring and calculations were done in a fabric textile company according to the relationship between customer requirements and technical characteristics. The quality function deployment was ranked from bigger to smaller ones according to the weight of customer requirements in this fabric factory located in Halkalı to realize environment-focused production. With this ranking came recommendations for results with high values. This study includes recommendations for the improvement of the parameters of five characteristics constituting 6.1 percent of customer requirement weight in the first place and then the parameters of the two technical characteristics constituting 4.7 percent of customer weight in the second place. Following are these seven technical characteristic parameters in below:

a- Commercial title

e- Types of manufacture

gx- Export

n-Environmental oriented research with supplier

p-Machines' capacity of using rates

b- Number of activity

g- Environmental oriented

If there is a desire to make recommendations to improve these parameters;

- The trade name is associated with the size of the company. It is because large enterprises such as joint stock companies emit a huge amount of emissions to the air. For this reason, increasing the number of medium-sized enterprises is advantageous.
- Production types are important to carry out environment-focused production. The amount of water and energy consumed in the production are estimated according to the know production type(s). Processes can be modified to reduce the amount of water and energy consumed.
- Exports are important for environment-focused production. It is because establishing systems in accordance with international environmental protection standards are necessary to carry out exports.
- The number of non-value-added activities (number of activities) should be reduced.
- The machines should be used in the production process according to the capacity utilization rate. Protective and preventive maintenance should be performed on the machines.
- It is necessary to conduct a cost investigation for the use of renewable energy resources (sun panel, biomass etc.) and to ensure environment-focused production.
- Carbon dioxide emissions are reduced based on the vehicle type and fuel type used in transportation with the increase in the number of environment-focused activities with suppliers.
- The machines' capacity utilization rates are a very important parameter for production, and water and energy consumption are important based on the machine capacity. For example, putting materials with a low capacity in the dyeing machine, a machine with a high capacity, causes excessive use of water, paint, and energy. Thus, care must be taken to ensure that operations are conducted according to machine capacity.

The following four technical characteristics are common among those determined in two different QFD applications (underwear textile firm and fabric firm), and it is suggested that the recommendations be applied to both firms:

- b- Number of activity
- e- Types of manufacture
- g- Environmental oriented
- n- Environmental oriented research with the supplier

7.4. Evaluate the Survey About Carbon, Water and Energy Footprint for Environmental Oriented Production

The results of the survey prepared for carbon, water and energy footprints were evaluated and explained below for environment-focused production. The survey was sent to 73 textile companies, 34 out of which returned it.

The survey results were evaluated statistically, and the firms were evaluated in terms of their environment-focused characteristics.

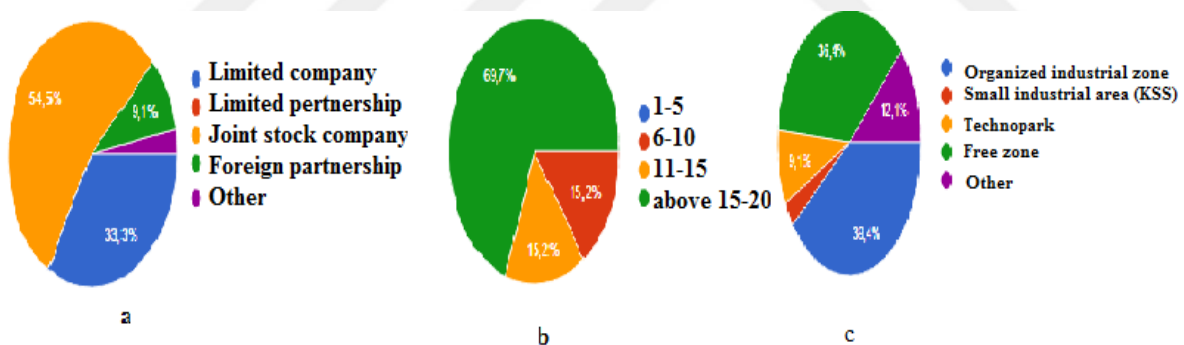


Figure 7.15 Company features (a) Commercial title (b) Company's age in years (c) Location

Figure 7.15 shows the evaluation of 34 textile companies through circular charts regarding company characteristics such as (a) commercial title, (b) activity period, (c) activity place. In this evaluation, the textile companies had the following commercial titles: 19 joint stock companies (54 percent), 12 limited companies (33.3 percent), partnerships between foreign and local companies (9.1 percent) and 1 textile company with 3.1%. In general, the activity period of 24 textile companies is over 16-20 years (69.7 percent). In the evaluation of the activity place, 15 textile firms (39.4 percent) are located in the industrial zone, 12 textile

companies (36.4 percent) are located in free zones, three textile firms (22.1 percent) are located in technopark areas, and four textile firms (12.1 percent) are other regions.

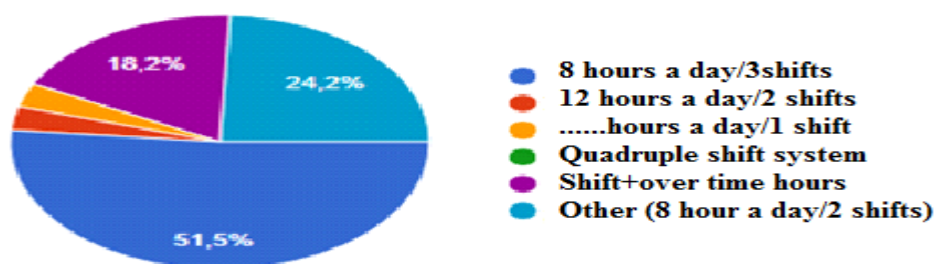


Figure 7.16 Work schedule of the company

Figure 7.16 shows, through a circular chart, the percentage ratios of the working order of the companies based on their characteristics. The working order varies depending on the number of staff and the company title. However, the shift arrangement appear as follows in the textile companies: eight hours per day and three shifts in 18 textile companies (51.1 percent), eight hours per day and two shifts in eight textile companies (24.2 percent), six textile companies with one shift+hour overtime (18.2 percent), 12 hours per day and two shifts in two textile companies (6 percent).

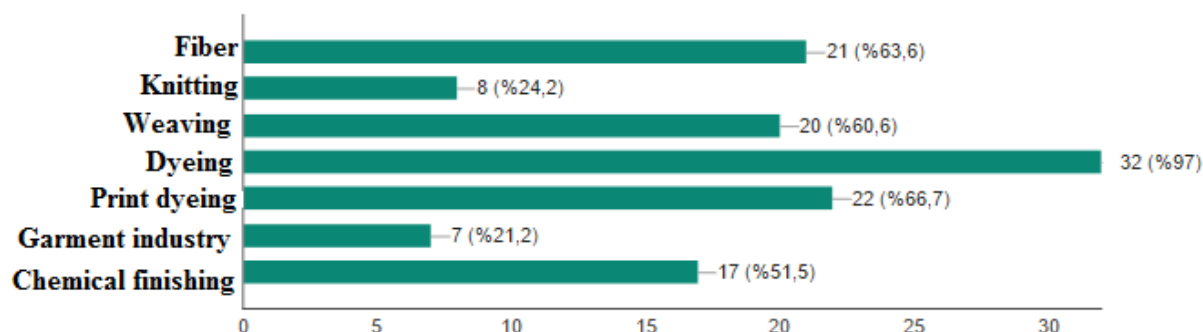


Figure 7.17 Types of production of the companies

Figure 7.17 shows the companies' production types on the column chart. These types of production vary based on each company's products. Some companies have more than one type of production, while others have a uniform production method. The figure shows characteristics such as percentage ratios and number of companies.

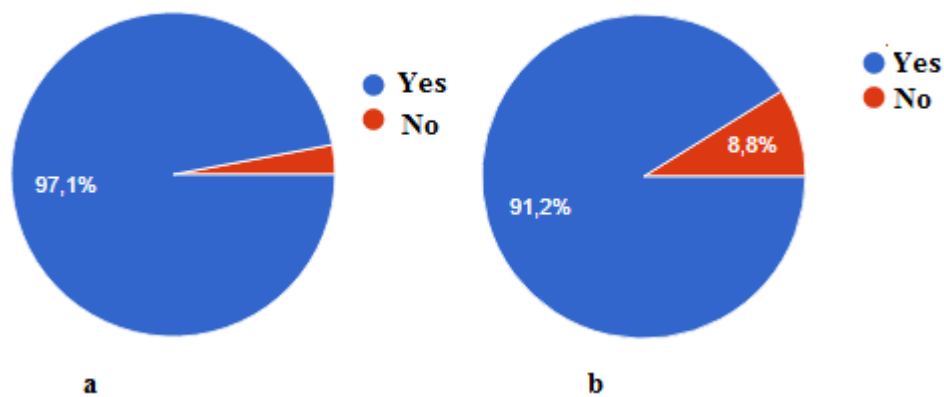


Figure 7.18 Company and environmental oriented production characteristics (a)Export (b) Certificate of conformity to standard

Figure 7.18 shows companies and percentage ratios for (a) imports and (b) having standards, as environment-focused production characteristics. 33 textile companies (97.1 percent) are involved in imports. 31 textile companies (91.2 percent) have standardization documents.

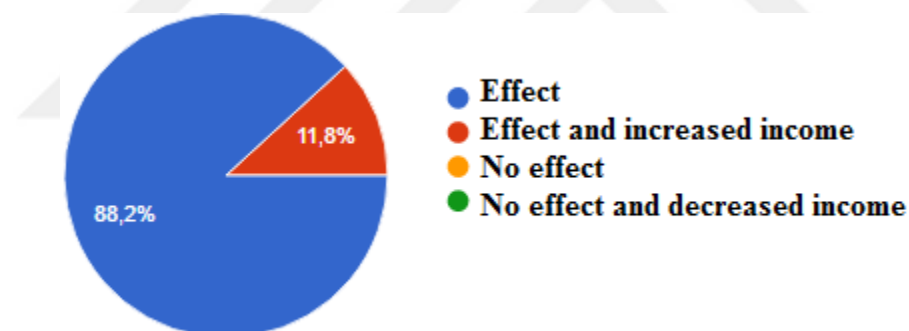


Figure 7.19 Effect on environmental oriented production

They have Oeko-Tex Standard 100, ISO 14001, ISO 18001, TSE and CE, etc standardization documents. All textile companies have the ISO 14001 standard. Figure 7.19 shows, through a circular chart, the percentage values of the environment-focused production's effect on the companies' economic dimensions. The firms can be said to do their best to realize environment-focused production in all textile industries by taking costs into account. Environment-focused production is important with 88.2 percent regarding economic cost in reducing carbon, water, and energy footprints.

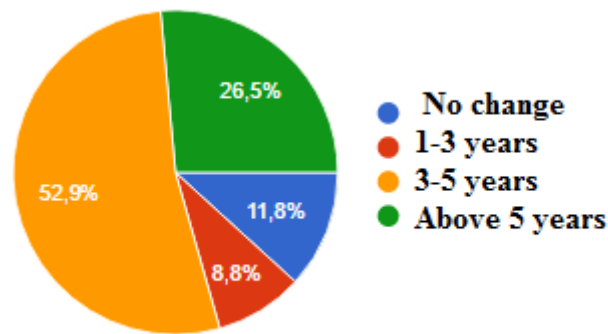


Figure 7.720 Changes in machine technologies

Changes in machine technology are crucial for environment-focused production. Figure 7.20 shows, through a circular chart, the durations and percentage values of the changes to the machine technologies of the textile firms. Regarding the evaluation of changes to machine technology; 18 textile firms (52.9 percent) make changes in 3-5 years; nine textile firms (26.5 percent) over 5 years, three textile firms (8.8 percent) in 1-3 years, whereas four textile firms (11.8 percent) do not make any changes. In all textile companies, less pollutant material is used to achieve environment-focused production.

