INVESTIGATION OF SECTORAL PRIORITIES FOR CLEANER (SUSTAINABLE) PRODUCTION AT REGIONAL AND NATIONAL LEVEL

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ABSTRACT

INVESTIGATION OF SECTORAL PRIORITIES FOR CLEANER (SUSTAINABLE) PRODUCTION AT REGIONAL AND NATIONAL LEVEL

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One of the most important factors leading to success of a regional/national cleaner (sustainable) production strategy is sector-focused approach. Due to limited resources and other constraints, it is a necessity to make a prioritization between sectors for cleaner (sustainable) production practices. Thus, within the scope of this study, manufacturing industry sub-sectors in İzmir and in Turkey were prioritized based on various criteria. The results should assist policy makers in the preparation of related sectoral roadmaps and action plans.

The prioritization of manufacturing industry sub-sector was accomplished via Multi-Criteria Decision Making (MCDM) method with the integration of recent available data and by taking feedback from the stakeholders. Investigation of the sectoral priorities was carried out both at regional (İzmir) and national (Turkey) level. The criteria used in prioritization of manufacturing industry sub-sectors in İzmir were water and energy consumption, amount of wastewater discharged, amount of solid waste and hazardous waste generated, greenhouse gas emissions, Herfindahl-

Hirschman Index (statistical measure of market concentration), sectoral employment, number of companies, export share, added value and suitability for cleaner (sustainable) production. In the prioritization analysis of Turkey all of the aforementioned criteria for İzmir except Herfindahl-Hirschman Index, number of companies and added value were used.

Based on the results of this study, the top five high priority industrial sectors for cleaner (sustainable) production practices in İzmir are basic metal industry, food products and beverages, chemicals and chemical products, other non-metallic mineral products and coke and refined petroleum. In the sectoral prioritization analysis for cleaner (sustainable) production in Turkey textile industry takes the place of coke and refined petroleum. These sectors coincide with the priority sectors identified based on different purposes by other regional and national institutions.

Keywords: Prioritization, Cleaner (Sustainable) Production, Manufacturing Industry, Multi-Criteria Decision Making Method

ÖZ

BÖLGESEL VE ULUSAL ÖLÇEKTE TEMİZ (SÜRDÜRÜLEBİLİR) ÜRETİM İÇİN SEKTÖREL ÖNCELİKLERİN BELİRLENMESİ

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Ulusal temiz (sürdürülebilir) üretim stratejilerinde başarıya ulaşmayı sağlayan en önemli bileşenlerden birisi de sektör odaklı yaklaşımlardır. Kaynakların sınırlılığı ve diğer kısıtlar göz önüne alındığında, temiz (sürdürülebilir) üretim uygulamaları için sektörler arasında önceliklendirme yapılması bir zorunluluktur. Bu nedenle, bu çalışma kapsamında İzmir'de ve Türkiye'de bulunan imalat sanayi alt sektörlerinin çeşitli kriterler baz alınarak önceliklendirilmesi amaçlanmıştır. Önceliklendirme sonuçlarının ilgili sektörel yol haritaları ve aksiyon planlarının hazırlanması sürecinde politika yapıcılara yardımcı olması hedeflenmiştir.

Bu çalışma kapsamında, ilgili paydaşların katkılarıyla belirlenen kriterler ve ulaşılabilen en güncel bilgiler çerçevesinde, Çok Ölçütlü Karar Verme (ÇÖKV) Metodu ile ülkemizdeki imalat sanayi alt sektörleri temiz (sürdürülebilir) üretim uygulamaları için önceliklendirilmiştir. Sektörel önceliklerin belirlenmesi hem bölgesel (İzmir) hem de ulusal (Türkiye) ölçekte gerçekleştirilmiştir. İzmir'deki imalat sanayi sektörlerinin önceliklendirmesi için kullanılan kriterler; su ve enerji tüketimleri, deşarj edilen atıksu miktarı, üretilen katı atık ve tehlikeli atık miktarları, hava emisyonları, Herfindahl-Hirschman Endeksi (pazar yoğunluğuna yönelik istatistiki bir ölçü), sektörel istihdam, firma sayısı, ihracat payı, katma değer ve temiz (sürdürülebilir) üretime uygunlukları olarak sıralanmaktadır. Türkiye için yapılan önceliklendirme çalışmasında ise Herfindahl-Hirschman Endeksi, firma sayısı ve katma değer kriterleri dışında İzmir için bahsi diğer tüm kriterler kullanılmıştır.