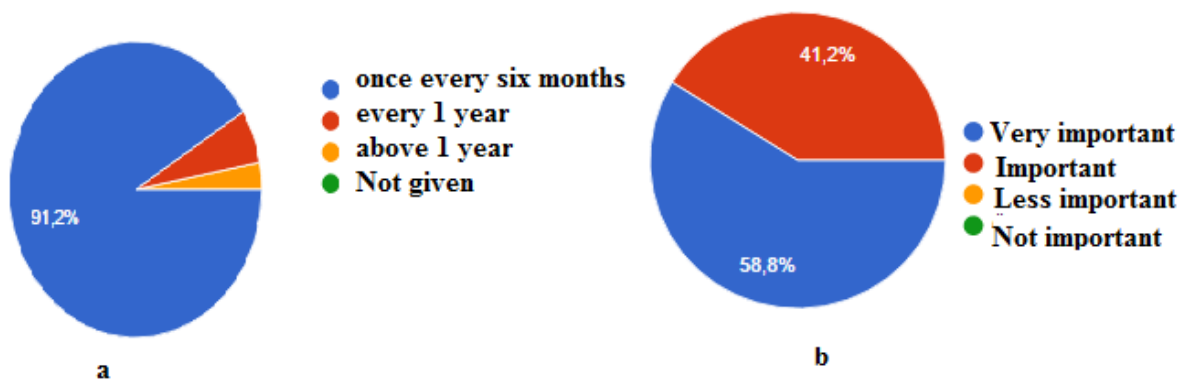


Figure 7.21 Education (a) Training period (b) Degree of importance

Figure 7.21 shows, through circular graphs, percentage ratios about the importance of education and training regarding environment-focused production. The training period seems very important for environment-focused production in 31 textile firms (91.2 percent) and three textile firms (8.8 percent). Environment-focused training is very important for 20 textile firms with 58.8 percent, and it is important for 14 textile firms at 41.2 percent

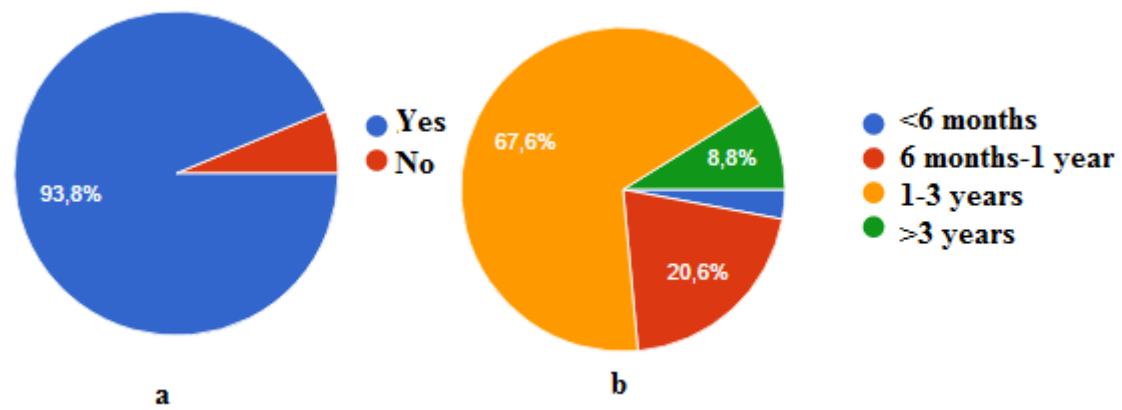


Figure 7.22 Strategic plan (a) available (b) time of environmentally oriented production in strategic plan

Figure 7.22 shows, in circular graphs, the percentages for (a) the current situation for the strategic plan, and (b) the targeted period of the environment-focused production in the strategic plan. 30 textile companies (93.8 percent) have strategic plans. The strategic plan is generally important for all textile companies. Following is the evaluation of targeted periods for environment-focused production as part of the strategic planning: 23 textile firms (67.6 percent) aim to achieve it in 1-3 years, seven textile firms (20.6 percent) in 6 months to 1 year, three textile firms (8.8 percent) in over 3 years and 3 percent in less than six months. Activities are underway among textile firms and their suppliers for environment-focused production.

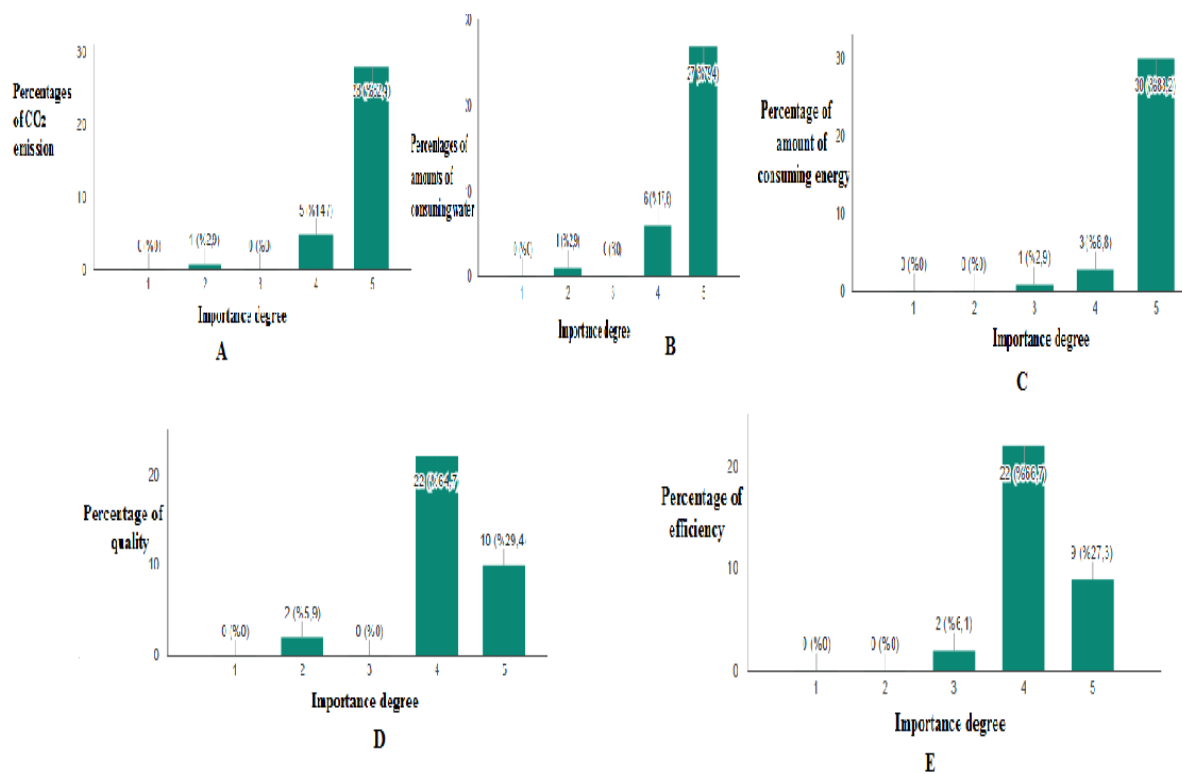


Figure 7.23 Importance of factors (1-Not important 2-less important 3-middle important 4-important 5-very important)(A-CO₂ emission, B-Amounts of consuming water, C-Amounts of consuming energy, D-Quality, E-Efficiency)

34 textile firms evaluated the following factors according to their importance: (A) CO₂ emissions, (B) water consumption, (C) energy consumption, (D) quality and (E) productivity. The following rating system was used when determining the importance level: 1-Unimportant, 2-less important, 3-moderately important, 4-important, 5-very importantly. In the column charts of Figure 7.23, 28 textile firms stated that CO₂ emissions are very important to 82.4 percent, whereas 32 textiles firms stated the same for water consumption with 94.1 percent. In general, companies reduced their water consumption by recycling 20 percent of water.

In general, textile companies carry on their efforts for the use of biological treatment and membrane technology in the treatment of waste water.

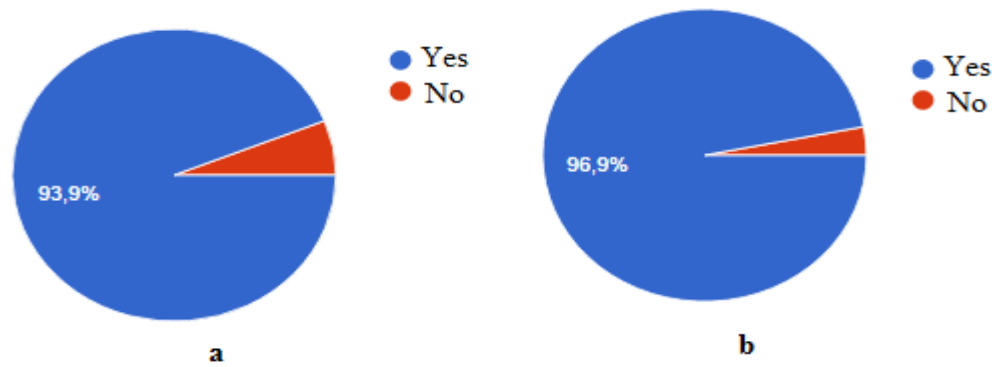


Figure 7.24 Efforts (a) Toxicity reduction (b) Energy savings

Figure 7.24 shows, through circular graphs, the ratios of firms' efforts towards toxicity and energy use. 93.9 percent of the firms strive to reduce the toxic effect for a healthy life. They conduct research on toxicity through various technical sources. 96.9 percent of the textile companies conduct research on energy conservation. The percentage savings for energy conservation (natural gas and electricity) vary. The consumed water and energy amounts vary according to processes.

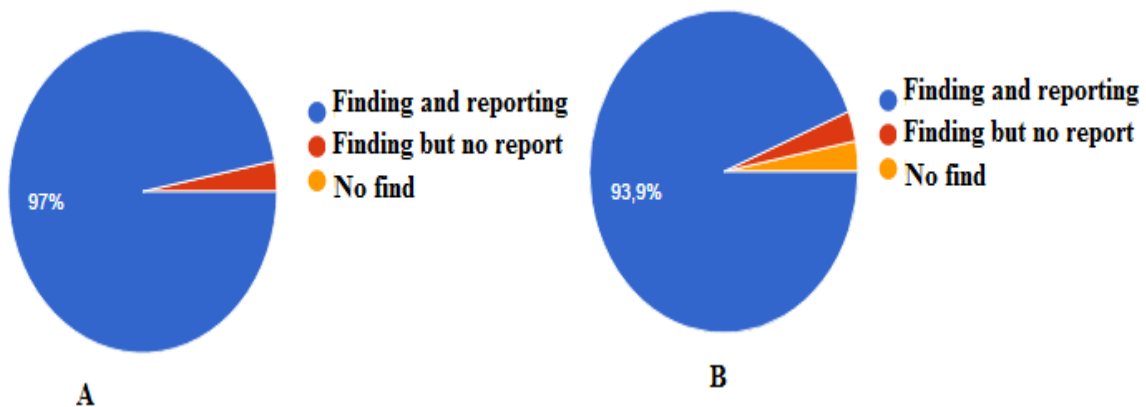


Figure 7.25 Meter available end meter readings reported (A-Water, B-Energy)

Figure 7.25 shows, through circular graphs, percentages for 34 textile firms regarding whether the measurements of water and energy meters are reported or not. 32 textile firms (97 percent) reported meter measurements of their annual water consumption. 31 textile firms (93.9 percent) reported meter measurements of their annual energy consumption.

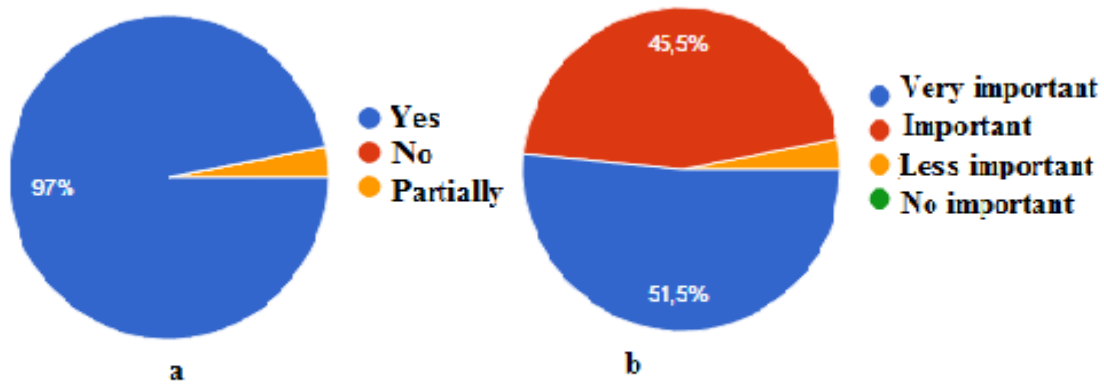


Figure 7.26 Machines' some characteristics (a) periodic maintenance (b) capacity usage rate

Figure 7.26 shows, through circular graphs, the situation regarding the periodical maintenance and the capacity utilization rates of the machines in 34 textile companies. Figure 7.25-a shows that 32 textile firms carry out periodic maintenance at 97 percent, whereas two textile firms carry out partial periodical maintenance. Figure 7.25-b shows the importance of the utilization capacities of the machines as such: 17 textile firms (51.5 percent) consider it to be very important, 15 textile firms (45.5 percent) consider it to be important, and the 2 textile firms (3 percent) consider it to be less important.

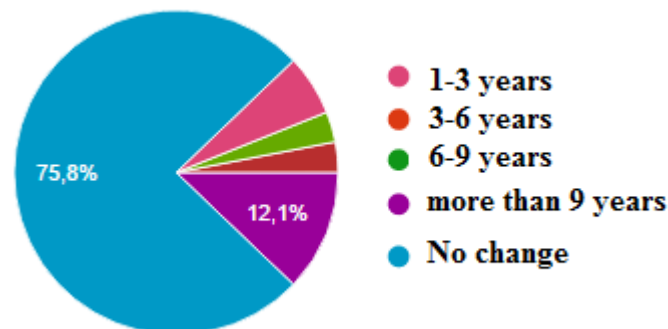


Figure 7.27 Burn systems technology

Figure 7.27 shows, through a circular graph, the number of years and percentage ratios before the combustion system is changed. In general, 25 textile companies (75.8) concluded that they would not make any changes to their combustion systems technology.

The number of vehicles used in the transportation of products, raw materials and staff, vehicle types, fuel types and the amount of fuel consumed vary by factors such as the companies' commercial titles, working orders, and the number of employees.

All the textile firms conduct emission measurements every other year. Quantities of CO, SO₂, NO, NO₂ and NO_x gases are measured every other year in emission measurement. The measured quantities vary according to the type of production.

As a result, the survey on carbon, water and energy footprint regarding the environment-focused production was sent to 73 textile companies, 34 of which returned it allowing for its statistical evaluation. In the survey, 34 textile firms answered the question "Are you environmentally oriented?" as "Yes." However, the cost of being environment-focused should not be forgotten although companies may attach importance to it. If the cost is appropriate, strategic plans are put into practice to facilitate environment-focused production.

8. RESULTS

8.1. EVALUATION AND CONCLUSION

Almost all production industries emit greenhouse gas emissions directly or indirectly to the air as a result of their production activities. Carbon dioxide has the highest potential to cause global warming among greenhouse gases. In this thesis study, we determined different energy types and water quantities consumed in a selected textile production plant in detail for all production stages while calculating carbon, water, and energy footprints accordingly.

For each process, energy and carbon footprints were obtained based on the energy resource used. We used energy resource-related emission factors in the carbon footprint calculation. As the emission factors associated with electricity energy vary depending on countries' energy production conditions, the emission factor for the purchased electricity was calculated based on our country's production data. We conducted Pareto analysis using both carbon and energy footprint values. The resulting Pareto analysis led to suggestions for processes that constituted problems or problems with the 80/20 ratio. In addition, a survey regarding the environment-focused production was conducted in two different textile firms (underwear and fabric production facilities) for quality function evaluation. In addition, the survey was conducted at other textile companies in Turkey, and the results were evaluated. The results obtained from such examinations are summarized below:

- In 2015, the wool fabric company produced 475 tons of fabric using 450 tons of wool and 150 tons of polyester fiber. It consumed, in this production, 37.259 m³ of water, 20.455,740 kWh of electricity and 18.825,600 kWh of natural gas energy.
- The annual diesel fuel consumption was calculated as 167.832 L, taking into consideration the two-way travel of the shuttles serving 45 staff. The corresponding carbon footprint was calculated as 1.02 kg CO₂/kg-fabric.
- The plant's total carbon footprint was calculated as 31.2 [kg CO₂/kg-fabric] taking into account the production and all the stages supporting it (natural gas and electricity used in production, staff shuttles, forklift use, raw material transport). The total carbon footprint of the fabric was calculated as 52.8 kg CO₂/kg-fabric with the inclusion of the emissions resulting from the production of wool and polyester fiber raw materials as inputs and the transportation of the manufactured fabrics to the consumption points.

- The total energy footprint created by the plant for production processes was calculated as 86.83 [kWh/kg-fabric]. The total energy footprint of the fabric was calculated as 103.23 [kWh/kg-fabric] with the inclusion of the emissions resulting from the production of wool and polyester fiber raw materials as inputs and the transportation of the manufactured fabrics to the consumption points.
- The total water consumption-related footprint in fabric production was found to be 2.21 m³ water/kg fabric based on the water footprint values given in the literature for polyester and wool fiber, the raw materials necessary for production.
- Carbon, water, and energy footprint values were shown in Table 8.1 for each process.
- As a result of the application of Pareto to the carbon footprint values calculated for all the processes where energy is used, the first six processes were determined as air conditioning, offices+treatment, chemical finishing, new steam boiler, painting and old steam boiler, respectively. We can recommend improving the thermal efficiency of these processes and the maintenance of the equipment whereby these processes are performed to reduce carbon footprints.
- As a result of the application of the Pareto analysis to all the processes causing carbon emissions, electricity energy was found to make the biggest contribution to the carbon footprint according to the 80/20 rule. Starting with this premise, we think that deploying appropriate renewable energy resources would be beneficial in reducing carbon footprint provided that it leads to acceptable levels of cost.
- The Pareto analysis for the energy footprint was applied first on the following five processes: boiler room, air conditioners, office treatment, new drying (New stove-RAM) and chemical finishing. We can recommend improving the thermal efficiency of these processes and the maintenance of the equipment whereby these processes are performed to reduce carbon footprints. Also, the utilization of geothermal heat pumps is an alternative that can make a positive contribution.
- We did not conduct any Pareto analysis regarding the water footprint.
- A questionnaire with questions on energy, water, and many other factors was prepared for the evaluation of the quality function regarding the environment-focused production, and these questionnaires were grouped as technical characteristics. The grouping consists of four general groups and thirty-eight sub-groups below them.

- Questionnaires were conducted for the two textile firms followed by evaluations. Four common sub-groups were identified for both textile firms. These are the number of company activities, production types, the degree of company's environmental focus, and environment-focused activities with suppliers, respectively. These are important to enable environment-friendly production.
- The questionnaire on energy and water footprint regarding the environment-focused production was sent to 73 textile companies, 34 of which returned the questionnaire allowing for its statistical evaluation. In the questionnaire, 34 textile firms answered the question "Are you environmentally oriented?" as "Yes." However, the cost of being environment-focused should not be forgotten although companies may attach significance to it. If the cost is appropriate, putting strategic plans into practice to help environment-focused production will be easier.

The results obtained from some projects similar to this thesis are summarized below (Table 8.2):

- For polyester fiber production, it was determined to have 60 MJ/kg fiber or 16.5 kWh/kg fiber (DEPA, 1997).
- The study on the wool fiber production in New Zealand determined 20 MJ/kg and 21.62 MJ/kg energy values for raw material containing 100 percent wool. (Url-1).
- Accordingly, the carbon footprint for a t-shirt made of polyester was determined as approximately 7.1 kg CO₂ (Kirchain et al., 2015). Accordingly, the carbon footprint value for five t-shirts (weighing nearly one kg) would be 35 kg CO₂/kg-t-shirt.
- In another study conducted in China (Yan,Y. et al., 2016), the carbon footprint resulting from the production of pure wool and wool-polyester mix fabrics were determined as 14 kg CO₂/kg fiber and 13.5 kg CO₂/kg fiber, respectively. The same study stated these values would rise by 70.8 percent if yarn dyeing process was included. Accordingly, the value in question will be 23.1 kg CO₂/kg fabric. It is also understood to lead to an additional increase of 76.2 percent and 40.8 kg CO₂e/kg-fabric value if plain weave technique was used for fabric knitting. The carbon footprint resulting from wool and polyester fiber production was not added to this value.

- In a study conducted for the Iranian textile industry (Hasanbeigi and Price, 2012), energy footprint values for woolen fabrics were given in a range of 73-132 kWh/kg of fabric.

In addition to the above recommendations, we can suggest the generally accepted best techniques and recommendations found in the European Union references regarding the reduction of carbon, water, and energy footprints in line with environmental standards in the textile industry (IPCC, 2003; Federal Environment Agency, 2011):

- ❖ Workers should get monthly training regarding environmental protection, etc.
- ❖ There should be maintenance on the machines and all kinds of sealing checks for the systems
- ❖ It is important to use regular pumps and piping systems to prevent chemical leaks
- ❖ Equipment parts such as pumps, valves, etc. should be checked
- ❖ Monthly regular filter cleaning and maintenance check should be conducted
- ❖ Measurement tools should be calibrated for chemicals and thermometer as well as measurement and dosing systems
- ❖ Thermal treatment tools should be cleaned and maintained regularly
- ❖ Technical measurements should be safeguarded reliably and individually
- ❖ Care should be given to the use of automated systems for the optimum use of raw materials in the chemical dosage amounts and processes.
- ❖ Water and energy consumption needs to be checked every month.
- ❖ Thermal insulation should be applied to pipes, valves, machines, and other similar places.
- ❖ Process optimization must be ensured in production
- ❖ Effective washing processes must be applied
- ❖ Water should be reused
- ❖ Closed machines must be designed to reduce steam loss
- ❖ Using heat recovery systems becomes increasingly important.

- ❖ Optimization-condensate recovery, pre-heating of air suction and heat recovery from waste gases must be ensured in steam boilers.
- ❖ Controlled electric motors should be installed and used effectively
- ❖ Emphasis should be given to the refining and reuse of waste water
- ❖ Mechanical dewatering equipment reduces water consumption in the finishing process.

8.2. Future Research

The basic aim of this thesis study was to determine carbon, energy, and water footprints in a textile company by considering all the components in the production process. Pareto analysis technique was used to determine the possible alternatives for reducing the footprints for an environmentally oriented production in the selected textile factory.

Some other techniques such as Analytic Hierarchy Process (AHP) Method, SWOT Analysis, or Failure Mode and Effects Analysis (FMEA) can also be used in future studies.

Table 8.1 Calculated values for carbon, energy, and water footprints in the fabric production processes.