Bu çalışmanın sonuçlarına göre İzmir'de temiz (sürdürülebilir) üretim uygulamaları için öncelikli olarak ortaya çıkan ilk beş sektör sırasıyla; ana metal sanayi, gıda ürünleri ve içecek imalatı, kimyasal madde ve ürünleri imalatı, metalik olmayan diğer mineral ürünlerin imalatı ve kok ve rafine edilmiş petrol ürünleri imalatıdır. Türkiye'de temiz (sürdürülebilir) üretim için yapılan sektörel önceliklendirmede ise tekstil sektörü, kok ve rafine edilmiş petrol ürünleri imalatının yerini almaktadır. Bu çalışma kapsamında öncelikli olarak belirlenen sektörler diğer bölgesel ve ulusal kurumların farklı amaçlarla belirlediği öncelik listeleri ile de önemli ölçüde örtüşmektedir.

Anahtar Kelimeler: Önceliklendirme, Temiz (Sürdürülebilir) Üretim, İmalat Sanayi, Çok Ölçütlü Karar Verme Yöntemi

To mom & dad

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LIST OF ABBREVIATIONS

AHP	: Analytical Hierarchy Process
APO	: Asian Productivity Organization
BTSB	: Ministry of Science, Industry and Technology
ÇMO	: Chamber of Environmental Engineers
ÇOB	: Ministry of Environment and Forestry
DPT	: State Planning Organization
DSİ	: State Hydraulic Works
EBSO	: Aegean Region Chamber of Industry
EEA	: European Environment Agency
EU	: European Union
GEKA	: South Aegean Development Agency
GHG	: Greenhouse Gas Emissions
GIS	: Geographical information system
I.R	: Inconsistency Ratio
IPCC	: Intergovernmental Panel on Climate Change
ISIC	: International Standard Industrial Classification
İBB	: İzmir Metropolitan Municipality
İZKA	: İzmir Development Agency
İZTO	: İzmir Chamber of Commerce
MCDM	. Multi-Criteria Decision Making
NACE	: Statistical Classification of Economic Activities in the European Community
OECD	: Organization for Economic Co-operation and Development
RPA	: Risk and Policy Analysts Ltd
SCI	: Social Security Institution
SME	: Small and Medium Enterprises
STB	: Ministry of Industry and Trade
TTGV)	: Technology Development Foundation of Turkey
TUBITAK	: The Scientific and Technological Research Council of Turkey
TÜİK	: Turkish Statistical Institute
TÜSİAD	: Turkish Industry and Business Association
UNEP	: United Nations Environmental Programme

UNEP-DTIE	: UNEP Department of Technology, Industry and Economy
UNFCC	: United Nations Framework Convention on Climate Change
US EPA	: United States. Environmental Protection Agency
WBCSD	: World Business Council for Sustainable Development
WSM	: Weighted Sum Method

CHAPTER 1

INTRODUCTION

Cleaner (sustainable) production concept is defined as “decreasing risks on human and environment by continuous application of an integrated and preventive environmental strategy on products and processes”. It aims to prevent/minimise pollution, contrary to common pollution control approaches. Pollution control approaches accept the production and design phases as unchangeable factors; therefore pollution is seen as an inevitable result of these phases, and solutions are sought after pollution occurs. Consequently, these approaches lead to additional costs for the institutions by focusing on waste treatment facilities. On the other hand, cleaner production approaches accept pollution as a result of deficiencies and inefficiencies during design, raw material use and production processes and aim to find solutions through necessary improvements during these processes (United Nations Environmental Programme [UNEP], 2007). Cleaner production has a close relation with sustainability, besides development of new products, processes, systems and services (Glavic & Lukman 2007).

UNEP Department of Technology, Industry and Economy (UNEP-DTIE) took first significant step by launching cleaner production programme in 1989. The main aim was to raise awareness regarding subject, form a structure and generalise sustainable development works by stressing its benefits. Cleaner production concept that has been adopted by many countries, agencies and institutions has obtained a global qualification since then (UNEP, 2002). Then, it was evolved to ‘sustainable production’ (Narayanaswamy & Stone, 2007). Sustainable production was defined as “the creation of goods and services using processes and systems that are non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for employees, communities and consumers; and socially and creatively rewarding for all working people” (Veleva & Ellenbecker, 2001). ‘Cleaner production’ concept is still used by many related institutions while ‘sustainable production’ concept has been rapidly adopted (Veleva & Ellenbecker, 2001; Glavic & Lukman, 2007; TTGV, 2010). Therefore, the term ‘cleaner (sustainable) production’ is adopted in this study.