PROCESS	CF [kg CO₂/kg fabric]	EF [kWh/kg fabric]	WF [m³/kg fabric]
Singeing hair burn liquid dust holding	0.14	0.76	-
Old Ram chimney (Finish old stove)	1.10	4.42	-
New Ram Chimney (Finish new stove)	2.00	8.52	-
Boilers (Old evaporate 320 m ² + New evaporate 400 m ²)	6.67	30.83	-
Chemical finishing	3.88	7.4	-
Dyeing	2.69	5.1	-
Warping	0.48	0.9	-
Climates	5.69	10.9	-
Compressors	0.79	1.5	-
Doffer	0.79	1.5	-
Offices+treatment	5.63	10.8	-
Raw material transportation	0.18	0.7	-
Forklift use	0.15	0.6	-
Personnel transportation	1.02	3.8	-
Fabric production company's Total Footprints	31.2	87.7	0.064
Contribution from wool and polyester fiber production	21.4	15.6	2.146
Fabric product transportation	0.22	0.8	-
General Total	52.8	104.1	2.21

Table 8.2 Comparison of literature

Studied parameter	Result of study	Reference
Energy footprint	73-132 kWh/kg-fabric for woolen weave fabrics In Iran's textile industry	Hasanbeigi et al., 2012
Carbon footprint	pure wool fabrics (14 kg-CO ₂ e/kg-fabric) wool-polyester fabrics (13,5 kg-CO ₂ e/kg-fabric) in China	Yan et al., 2016
Carbon footprint	T-shirt made of polyester (7,1 kg-CO ₂ e/ tshirt) which corresponds to approximately 35 kg-CO ₂ e/kg-tshirt in USA	Kirchain et al., 2015
Carbon footprint (This study)	31.2 kg-CO ₂ e/kg-fabric	
Energy footprint (This study)	87.7 kWh/kg-fabric	

REFERENCES

- Akao, Y., **(1990)**. QFD (Quality Function Deployment) Integrating Customer Requirements into Product Design.
- Akıllı, H, Kemahlı, F, Okudan, K., Polat, F. **(2008)**. The Content Of Ecological Footprint Concept And Calculation Of Individual Ecological Footprint In The Akdeniz Universty Economics And Administrative Sciences FacultyAkdeniz İ.İ.B.F. Dergisi 15:1-25.
- Albritton, D. L., Cicerone, R. J., Barron, E. J., Dickinson, R. E., Fung, I. Y., Hansen, J. E and Karl, T. R., **(2001)**. Climate Change Science: An Analysis of Some Key Questions, pages: 9-14, Committee on Science of Climate Change,National Academy Press, Washington, D.C.
- Alkaya, E., Demirer, G.,N., **(2014)**. Sustainable textile production: a case study from a woven fabric manufacturing mill in Turkey, Journal of Cleaner Production 65:595-603.
- Asaka, T. and Ozeki, K., **(1990)**. Handbook of Quality Tools: The Japanese Approach, Productivity Press, Portland.
- Aslanoğlu, S.Y., Köksal, M. A. **(2012)**. Elektrik Üretimine Bağlı Karbondioksit Emisyonunun Bölgesel Olarak Belirlenmesi ve Uzun Dönem Tahmini, Hava Kirliliği Araştırmaları Dergisi 1 : 19–29, Ankara.
- Atabey, T. **(2013)**. Karbon Ayak İzinin Hesaplanması: Diyarbakır Örneği, Fırat Üniversitesi Yüksek Lisans Tezi, Elazığ.
- Aydın, A. **(2008)**. Yeni Bir Dünyaya Doğru 1-Çevre Tüketim ve Moda,Sevgi Okulu Yayını,1.Basım, Ekim 2008, ISBN 978-605-89996-0-2.
- Aylık Enerji İstatistikleri, **(2016)**. EİGM raporu
- Baird, C. **(1999)**. Environmental Chemistry Part IV: The Greenhouse Effect and Global Warming, 173-213.
- Bevilacqua, M., Ciarapica, F. E., Giacchetta, G., and Marchetti, B. **(2011)**, A carbon footprint analysis in the textile supply chain, International Journal of Sustainable Engineering Vol. 4, No. 1;24–36,March 2011, Italy.
- Borenstein, Seth **(2015)**. "Earth is a wilder, warmer place since last climate deal made". Retrieved 29 November 2015.

Besterfield, D.H, **(1990)**. “Quality Control”, 3rd Ed.: Prentice Hall, Inc., New Jersey, USA, pp2-7.

BP Statistical Review of World Energy, **(2012)**. British Petroleum (BP), London, UK.

Business for Social Responsibility, **(2009)**. “Apparel Industry Life Cycle Carbon Mapping”, June.

Cefic-ECTA, **(2011)**. Guidelines for measuring and managing CO₂ emissions from transport operations Final 30.03.2011 Report, Issue :1

Chapagain, A.K, Hoekstra, A.Y., Savenije, H.H.G., Gautam, R. **(2006)**. The water footprint of cotton consumption: An assessment of the impact of worldwide consumption of cotton products on the water resources in the cotton producing countries, Ecological Economics 60:186-203.

Chavan, R.B. **(2001)**. Environment-friendly dyeing processes for cotton. Ind. J. Fibre Textile Res. 4:239-242.

Chico, D., Aldaya, M. M., Garrido, A. **(2013)**. A water footprint assessment of a pair of jeans: the influence of agricultural policies on the sustainability of consumer products, Journal of Cleaner Production 57:238-248, Spain.

Chisholm, Hugh, ed. **(1911)**. "Ammonia". Encyclopædia Britannica (11th ed.). Cambridge University Press.

"Climate Change **(2014)**. Synthesis Report. Summary for Policymakers” (PDF).ipcc.Retrieved 7 March 2015.

Coe, H.S.; Clevenger, G.H. **(1916)**. Methods for determining the capacities of slime-settling tanks, Transactions of the American Institute of Mining and Metallurgical Engineers. 55: 356.

Collier, A.M.**(1970)**. A Handbook of Textiles, Pergamon Press, p. 258, ISBN0080180574, ISBN0080180566.

Dean, E. B. **(1992)**. Quality Function Deployment for Large Systems", Proceedings of the 1992 International Engineering Management Conference, Eatontown, NJ, 25-28 October.

DEPA, **(1997)**. Cotton, viscose, polyester, acrylic: Danish Environmental Protection Agency Environmental Report Number 369: Environmental Assessment of Textiles, page 174.

Doll, J. E., and Baranski, M. **(2011)**. Greenhouse gas basic, Climate Change, and Agriculture Fact Sheet Series E3148, April 2011.

Domingo, **(2010)**. Early History of Water Heater Technology, Mammoth plumbing. Posterous .com. Archived from the original on March 14, 2012. Retrieved 2016-06-06.

Dong, H., Geng, Y. , Xi, F., Fujita, T. **(2013)**. Carbon footprint evaluation at industrial park level: A hybrid life cycle assessment approach, Energy Policy: 298–307.

Dyson, F.J. **(1977)**. Can We Control Carbon Dioxide in the Atmosphere, Energy 2: 287–291.

EPA, **(2010)**. Environmental Protection Agent Report

EPA, **(2013)**. “Myth vs Facts...”The U.S. Global Change Research Program, the National Academy of Sciences, and the Intergovernmental Panel on Climate Change (IPCC) have each independently concluded that warming of the climate system in recent decades is 'unequivocal'.

EPA, **(2014)**. Energy Protection Agent Report

EPA, **(2015)**. Energy Protection Agent Report

EPDK, **(2015)**. Elektrik Piyasası Gelişim Raporu

Energy Institute, **(2012)**. Enerji Enstitüsü Raporu

EUAAŞ, **(2011)**. Termik Santrallerimiz, Santral Bilgisi

EUAAŞ, **(2015)**. Elektrik Üretim Anonim Şirketi Raporu

Federal Environment Agency, **(2011)**. Environmental Standards In The Textile And Shoe Sector-A Guideline On The Basis Of The Briefs-Best Available Techniques Reference Documents Of The EU-Umwelt Bundes Amt., Brigitte Zietlow. Lichtl Ethics& Brands, May.

Geijer, A. **(1982)**. A History of Textile Art, New York: Pitman Press.

George, A., Prince, M. G. **(2013)**. Performance optimization of thermal systems in textile industries, IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 8, Issue 5, Sep. - Oct. 2013, pp. 62-68, India.

Gillenwater, M., Van Pelt, M. M. and Peterson, K., **(2002)**. Greenhouse Gases And Global Warming Potential Values, Excerpt From The Inventory of US Greenhouse Emissions And Sinks: 1990-2000, pages: 4-9, US Environmental Protection Agency, USA.

Gillis, Justin **(2015)**. “Short Answers to Hard Questions about Climate Change”.The New York Times.Retrieved 29November 2015.

Grubb and Ellis **(2007)**. Meeting the Carbon Challenge: The Role of Commercial Real Estate Owners, Users & Managers, Chicago.

Hall, A.J. **(1965)**. The standard Handbook of Textiles, New York: Chemical Publishing Co., Inc.

Hartmann, D. L.; Klein Tank, A. M. G.; Rusticucci, M. **(2013)**. "2: Observations: Atmosphere and Surface" (PDF). IPCC WGI AR5 (Report). p. 198.

Hasanbeigi, A., Price, L. **(2012)**. A review of energy use and energy efficiency technologies for the textile industry. Renewable and Sustainable Energy Reviews 16: 3648-3665.

Hindman, Hugh D. **(2009)**. The World of Child Labor: An Historical and Regional Survey. M.E. Sharpe. ISBN 978-0-7656-1707-1. Retrieved 2012-06-30.

Hussain, M.A. **(2001)**. Vacuum degasifier: Comprehensive modeling and simulation, Vacuum Volume 60, Issue 3, March 2001, pp. 325–337.

IPPC, **(2003)**. Reference document on best available techniques (BAT) for the textiles industry. Integrated Pollution Prevention and Control (IPPC), European Commission, July 2003.

IPCC, **(2006)**. Guidelines for National Greenhouse Gas Inventories, Volume.2: Energy, Chapter2: Stationary Combustion.

Ishikawa, K. **(1982)**. Guide to Quality Control, Quality Resources.

Keskin , T. **(2012)**. İklim Değişikliği Ve Enerji Sektörü, Mühendis ve Makina • Cilt: 52 Sayı: 617.

Keskinel, F. **(2006)**. Türkiye'deki Elektrik Üretimi ve Doğalgaz Kombine Çevrim Santralleri. İstanbul Bülteni 87: 17 – 26.

Khalil, M. A. K. **(1999)**. "Non-CO₂ Greenhouse Gases in the Atmosphere". Annual Review of Energy and the Environment.24: 645–661. doi:10.1146/annurev.energy.24.1.645.

Kıncay, O., Ozturk, R. **(2003)**. Thermal Power Plants in Turkey. Energy Sources 25: 135-151.

King, B. **(1989)**. Better Designs in Half the Time: Implementing Quality Function Deployment in America, GOAL/QPC, Methuen MA.

Kercher, B., Prideaux, B., Catherine Cheung, C., and Law, R. **(2010)**. Achieving voluntary reductions in the carbon footprint of tourism and climate change, Journal of Sustainable Tourism Vol. 18, No. 3, April 2010, 297–317.

Kirchain, R., Olivetti, E., T Reed Miller, T., R., and Greene, S. **(2015)**. Sustainable Apparel Materials An overview of what we know and what could be done about the impact of four major apparel materials: Cotton, Polyester, Leather, & Rubber”, Materials Systems Laboratory Massachusetts Institute of Technology Cambridge, MA, 7 October 2015.

Koohestanian, A., Hosseini, M., and Abbasian, Z. **(2008)**. “The Separation Method for Removing of Colloidal Particles from Raw Water” (PDF). American-Eurasian Journal Agriculture& Environment Science 4:266-273.ISSN1818-6769.See p.267.

Lide, David R., ed. **(2006)**. CRC Handbook of Chemistry and Physics (87 th edition). Boca Raton, FL:CRC Press.ISBN 0-8493-0487-3.

Lin, B., Moubarak, M. **(2013)**. Decomposition analysis: Change of carbon dioxide emissions in the Chinese textile industry, Renewable, and Sustainable Energy Reviews 26:389-396.

MEB (Milli Eğitim Bakanlığı), **(2013)**. Cord machine, Milli Eğitim Bakanlığı Ders Kitabı.

Metcalf & Eddy. **(2003)**. Wastewater Engineering, Treatment and Reuse. 4th ed. New York: McGraw-Hill, pp. 526-532.

Miller, E.**(1995)**. Properties, and Behaviour In Clothing Use, London: B T Batsford Ltd.

Montgomery, D.C. **(2004)**. “Introduction to Statistical Quality Control”,5 th Edition: John Wiley&Sons, Inc., New Jersey, USA, p.2-183.

Mulder M. **(1996)**. Basic Principles of Membrane Technology, Kluwer Academic Publishers, Netherlands.

Muslu, Y., **(2000)**. Ekoloji ve Çevre Sorunları, pages: 223, 255-260, Aktif Yayınevi, İstanbul.

Muthu, S-S, Li, Y. , Hu, J.Y., Mok, P.Y.(**2011**). Carbon footprint of shopping (grocery) bags in China, Atmospheric Environment 45:469-475, Hong Kong and India.

Muthu, S. S. (**2016**). Carbon Footprint Handbook International Standard Book Number-13: 978-1-4822-6223-0 (eBook - PDF)

Nasa Giss: Climate Change, (**1880**)

Natascha, M., Velden, V. D., Martin, K., Patel, Joost, G., Vogtländer, (**2014**). LCA benchmarking study on textiles made of cotton, polyester, nylon, acryl, or elastane, Int J Life Cycle Assess 19:331–356, DOI 10.107/s11367-013-0626-9.

National Research Council, (**2010**). America's Climate Choices: Panel on Advancing the Science of Climate Change, Advancing the Science of Climate Change. Washington, D.C.: The National Academies Press. ISBN 0-309-14588-0.

Oktay, Z., (**2009**). Investigation of Coal-Fired Power Plants in Turkey and a Case Study: Can Plant. Applied Thermal Engineering 29: 550-557.

Osada, Y., Nakagawa, T. (**1992**). Membrane Science and Technology, New York: Marcel Dekker.

Özer, Z. (**2002**). Ekolojik ayak izleri, Bilim ve Teknik Dergisi, 419 (1): 82-84.

Pekin, M. (**2006**), Ulaştırma Sektöründen Kaynaklanan Sera Gazı Emisyonları Yüksek Lisans Tezi, Haziran 2006, İTÜ.

Penney, David, G. (**2000**). Carbon Monoxide Toxicity, CRC Press, p. 5, ISBN 0849320658.

Potter, D. and Corbman, B. P.,(**1967**). Textiles Fiber to Fabric, New York: McGrawHill.

Rhein, M.; Rintoul, S.R. (**2013**). “3: Observations: Ocean” (PDF).IPCC WGI AR5 (Report). p.257.

Richard,P.(**2012**). Sittig's Handbook of Toxic and Hazardous Chemicals and Carcinogens (2.edition).Elsevier.p. 572. ISBN 978-1-4377-78694.Retrieved 5September2015.

Schneider, S. H. (**1990**). The Global Warming Debate Heats Up An Analysis and Perspective, Bulletin American Meteorological Society Vol 71, No 9, September 1990.

Seinfeld, John, H., Pandis, Spyros, N. **(1997)**. Atmospheric Chemistry and Physics: From Air Pollution to Climate Change, Wiley-Interscience, ISBN 0-471-17816-0.

Sinke, G. C. **(1967)**. "The enthalpy of dissociation of nitrogen trifluoride". J. Phys. Chem. 71 (2): 359–360. doi:10.1021/j100861a022.

Stumm, W.; Morgan, J.J. **(1996)**. Water Chemistry. New York: Wiley. ISBN 0-471-05196-9.

Sullivan, L.P. **(1986)**. *Quality Function Deployment, Quality Progress*, June.

Talib, F., Rahman, Z., Qureshi, M.N. **(2010)**. Pareto Analysis of Total Quality Management Factors Critical To Success for Service Industries, International Journal for Quality research UDK- 005.6 Original Scientific Paper Vol.4, No. 2, India.

T.C. Çevre ve Şehircilik Bakanlığı, Çevresel Etki Değerlendirilmesi İzin ve Denetim Genel Müdürlüğü, İl Çevre Durum Raporları, **(2012)**, <http://www.csb.gov.tr>

TEİAŞ, **(2015)**. Aylık elektrik istatistikleri.

The World Bank, **(2012)**. "Gross Domestic Product per Capita by Country in Current US\$,"<http://data.worldbank.org/indicator/NY.GDP.PCAP.CD>, son erişim tarihi: 23.12.2012.

The Geography of Transport Systems,1998-2016

Thomas, B., Fishwick, M.,Joyce, J., Santen, A., V., **(2012)**, "A Carbon Footprint for UK Clothing and Opportunities for Savings", Environmental Resources Management Limited (ERM), draft <http://www.wrap.org.uk>.

Topçu, L. **(2008)**. Toplu Taşımacılık Sistemlerinin Sera Gazı Emisyonlarına Etkisi, Yüksek Lisans Tezi, İTÜ.

Toröz, A. S. **(2015)**. Gemi Kaynaklı Atıkları Alan Bir Atık Kabul Tesisinde Karbon Ayak İzinin Belirlenmesi Yüksek Lisans Tezi, İTÜ.

TUIK, **(2013)**. Türkiye İstatistik Kurumu Raporu

TUIK, **(2015)**. Türkiye İstatistik Kurumu Raporu

Turanlı, A. **(2015)**. Estimation of carbon footprint: A case study for Middle East Technical University Master Thesis, May 2015, Middle East Technical University.

Turkey in Statistics, **(1997)**. State Institue of Statistics.

Türkiye Tekstil, Hazirgiyim ve Deri (TTHD) Ürünleri Sektörleri Strateji Belgesi ve Eylem Planı, 2015–2018, Sanayi Genel Müdürlüğü, Türkiye Cumhuriyeti Bilim, Sanayi ve Teknoloji Bakanlığı.

Weber, C.L., and Clavin, C. (2012). Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications, Environmental Science & Technology 46:5688-5695.

Url-1<http://www.epa.gov/climatechange/climate-change-basic-information>29September 2016

Url-2http://www.mmo.org.tr/resimler/dosya_ekler/a8c16d2696b35f9_ek.pdf.

Url-3<http://www.tuik.gov.tr/PreHaberBultenleri.do?id=21582>

Url-4[http://www.undp.org/content/dam/turkey/docs/news-articles/UNDP-TR-30mayis%20Seragazi %20 Emisyon %20envanter %20hesaplama.pdf](http://www.undp.org/content/dam/turkey/docs/news-articles/UNDP-TR-30mayis%20Seragazi%20Emisyon%20envanter%20hesaplama.pdf)

Url-5https://www.csb.gov.tr/db/iklim/editordosya/NIR_TUR_2012.pdf

Url-6"Practical Winery & Vineyard Journal Jan/Feb 2009". www.practicalwinery.com. 1 Feb 2009.

Url-7https://unfccc.int/files/press/backgrounders/application/pdf/fact_sheet_the_kyoto_protocol.pdf, February 2011

Url-8<https://eo.ucar.edu/kids/greenimages/carboncycle.jpg>

Url-9[https://www.capetown.gov.za/en/EnvironmentalResourceManagementDocuments Smart_Office_Toolkit/SOH_pres_Energy_2013-03-04_v2.pptx](https://www.capetown.gov.za/en/EnvironmentalResourceManagement/Documents/Smart_Office_Toolkit/SOH_pres_Energy_2013-03-04_v2.pptx) Access date 16/11/2016

Url-10<http://www.semplastik.com.tr/pdf/no7.pdf>

Url-11<http://www.wordcarbon.co.uk>

Url-12<http://www.footprintnetwork.org/it/index.php/GFN/page/calculators/> Access date 18/12/2016

Url-13http://www.slideshare.net/johick68/exploring-hotspots-in-the-carbon-footprint-and-energy-use-profiles-of-fresh-tomatoes-girija-page?qid=09303df9-3b0a-4406-9947-28488277ac90&v=qf1&b=&from_search=2 Access date 18/12/2016

Url-14 <http://www.met.sjsu.edu/.../Carbon%20Footprints.ppt>

Url-15<http://admin.izced.com/SF/204/karbonayakizi.pdf>

Url-16 [http://www.cefic.org/Documents/IndustrySupport/Transport-and-Logistics/ Best%20 Practice%20Guidelines%20-%20 General%20Guidelines/ CeficECTA%20Guidelines%](http://www.cefic.org/Documents/IndustrySupport/Transport-and-Logistics/Best%20Practice%20Guidelines%20-%20General%20Guidelines/CeficECTA%20Guidelines%20-%20General%20Guidelines.pdf)

20for%20measuring%20and%20managing%20CO2%20emissions%20from%20transport%20operations%20Final%2030.03.2011.pdf

Url-17http://www.ccr-zkr.org/temp/wrshp120411/Presentations/1_02_JVerlinden_en.pdf

Url-18 http://waterfootprint.orgmediadownloadsCA_Strategy_Final_Report_Formatted_06.08.2013.pdf

Url-19<http://waterfootprint.orgmediadownloadsReport16Vol1.pdf>

Url-20 http://waterfootprint.orgmediadownloadsTheWaterFootprintAssessmentManual_2.pdf

Url-21http://www.pseau.orgoutilsouvrageswaterfootprint_comprehensive_introduction_to_water_footprints_en.ppt

Url-22<https://www.utwente.nl/igsconferences2011-resilient-societiesKeynote%20presentationsHoekstra-IGS-SENSE-Oct11.ppt> **Access date:** 10/11/2016.

Url-23<http://www.how-green-is.co.uk/> **Access date** 10/12/2016

Url-24<http://asq.org/learn-about-quality/qfd-quality-function-deployment/overview/overview.html> **Access date** 25/03/2016

Url-25http://www.warrenhills.orgcms...Ch_06%20PPT.ppt **Access date:** 11/11/2016.

Url-26[http://www.megep.meb.gov.tr/mte_program_modulmoduller_pdf/Fitil%20\(finis%C3%B6r\)%20Makinesi%20Hesaplar%C4%B1.pdf](http://www.megep.meb.gov.tr/mte_program_modulmoduller_pdf/Fitil%20(finis%C3%B6r)%20Makinesi%20Hesaplar%C4%B1.pdf) **Access date:** 12/12/2016.

Url-27<http://www.temyad.comappkullanici-dosyalariTAHAR.pdf> **Access date:**15/10/2016.

Url-28 <http://www.fabricsearch.org> **Access date:** 15/10/2016.

Url-29 <http://www.temyad.comappkullanici-dosyalariTAHAR.pdf> **Access date:** 10/10/2016.

Url-30 <http://dardel.info/IX/processes/degasser.html> **Access date:** 08/10/2016.

Url-31<http://www.teias.gov.tr/yukdagitim/2015yiliuretimtuketimgecici.xlsx> **Accessdate:** 08/10/2016

Url-32<http://www.epdk.org.tr/TR/Dokuman/6752> **Access date:** 08 /10/ 2016

Url-33<http://www.enerji.gov.tr/tr-TR/EIGM-Raporlari> **Access date:** 08/10/2016

Url-34 <http://www.undp.org/content/dam/turkey/docs/news-articles/UNDP-TR-30mayis%20seragazi%20emisyon%20envanter%20hesaplama.pdf> **Accessdate:** 15/10/2016.