Cleaner (sustainable) production concept has been firstly brought to the agenda of Turkey by The Scientific and Technological Research Council of Turkey (TUBITAK) and Technology Development Foundation of Turkey (TTGV) in 1999 (Science-Technology-Industry Discussion Platform, 1999). Cleaner production concept is placed in the priority areas of the Supreme Council for Science and Technology which determines the national science and technology policies. This concept has also been emphasised in the Environment and Sustainable Development Panel in the scope of the TUBITAK’s Vision 2023 Project (TUBITAK, 2011). Moreover, it was among the main themes stated in Eighth Five Year (State Planning Organization [DPT], 2000) and Ninth Seven Year Development Plans (DPT, 2007) and documents prepared for European Union (EU) accession efforts (Ministry of Environment and Forestry [ÇOB], 2006; Ulutaş et al., 2012).

The term cleaner (sustainable) production has been cited in many other policy and strategy documents of the top level agency/institutions on science, technology, development, etc., in Turkey for over a decade. However, it is not sufficiently known and applied except its energy efficiency aspect in Turkey (Ulutaş et al., 2012). One of the most important factors leading to success of a national/regional cleaner (sustainable) production strategy is sector-focused approach. Due to limited resources and other constraints, it is a necessity to make a prioritization between sectors for cleaner (sustainable) production applications.

To overcome the deficiency in this area, the Ministry of Environment and Forestry (with its former name) supported the project “Determination of the Framework Conditions and Research-Development Needs for the Dissemination of Cleaner (Sustainable) Production Applications in Turkey” which was carried out in 2009 by TTGV and Prof. Dr. Göksel N. Demirer, as the consultant. Another project in this area at a regional scale is “Dissemination of Eco-Efficiency (Cleaner Production) Applications in İzmir” which has been started in 2011 by TTGV and Prof. Dr. Göksel N. Demirer, as the consultant in cooperation with İzmir Development Agency (İZKA) and Aegean Region Chamber of Industry (EBSO). One of the specific targets in these projects is to prioritize manufacturing industry sub-sectors in Turkey and in İzmir respectively for cleaner (sustainable) production implementations.

Simple cleaner (sustainable) production tools such as good housekeeping are developed for the implementation mainly in small and medium enterprises (SME) regardless of sector. These tools can provide improvements only in very general issues (prevention of water or raw material losses). Significant gains in large enterprises are only possible using more comprehensive and sector-specific cleaner (sustainable) production tools. Due to the requirement for more resources and higher expertise, use of this kind of tool without sectoral prioritisation could lead to significant loss of time and resources. In this context, sectoral prioritisation has an important role in cleaner (sustainable) production practices (Ulutaş et. al, 2011; Böğürcü et. al., 2010).

The motivation of the study comes mainly from all the points mentioned above, especially the need for a sector focused approach in order to achieve a successful national/regional cleaner (sustainable) production strategy. Purpose of this study is to prioritize manufacturing industry sub-sectors in Turkey (national scale) and in İzmir (regional scale) for cleaner (sustainable) production applications. Prioritization has been carried out based on the selected criteria that are thought to be important for cleaner (sustainable) production. During the prioritization process two different methods of Multi-Criteria Decision Making Method (MCDM) were used: Weighted Sum Method (WSM) and Analytical Hierarchy Process (AHP). Furthermore, for the determination of the importance level of selected criteria with respect to each other, three different criteria weighting methods were used (Entropy Method, Simple Ranking Method, and Eigen Value Method). During weighting of the criteria, feedbacks from the stakeholders have also been included. Weighting of the selected criteria and prioritization of manufacturing industry sub-sectors were carried out for Turkey and İzmir separately.

Following the Introduction part, Chapter 2 reviews the relevant literature including cleaner (sustainable) production concept from its definition, evolution, benefits and options to related case studies from Turkey and other countries. Furthermore, explanation of MCDM principle, MCDM methods and summary of the relevant literature regarding the integration of these methods with environmental problems were among the subjects reviewed in Chapter 2. Chapter 3 discusses the research methodology and data sets that were used in this study. Chapter 4 includes the results of criteria weighting analysis and prioritization analysis of manufacturing industry sub-sectors for cleaner (sustainable) production in addition to the comparisons and discussion of these results. Finally Chapter 5 presents the conclusions.