Url-35<http://www.cefic.org/Documents/RESOURCES/Guidelines/Transport-and Logistics / Best %20Practice%20Guidelines%20-%20General%20Guidelines/Cefic ECTA %20 Guidelines%20for%20measuring%20and%20managing%20CO2%20emissions%20from%20 transport%20operations%20Final%2030.03.2011.pdf?epslanguage=en> **Access date:**30/04/2016

Url-36https://people.hofstra.edu/geotrans/eng/ch8en/conc8en/fuel_consumption_container ships.html **Access date:**08/10/2016

Url-37http://www.leics.gov.ukcalculating_our_carbon_footprint.pdf **Access date :**30 /04/2016

Url-38<http://www.bilgiufku.com/kamyon-tir-ve-otobus-kilometrede-ne-kadar-yakit-yakar.html> **Access date:**30/04/2016

Url-39<http://www.persemerotasi.com/2013/01/gemiler-bunkercilere-calisiyor/>**Access date:**08/10/2016

Url-40 <http://www.mazotkacakcisi.com/1-litre-mazot-dizel-yakit-kac-kg-eder/> **Access date:**10/10/2016

Url-41<http://www.yurtdisinakargo.com/09/10/turkiye-cin-kargo-kac-gunde-gider-gonderim-suresi/> **Access date:**10/10/2016

Url-42https://forum.donanimhaber.com/m_29070140/tm.htm **Access date:**10/10/2016

Url-43<http://www.otoalsat.com/sifir-0-km-araba/mercedes-sprinter-mercedes-315-cdi-s316-minibus-uzun-16-1-2011.html> **Access date:** 08/10/2016

Url-44 <http://www.lojistikdunyasi.com/teu-nedir.html> **Access date:** 27/10/2016

Url-45 <http://www.gemijurnali.com/2014/10/teu-feu-nedir.html> **Access date:** 27/10/2016

Url-46<http://www.disticaret.biz.tr/2016/02/teu-ve-feu-nedir.html>**Accessdate:** 27/10/2016

Url-47<http://www.gemipersoneli.com/makalebak.asp?makid=31> **Access date:** 27/10/2016

Url-48http://tr.mesafe-hesaplama.himmera.com/mesafe-arjantin-istanbul-arasi_kac_saat_km_yol-24300.html **Access date:** 30/04/2016

Url-49http://tr.mesafe-hesaplama.himmera.com/mesafe-cin-istanbul-arasi_kac_saat_km_yol-20799.html **Access date:** 30/04/2016

Url-50http://tr.mesafe-hesaplama.himmera.com/mesafe-fransa-istanbul-arasi_kac_saat_km_yol-12245.html **Access date:** 30/04/2016

Url-51http://tr.mesafe-hesaplama.himmera.com/mesafe-istanbul-almanya-arasi_kac_saat_km_yol-12943.html **Access date:** 30/04/2016

Url-52http://tr.mesafe-hesaplama.himmera.com/mesafe-istanbul-japonya-arasi_kac_saat_km_yol-19643.html **Access date:** 30/04/2016

Url-53http://tr.mesafe-hesaplama.himmera.com/mesafe-istanbul-fransa-arasi_kac_saat_km_yol-15352.html **Access date:** 30/04/2016

Url-54 <http://www.sabah.com.tr/ekonomi/2015/02/06/elektrikte-kayipkacak-orani-yuzde-13e-dustu> **Access date:** 08/10/2016

Url-55http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf, **Access date:** 08/10/2016.

Url-56 <http://www.euas.gov.tr/>, **Access date:** 08/10/2016.

Url-57 [http://www.wrap.org.uk/sites/files/wrap/AppendixV-Water footprint report.pdf](http://www.wrap.org.uk/sites/files/wrap/AppendixV-Water_footprint_report.pdf)/ WRAP Project Brief, February 2011, **Access date:** 08/10/2016.

Url-58 <http://gazelektrik.com/s-s-s/dogalgaz-metrekup-fiyati>, **Access date:** 08/10/2016.

Url-59http://www.benningergroup.com/uploads/media/Karbon_ayakizi.pdf, Karbon ayak izi, Jürgen Ströhle **Access date:** 08/10/2016.

Url-60<http://www.uphs.upenn.edu/gme/pdfs/Pareto%20Chart.pdf> **Access date:** 08/10/2016.

Url-61 http://www.health.state.mn.us/divs/opi/qi/toolbox/docs/paretodiagram_ihi.pdf **Access date:** 08/10/2016.

Url-62<http://oceanservice.noaa.gov/education/pd/climate/factsheets/whatgreenhouse.pdf> **Access date:** 08/10/2016.

Url-63https://www.allianz.com/en/about_us/openknowledge/topics/environment/articles/101220-what-is-the-greenhouse-effect.html/ **Access date:** 08/10/2016.

Url-64https://www.esrl.noaa.gov/gmd/outreach/carbon_toolkit/basics.html **Access date:** 08/10/2016.

Url-65 http://www.merinoinc.co.nz/Reports/LCA_NZ_Merino_Wool.pdf **Access date:** 16/03/2017.

Url-66 http://www.ebilge.com/6221/Enerji_ve_guc_birimleri_nelerdir.html

Url-67 <https://www.extension.iastate.edu/agdm/wholefarm/pdf/c6-87.pdf>

Url-68<http://www.sanayi.gov.tr/DokumanGetHandler.ashx?dokumanId=17a4c14f-6cf1-4276-a804-c1c17975cf30> **Access date:** 10/08/2017.

Url-69 <http://www.ormegiyim.com/2016/05/18/tekstilde-ihracatin-liderleri-belli-oldu/> **Access date:** 10/08/2017.

Wackernagel, M., B. Schulz, D. Deumling, A. Callejas Linares, M. Jenkins, V. Kapos, C. Monfreda, J. Loh, N. Myers, R. Norgaard and J. Randers **(2002)**. Tracking the Ecological Overshoot of the Human Economy, Proc. Natl. Acad. Sci. 99 (14): 9266-9271.

Walker, G., King, S. D. **(2010)**. Dünyamız Isınıyor!-Küresel Isınmayla Nasıl Başa Çıkabiliriz?, Boğaziçi Üniversitesi Yayınevi, Mayıs 2010, ISBN 978-605-4238-29-3.

Wiedmann T., Minx J., Barrett J. and Wackernagel M. **(2006)**. Allocating Ecological Footprints to Final Consumption Categories with Input-Output Analysis, Ecological Economics 56 (1): 28-48.

Wingate, I. B. **(1981)**. Textile Fabrics and Their Selection, London: Addison-Wesley Publishing Com. Inc.

WRAP Project Brief, 2011

Vidyasagar, P. V. **(2000)**. Encyclopedia Textiles, Textile Spinning and Weaving Technology Volume 5, Mittal Publications, New Delhi, India.

Vineeth C., Prince M. G. **(2013)**. Impact of Condensate Recovery on Boiler Fuel Consumption in Textile Sector, Vineeth C et al. Int. Journal of Engineering Research and Applications Vol. 3, Issue 5, Sep-Oct 2013, pp.190-193, Kerala.

Yan, Y., Wang, C., Ding, D., Zhang, Y., Wu, G., Wang, L., Liu, X., Du, C., Zhang, Y., Zhao, C. **(2016)**. The Industrial carbon footprint of several typical Chinese textile fabrics, Acta Ecologica Sinica 36:119–125.

Yavuz,S.(2006). “Altı sigma yaklaşımı ve bir sanayi işletmesinde uygulama”,Doktora tezi,Atatürk Üniversitesi Sosyal Bilimler Enstitüsü İşletme Anabilim Dalı,Erzurum,Türkiye, p.9-61.

Yılmaz H. (2009). “Optimization of The Product Design Through Quality Function Deployment (QFD) and Analytical Hierarchy Process (AHP): A Case Study In A Ceramic Washbasin”, Master Thesis, İzmir.

Zonderman, David A. (1992). Aspirations and Anxieties: New England Workers and the Mechanized Factory System, 1815–1850. Oxford University Press. ISBN 978-0-19-505747-8. Retrieved 2012-06-28.



APPENDIX

Appendix-1 2014 Emission Report



Belge No: Y-41/100/2013

Rapor No: ESC-14-02-0695-497-ÖZET



10.07.2014



Sayfa No: 6/6

ESÇEM ENERJİ SİSTEMLERİ ve ÇEVRE ETÜT MERKEZİ SAN. TİC. LTD. ŞTİ

Sanayi Mah. Mor Salkım Sok. No:24
41140 İzmit/KOCAELİ

Tel: 0262 335 40 20 Faks : 0262 335 40 08

EMİSYON ÖLÇÜM ÖZET RAPORU

Rapor No	Ölçüm Tarihi	Rapor Tarihi
ESC-14-02-0695-497	28.04.2014-29.04.2014	10.07.2014

SAN. VE TİC. A.Ş.

Açıklama: Bu özet raporu ESC-14-02-0695-497 nolu Emisyon Ölçüm Raporunda verilen bilgilere göre düzenlenmiştir.

ESÇEM Enerji Sistemleri ve Çevre Etüt Merkezi San. Ve Tic. Ltd. Şti. tarafından, ... San. ve Tic. A.Ş. de 28.04.2014-29.04.2014 tarihlerinde yapılan emisyon ölçümleri için hazırlanan ESC-14-02-0695-497-ÖZET nolu raporda yer alan bilgilere göre hazırlanan bu özet rapor kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir. Sonuçlar sadece deneyi yapılan numune ve ölçüm sırasındaki proses koşulları ile ilgilidir.



Belge No: Y-41/100/2013
Rapor No: ESC-14-02-0695-497-ÖZET



10.07.2014



Sayfa No: 2/5

Tablo 1. Emisyon Kaynakları ve Bu Kaynaklarda Ölçümü Gerçekleştirilen Parametreler

Baca Kodu	Tarih	Emisyon Kaynağı	Parametre				
			CO	NO _x	SO ₂	Toz	VOC
1	29.04.2014	Gaze Tüyl Yakma Sulu Sistem Bacası	x	x	x	x	-
2	28.04.2014	Eski Ram Bacası	x	x	x	x	x
3	28.04.2014	Yeni Ram 1 Bacası	x	x	x	x	x
4	28.04.2014	Yeni Ram 2 Bacası	x	x	x	x	x
5	28.04.2014	Fleissner Lizöz Elyaf Kurutma Bacası	-	-	-	x	-
6	28.04.2014	Bursa Lizöz Elyaf Kurutma Bacası	-	-	-	x	-
7	29.04.2014	Eski Buhar Kazanı 320 m ² Baca	x	x	x	x	-
8	29.04.2014	Yeni Buhar Kazanı 400 m ² Baca	x	x	x	x	-
9	29.04.2014	Boyahane Ortam Havalandırma Asp. Bacası	-	-	-	x	x
10	29.04.2014	Vigüre Baskı Bacası	-	-	-	x	x

Tablo 2. Yakma Sistemleri ve Özellikleri

Yakma Sistemi	Isıl Gücü MW	Yakıt türü	Yakıt Miktarı (m ³ /saat)	Alt ısı değer (kcal/m ³)	Yanma Tekniği
Eski Buhar Kazanı 320 m ² Baca	10,0	Doğalgaz	1042,2	8250	Brülör
Yeni Buhar Kazanı 400 m ² Bacası	12,9	Doğalgaz	1344,5	8250	Brülör
Toplam	22,9	-	2386,7	-	-

Tablo 3. Isıl gücü olan Proses Yakma Sistemleri ve Özellikleri

Proses Yakma Sistemi	Isıl Gücü MW	Yakıt türü	Yakıt Miktarı (m ³ /saat)	Alt ısı değer (kcal/m ³)	Yanma Tekniği
Gaze Tüy Yakma- Sulu Toz Tutma Bacası	0,43	Doğalgaz	44,82	8250	Brülör
Eski Ram Bacası	3,48	Doğalgaz	362,7	8250	Brülör
Yeni Ram Bacası 1	3,48	Doğalgaz	362,7	8250	Brülör
Yeni Ram Bacası 2	3,48	Doğalgaz	362,7	8250	Brülör
Toplam	10,87	-	1132,92	-	-

ESÇEM Enerji Sistemleri ve Çevre Etüt Merkezi San. Ve Tic. Ltd. Şti. tarafından, ... San. ve Tic. A.Ş. 'de 28.04.2014-29.04.2014 tarihlerinde yapılan emisyon ölçümleri için hazırlanan ESC-14-02-0695-497-ÖZET nolu raporda yer alan bilgilere göre hazırlanan bu özet rapor kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir. Sonuçlar sadece deneyi yapılan numune ve ölçüm sırasındaki proses koşulları ile ilgilidir.



Belge No: Y-41/100/2013

Rapor No: ESC-14-02-0695-497-ÖZET



10.07.2014



Sayfa No: 3/5

Tablo 4. Tesiste Gerçekleştirilen Emisyon Ölçüm Sonuçları ve SKHKY Yönetmeliği Ek-5 Sınır Değerleri

Emisyon Kaynağı Kodu	Emisyon Kaynağı Adı	SKHKY (Ek-5'de Yer Aldığı Grup)	Parametre (mg/Nm ³)							
			Toz		CO		NO _x		SO ₂	
			Ort.	SD.	Ort.	SD.	Ort.	SD.	Ort.	SD.
6	Eski Buhar Kazanı 320 m ² Baca	A.5	8,51±1,28	10	0,0	100	17,41±1,77	800	0,0	100
7	Yeni Buhar Kazanı 400 m ² Bacası	A.5	8,40±1,26	10	0,0	100	38,23±3,90	800	0,0	100

Tablo 5. Tesiste Gerçekleştirilen Emisyon Ölçüm Sonuçları ve SKHKK Yönetmeliği Ek-1 (01.01.2012 tarihinden itibaren Ek-7'de yer alan sınır değerler geçerli olacaktır.) Sınır Değerleri

Emisyon Kaynağı Adı	Kuru Bazda Baca Gazı Debisi	Toz		Organik Buhar ve Gazlar *			
				II.Sınıf			
		mg/Nm ³	mg/Nm ³		kg/saat		
			Nm ³ /saat	Ort.	SD.	Ort.	SD.
Gaze Tüy Yakma Sulu Sistem Bacası	1098,2	11,56±1,73	179	-	100	-	2
Eski Ram Bacası	8795,1	8,74±1,31	166	0,53±0,01	100	0,01	2
Yeni Ram 1 Bacası	5816,9	11,33±1,70	171	0	100	0	2
Yeni Ram 2 Bacası	1803,0	9,20±1,38	178	0,53±0,01	100	0,001	2
Fleissner Lizöz Elyaf Kurutma Bacası	1553,4	6,91±1,04	178	-	100	-	2
Bursa Lizöz Elyaf Kurutma Bacası	1507,1	11,95±1,79	178	-	100	-	2
Boyahane Ortam Hav. Asp. Bacası	10276,6	12,01±1,80	164	0	100	0	2
Vigüre Baskı Bacası	1118,2	15,78±2,37	178	0	100	0	2

*Sınır değerler Ek-7 Tablo 7.2.2 'den alınmıştır.

ESÇEM Enerji Sistemleri ve Çevre Etüt Merkezi San. Ve Tic. Ltd. Şti. tarafından, ... San. ve Tic. A.Ş. 'de 28.04.2014-29.04.2014 tarihlerinde yapılan emisyon ölçümleri için hazırlanan ESC-14-02-0695-497-ÖZET nolu raporla yer alan bilgilere göre hazırlanan bu özet rapor kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir. Sonuçlar sadece deneyi yapılan numune ve ölçüm sırasındaki proses koşulları ile ilgilidir.



Belge No: Y-41/100/2013
Rapor No: ESC-14-02-0695-497-ÖZET



10.07.2014



Sayfa No: 4/6

Tablo 6. SKHKKY Ek-1 kapsamında Tozumaya Karşı Alınan Önlemler

Yönetmelik Maddesi	Tozumaya Karşı Alınan Önlemler
Ek-1.b.2	-
Ek-1.c	İşletmede açıkta depolanan toz yapıcı yığma malzeme bulunmamaktadır.
Ek-1.d	Tesiste toz yapıcı yanma ve üretim artığı bulunmamaktadır.
Ek-1.e	Tesis içi yollar asfalt ile kaplıdır.
Ek-1.f	Gaze Tüy Yakma Sulu Toz Tutma Bacasında sulu filtre bulunmaktadır. Filtreler kapalı ortamda boşaltılmaktadır.

Tablo 7. Tesiste Bulunan Baca Yükseklikleri ve Hızlarının Değerlendirmesi

YAKMA SİSTEMİ									
Kaynak Kodu	Emisyon Kaynağı Adı	Isıl Güç MW	Baca Gazı Hızı (m/sn)	Sınır Değer (m/sn)	Çatı Tipi (Eğik/Düz)	Baca Yüksekliği Yerden		Baca Yüksekliği Çatıdan	
						Baca Yerden (m)	Sınır Değer (m)	Çatıdan (m)	Sınır Değer (m)
1	Gaze Tüyl Yakma Sulu Sistem Bacası	0,43	5,5	2	Eğik	10	-	2	1
2	Eski Ram Bacası	3,48	6,4	4	Eğik	12	10	6	3
3	Yeni Ram 1 Bacası	3,48	7,4	4	Eğik	11	10	5	3
4	Yeni Ram 2 Bacası	3,48	9,4	4	Eğik	14	10	1,5	3
7	Eski Buhar Kazanı 320 m ² Baca	10,0	6,5	4	Düz	19	10	9	3
8	Yeni Buhar Kazanı 400 m ² Baca	12,90	6,4	4	Düz	18	10	9	3
PROSES SİSTEMİ									
Kaynak Kodu	Emisyon Kaynağı Adı	Isıl Güç MW	Baca Gazı Hızı (m/sn)	Sınır Değer (m/sn)	Çatı Tipi (Eğik/Düz)	Baca Yüksekliği Yerden		Baca Yüksekliği Çatıdan	
						Baca Yerden (m)	Sınır Değer (m)	Çatıdan (m)	Sınır Değer (m)
5	Fleissner Lizöz Elyaf Kurutma Bacası	-	6,6	4	Eğik	10,5	-	1,55	1,5
6	Bursa Lizöz Elyaf Kurutma Bacası	-	5,3	4	Eğik	11,3	-	2,3	1,5
9	Boyahane Ortam Havalandırma Asp. Bacası	-	5,5	4	Eğik	14,65	-	2,65	1,5
10	Vigüre Baskı Bacası	-	4,7	4	Eğik	10,5	-	1,5	1,5

ESÇEM Enerji Sistemleri ve Çevre Etüt Merkezi San. Ve Tic. Ltd. Şti. tarafından, ... San. ve Tic. A.Ş. de 28.04.2014-29.04.2014 tarihlerinde yapılan emisyon ölçümleri için hazırlanan ESC-14-02-0695-497-ÖZET nolu raporla yer alan bilgilere göre hazırlanan bu özet rapor kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir. Sonuçlar sadece deneyi yapılan numune ve ölçüm sırasındaki proses koşulları ile ilgilidir.



Tablo 8. Tesiste Gerçekleşen Emisyonların Kütlesel Debileri ve SKHKK Yönetmeliği Sınır Değerleri

Emisyon Kaynağı Kodu	Emisyon Kaynağı Adı	Parametre (kg/saat)						Sürekli * Ölçülen Parametreler
		CO	NO _x	NO	SO ₂	Toz	VOC	
1	Gaze Tüy Yakma Sulu Sistem Bacası	0,22	0,003	0,0	0,0	0,01	-	-
2	Eski Ram Bacası	0,06	0,02	0,01	0,0	0,08	0,01	-
3	Yeni Ram 1 Bacası	0,33	0,01	0,0	0,0	0,07	0	-
4	Yeni Ram 2 Bacası	0,01	0,0	0,0	0,0	0,02	0,001	-
5	Fleissner Lizöz Elyaf Kurutma Bacası	-	-	-	-	0,01	-	-
6	Bursa Lizöz Elyaf Kurutma Bacası	-	-	-	-	0,02	-	-
7	Eski Buhar Kazanı 320 m ² Baca	0,0	0,13	0,09	0,0	0,07	-	-
8	Yeni Buhar Kazanı 400 m ² Bacası	0,0	0,21	0,14	0,0	0,05	-	-
9	Boyahane Ortam Havalandırma Asp. Bacası	-	-	-	-	0,12	0	-
10	Vigüre Baskı Bacası	-	-	-	-	0,02	0	-
Toplam Değer		0,62*	0,373	0,24	0,0	0,47	0,011	
		0,0**						
SINIR DEĞERLER								
SKHKKY Ek-3.d		5*	-	20	60	10	10	
		50**						
SKHKKY Ek-2 Baca		500	40	-	60	10	30	
SKHKKY Ek-2 Baca Dışı		50	4		6	1	3	

ESÇEM Enerji Sistemleri ve Çevre Etüt Merkezi San. Ve Tic. Ltd. Şti. tarafından, ... San. ve Tic. A.Ş. de 28.04.2014-29.04.2014 tarihlerinde yapılan emisyon ölçümleri için hazırlanan ESC-14-02-0695-497-ÖZET nolu raporda yer alan bilgilere göre hazırlanan bu özet rapor kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir. Sonuçlar sadece deneyi yapılan numune ve ölçüm sırasındaki proses koşulları ile ilgilidir.



İş bu form Esçem Enerji Sistemleri ve Çevre Etüt Merkezi San. Tic. Ltd. Şti Laboratuvarı tarafından doldurulmuştur.

Formdaki tüm bilgiler hava emisyonu ölçüm raporunda mevcuttur. Tesisin hava emisyonu ölçüm raporu ve bu form SKHKKY'nin ilgili hükümleri dikkate alınarak düzenlenmiştir.

Ölçümü Yapan

İmran KÖKERER

Tekniker

Onay

Raporu Onaylayan

Engin TUNCA

Laboratuvar Sorumlusu

Onay

ESÇEM Enerji Sistemleri ve Çevre Etüt Merkezi San. Ve Tic. Ltd. Şti. tarafından, ... San. ve Tic. A.Ş.'de 28.04.2014-29.04.2014 tarihlerinde yapılan emisyon ölçümleri için hazırlanan ESC-14-02-0695-497-ÖZET nolu raporda yer alan bilgilere göre hazırlanan bu özet rapor kısmen kopyalanıp çoğaltılamaz. İmzasız ve mühürsüz raporlar geçersizdir. Sonuçlar sadece deneyi yapılan numune ve ölçüm sırasındaki proses koşulları ile ilgilidir.



Appendix 2. Survey about Carbon, Water, and Energy Footprint for Environmental Oriented Production

Appendix 2.1- Survey About Carbon, Water, and Energy Footprint for Environmental Oriented Production (Original survey-Turkish)

1) İşletmenin ticari ünvanı nedir?

- A) LTD ŞİRKET
- B) AŞ
- C) DİĞER
- D) Yabancı ortaklık
- E) Adi komandit ŞTİ

2) İşletme kaç yıldır faaliyettedir?

- A)1-5
- B) 6-10
- C) 11-15
- D)16-20

3) İşletmenin yeri nerededir?

- a. OSB
- b. KSS
- c. Teknopark
- d. Serbest bölge
- e. Diğer

4) Çalışanların sayısı kaç?

Büro çalışanı kişi

Üretimde çalışan.....kişi

5) İşletmenizdeki çalışma düzeni nasıl?

- A) Günde 8 saat/3 vardiya
- B) Günde 12 saat/2 vardiya
- C) Günde.....saat/1 vardiya
- D) Dörtlü vardiya sistemi
- E) Vardiya +saat mesai
- F) Diğer

6) Üretim tipinize x işareti koyun.

İplik	
Örme	
Dokuma	
Boyama	
Baskı boyama	
Konfeksiyon	
Apreleme	

7) İhracat yapıyor musunuz?

- A) Yapıyoruz
B) Yapmıyoruz

8) Yurt dışına sattığınız ürünün standarda uygunluk belgesi var mı?

- A) Evet B)Hayır

Eğer cevabını Evetse, ne belge/leriniz var?

9) Yurt içi satışlarınız için ISO 14001 sertifikanız var mı? Hangi yılda aldınız?

10) İşletmenin sahip olduğu belge sertifikalar nelerdir?

- ☐ Oko Tex Standard 100
☐ ISO 9000/9001
☐ ISO 14000/14001
☐ TSE
☐ Diğer.....

11) Hammadde teminin nereden sağlıyorsunuz?

- A) Yurt içi B) Yurt dışı C) Her ikisi de

12) Firmanızdaki üretim çevre odaklı mı?

- A) Evet
B) Hayır

Cevabınız Evet ise 13-17 nolu soruları cevaplayınız. Hayır ise bu soruları atlayınız.

13) Üretiminizin çevre odaklı olmasının firmanın ekonomik boyutuna yansıması nasıl oldu?

- A) Yansıdı C) Yansımadı
B) Yansıdı ve gelir arttı D) Yansımadı ve gelir düştü

14) Üretiminizin çevre odaklı olması için üretim proseslerini değiştiriyor musunuz?

- A) Evet
B) Hayır

15) Üretiminizin çevre odaklı olması için makine teknolojisini hangi sıklıkla değiştiriyorsunuz?

- A) Hiç değiştirilmez C) 3-5 yıl
B) 1-3 yıl D) 5 yıldan daha fazla

16) Üretiminizin çevre odaklı olması için daha az kirlilik yaratan malzeme/ekipman kullanıyor musunuz?

- A) Evet B) Hayır

17) Çalışanlara çevre odaklı eğitim veriliyor mu?

- A) Evet B) Hayır

Cevabınız Evet ise firmada çalışanlara yönelik çevre odaklı eğitim hangi sıklıkla verilmektedir?

- A) 6 ayda bir C) 1 yıldan fazla sürede bir
B) 1 yılda bir D) Hiç verilmemektedir

18) Çalışanlara çevre odaklı eğitim verilmesi size göre önemli midir?

- A) Çok önemli C) Az önemli
B) Önemli D) Önemsiz

19) Çevre odaklı üretim, stratejik planlarınızda yer alıyor mu?

- A) Alıyor B) Almıyor

Cevabınız Evetse ne kadar süre içinde hedeflenmiştir?

- A) 6 aydan az C) 1 yıl-3 yıl
B) 6 ay-1 yıl D) 3 yıldan fazla

20) Tedarikçilerinizle çevre odaklı olmayla ilgili herhangi bir çalışmanız var mı?

- A) Var B) Yok

Cevabınız Var ise ne kadar süre içinde hedeflenmiştir?

21) Aşağıdaki faktörleri önem derecesine göre x işaretiyle işaretleyiniz.

Faktör/Önem derecesi	Önemsiz	Az önemli	Orta düzeyde önemli	Önemli	Çok önemli
CO ₂ emisyon					
SO ₂ emisyon					
Su tüketimi					
Enerji tüketimi					
Kalite					
Verimlilik					

22) Yıllık karbon ayak iziniz kaç kg CO2?

A) Bilinmemektedir

B)

<u>Yıllık ürün cinsi</u>	<u>Yıllık ürün miktarı</u>	<u>kg CO2 emisyon</u>

23) Malzeme/ürün türüne göre su kullanımı yılda m³su /ton ürün olarak ne kadardır?

<u>Ürün Türü</u>	<u>Su tüketimi [m³/ton su tüketimi]</u>

24) Üretimdeki su tüketiminin azaltılmasına yönelik çalışmanız var mı?

A) Var

B) Yok

Cevabınız Var ise, yıllık yüzde ne kadar tasarruf sağladınız?

25) Atık suyun arıtılmasına yönelik çalışmanız var mı?

26) Atık suyun geri kazanımı sağlanıyor mu? Ne şekilde bu geri kazanım (Membran teknolojisi, kimyasal, biyolojik arıtma vb) sağlanır? Yüzde ne kadar geri kazanım sağlanıyor?

27) Hammaddeyi ürüne dönüştürürken kullanılan maddelerin toksik etkileri en az olanlar olmasına (arasından seçilmesine) gayret ediyor musunuz?

A) Evet

B) Hayır

C) Evet ise nasıl?.....

28) Üretimdeki enerji tasarrufuna yönelik çalışmanız oldu mu?

A) Evet

B) Hayır

Evetse yıllık tasarruf ile ilgili bilgileri tabloya yazınız.

Enerji kaynağı	Yıllık tasarruf(%)
Elektrik	
Doğalgaz	
Kömür	
Fuel oil	
Yenilenebilir enerji kaynağı(güneş, rüzgar vb.)	

29) Üretimde enerji tasarrufuna yönelik ileriye dönük planınız var mı?

A) Evet

B) Hayır

Evitse hedeflenen tasarruf yüzdesi ne kadar, tabloyu doldurunuz.

Enerji kaynağı	Yıllık tasarruf(%)
Elektrik	
Doğalgaz	
Kömür	
Fuel oil	
Yenilenebilir enerji kaynağı (güneş, rüzgar vb.)	

30) Aşağıdaki su ve enerji tüketimiyle ilgili tabloyu doldurunuz.

Üretim Prosesi	Yıllık Su Tüketimi (m ³ /Yıl)	Yıllık Enerji Tüketimi(Kwh/Yıl)					
		Doğalgaz	Sıvı yakıt (Motorin, benzin vb.)	LPG	Katı yakıt (Kömür vb.)	Elektrik	Yenilenebilir enerji (güneş, rüzgar vb.)

- 31) Yıllık su tüketimi ölçümünü sağlayan sayaç sistemi bulunuyor mu? Bu ölçülen değerler raporlanıyor mu?
- A) Bulunuyor ve Raporlanıyor
 - B) Bulunuyor, fakat raporlanmıyor
 - C) Bulunmuyor
- 32) Yıllık enerji tüketimi ölçümünü sağlayan sayaç sistemi bulunuyor mu? Bu ölçülen değerler raporlanıyor mu?
- A) Bulunuyor ve Raporlanıyor
 - B) Bulunuyor, fakat raporlanmıyor
 - C) Bulunmuyor
- 33) Makinelerin periyodik bakımları imalatçının önerilerine uygun sıklıkta yapılıyor mu?
- A) Evet
 - B) Hayır
 - C) Kısmen
- 34) Makinelerin kapasite kullanım oranları size göre önemli midir?
- A) Çok önemli
 - B) Önemli
 - C) Az önemli
 - D) Önemsiz
- 35) Tesiste ki yakma sistemleri teknolojisi daha çevre dostu olabilir mi? Maliyete katlanılabilir mi?
- A) Olabilir ve katlanılabilir
 - B) Olabilir, fakat katlanılmaz
 - C) Olamaz

36) Yakma sistemleri teknolojisi deęiřiklięi hangi sıklıkla yapılır?

- A) 1-3 yıl
- B) 3-6 yıl
- C) 6-9 yıl
- D) 9 yıldan fazla sürede
- E) Hiç deęiřtirilmez

37) Ulaşım açısından bazı bilgileri yıllık bazda doldurunuz.

Ulaşım Türü	Araç sayısı	Araç türü	Yakıt türü	Yıllık ton miktarı[ton]
Nakliye				
Servis				

38) Emisyon ölçümünüz kaç yılda bir yapılıyor? Emisyon ölçümüyle ilgili aşağıdaki tabloyu doldurunuz.

Emisyon ölçülen yıl	Ölçülen miktarlar(mg/Nm ³)				
	CO	NO _x	SO ₂	CO ₂	VOC

Appendix 2.2-Survey About Carbon, Water and Energy Footprint for Environmental Oriented Production (Survey-English)

1- What is the commercial title of the company?

- a- Limited company
- b- Joint stock company
- c- Other
- d- Foreign partnership
- e- Limited partnership

2- How long has the company been operating?

- a- 1-5 b- 6-10 c- 11-15 d- 16-20

3- Where is the location of the company?

- a-Organized industrial zone
- b-Small industrial area (KSS)
- c-Technopark
- d-Free zone
- e-Other

4- How many numbers of employees in the company?

Office worker person

The person working in the production.....person

5- How is the work schedule of your company?

- a- 8 hours a day/3 shifts d- Quadruple shift system
- b- 12hours a day/ 2 shifts e- Shift+over time hours
- c- hours a day/1 shift f- Other (8 hours day/2 shifts)

6- Mark (x) your types of production.

Fiber	
Knitting	
Weaving	
Dyeing	
Print dyeing	
Garment industry	
Chemical finishing	

7- Do you export?

a-Yes

b-No

8- Do you have a certificate of conformity of the products you sell abroad?

a- Yes

b- No

If you answer is yes, what document(s) you have?

9- Do you have ISO 14001 certificate for your domestic sales? When did you take this certificate?

10- What are certificates of your company?

☐ Oko-Tex Standard 100

☐ ISO 9000/9001

☐ ISO 14000/14001

☐ TSE

☐ Other.....

11- Where do you supply the raw material?

- a- Domestic b- Abroad c-Both of them

12- Is your company focused on the environmental oriented production?

- a- Yes
b- No

If your answer is yes, you will answer 13-17 questions. If your answer is no, you will not answer these questions.

13- How is your production's environmental oriented affected in the economic dimension of your company?

- A-Effectuated C- No effect
B-Effectuated and increased income D- No effect and decreased income

14- Do you change your production processes for environmental oriented production?

- a-Yes
b-No

15- How often do you change the machine technology for to make your environmental oriented production?

- a-No change c-3-5 year
b-1-3 year d- >5 year

16- Do you use less polluting material/equipment for to make your environmental oriented production?

- a- Yes b- No

17- Do you give environmental oriented production training for your employees?

- a-Yes b- No

If your answer is yes, how often do you give the training for employees at the company?

- a-once every six months c- above 1 year
b-every 1-year d- not given

18- What is the importance of giving environmental oriented training to employees?

a-Very important

c- Less important

b-Important

d- Not important

19- Is environmental oriented production included in your strategic plans?

a- Yes

b- No

If your answer is yes, how long is your target?

A) <6-month

C) 1 year-3 year

B) 6 month-1 year

D)>3 year

20- Do you have any work on being environment-oriented with your suppliers?

a-Yes

b- No

If your answer is yes, how long it has been targeted.

21- Mark the following factors with the (x) sign according to their importance

Factor/Importance degree	No important	Less important	Middle degree important	Important	Very important
CO ₂ emission					
SO ₂ emission					
Consumed water					
Consumed energy					
Quality					
Efficiency					

22- How many carbon footprints as kg CO₂ per year in the production?

a-Unknown

b-Known

<u>Annual product type</u>	<u>Annual product quantity</u>	<u>kg CO₂ emission</u>

23- How much is water usage as m³water/tonne product per year according to the material/type of production?

<u>Type of product</u>	<u>Consumed water [m³/tonne water]</u>

24- Do you have any efforts to reduce water consumption in production?

a- Yes

b- No

If your answer is yes, how much savings did you make per year?

25- Do you have any efforts to treat the wastewater?

26- Is recycling of wastewater provided? How is this recovery (Membrane technology, chemical, biological treatment etc) provided? How much is the recovery achieved?

27- Are you trying to make the substances used to convert the raw material into the least toxic ones?

a-Yes

b-No

If your answer is yes, how is it provided?.....

28- Have you been working to save energy in production?

a- Yes

b- No

If your answer is yes, you will write about the annual saving information.

Energy source	Annual savings (%)
Electricity	
Natural gas	
Coal	
Fuel oil	
Renewable energy source (solar, wind etc.)	

29- Do you have any future plans for energy savings in production?

a-Yes

b-No

If your answer is yes, how much is the target saving percentage? Fill in the table.

Energy source	Annual savings (%)
Electricity	
Natural gas	
Coal	
Fuel oil	
Renewable source (solar, wind etc.)	

30- Fill in the below table regarding water and energy consumption.

Production process	Annual water consumption (m ³ water/year)	Yıllık Enerji Tüketimi(Kwh/Yıl)					
		Natural gas	Liquid fuel (diesel etc.)	LPG	Solid fuel (Coal etc.)	Electricity	Renewable (solar, wind etc.)

31- Is there a counter system that provides annual water consumption measurement?

a-Finding and Reporting

b-Finding, but not reported

c-Not find

32- Is there a counter system that provides annual energy consumption measurement? Are these measured values reported?

a-Finding and reporting

b-Finding, but not reported

c-Not find

33- Is the periodic maintenance of the machines carries out as often as the manufacturer suggests?

a-Yes

b-No

c-Partially

34- Are the capacity utilization rates of the machines important for you?

a-Very important

c- Less important

b-Important

d- Not important

35- Is it possible that the conventional combustion systems are more environmentally friendly? Can the cost be affordable?

a-Could and bearable

b-Could, but unbearable

c-Could not

36- How often does the combustion system technology change?

a-1-3 years

b-3-6 years

c-6-9 years

d-More than 9 years

e-No change

37- Fill in some information on an annual basis in terms of transportation

Types of transportation	Number of vehicles	Type of vehicle	Type of fuel	Amount of annual tonne [tonne]
Transportation				
Service				

38- How many years does the emission measurement take place? Fill in the table below regarding emission measurement

Year	Measured quantity (mg/Nm ³)				
	CO	NO _x	SO ₂	CO ₂	VOC

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