CHAPTER 2

BACKGROUND INFORMATION

2.1. Cleaner (Sustainable) Production Concept

2.1.1. Definition of Cleaner Production and Related Concepts

Cleaner Production stands for a proactive and preventive approach to industrial environmental management and focuses on process- and/or product-integrated solutions that are both environmentally and economically efficient (Berkel, 2000). Cleaner Production includes pollution prevention at source and minimization of waste flows, which are alternatives that seek to avoid pollution generation as a preferable strategy to end-of-pipe treatment (Regional Activity Center for Cleaner Production [CP/RAC], 2000).

The term “Cleaner Production” was first coined in September 1990, by UNEP. The formal UNEP definition of “Cleaner Production” states that: “Cleaner Production is the continuous application of an integrated, preventive strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment” (UNEP, 2007b). Cleaner Production aims at progressive reductions of the environmental impacts of processes, products and services, through preventative approaches rather than control and management of pollutants and wastes once these have been created (Berkel, 2000).

For *production processes*, Cleaner Production results from one of the following or combination of these; conserving raw materials and energy, substituting toxic/hazardous materials by more benign ones and reducing the quantity and/or toxicity of all emissions and wastes before they leave a production process (De BruJin et al., 2000). For *products*, Cleaner Production focuses on the reduction of environmental impacts over the entire life cycle of a product, from raw material extraction to the ultimate disposal of the product, by appropriate design. For *services*, Cleaner Production entails incorporating environmental concerns into the design and delivery of services (Azapagic, 1999; UNIDO/UNEP, 2004).

As it also underlined in the definition of UNEP, Cleaner Production works to advance;

- *Production* Efficiency: through optimization of productive use of natural resources (materials, energy, water) at all stages of the production cycle;
- *Environmental Management:* through minimization of the adverse impacts of industrial production systems on nature and the environment;
- *Human Development:* through minimization of risks to people and communities, and support to their development (UNEP, 2004).

Many concepts related to Cleaner Production concept have also been developed in the last couple decades. Some of them can be listed as; green productivity, eco-efficiency, waste minimization, pollution prevention, and industrial symbiosis.

- *Green Productivity*: It is a term used by the Asian Productivity Organization (APO) to address the challenge of achieving sustainable production. Green Productivity was launched in 1994 in line with the 1992 Rio Summit recommendations that both economic development and environmental protection would be key strategies for sustainable development (APO, 2006).

- *Eco-efficiency:* The term was coined by the World Business Council for Sustainable Development (WBCSD) in 1992. It is defined as the delivery of competitively priced goods and services that satisfy human needs and ensure quality of life, while progressively reducing ecological impacts and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity (DeSimone & Popov 1997; WBCSD, 2000). The terms of eco-efficiency and Cleaner Production are used interchangeably.

- *Waste Minimization:* The concept of waste minimisation was introduced by the United States Environmental Protection Agency (US EPA) in 1988. In this concept, waste prevention approach and its techniques are defined as on-site reduction, source reduction of waste by changes of input raw materials, technology changes, good operating practices and product changes. Off-site recycling by direct reuse after reclamation are also considered to be waste minimisation techniques, but have a distinctly lower priority compared to on-site prevention or minimisation of waste (Dorfman 1992; US EPA, 2002).

- *Pollution Prevention*: The terms Cleaner Production and pollution prevention are often used interchangeably. The US EPA defines pollution prevention as the source reduction - preventing or reducing waste where it originates, at the source - including practices that conserve natural resources by reducing or eliminating pollutants through increased efficiency in the use of raw materials, energy, water and land. Under the Pollution Prevention Act of 1990, pollution prevention is the national environmental policy of the United States (US EPA, 2002). Both concepts focus on a strategy of continuously reducing pollution and environmental impact through source reduction. However, Cleaner Production includes the aspect of reduction of impacts and risks across the life cycle of a product, and in this sense is a more comprehensive concept than pollution prevention (Allen & Rosselot, 1997).

- *Industrial Symbiosis*: Chertow has defined industrial symbiosis as "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products" (Ehrenfeld & Gertler, 1997). The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity (Chertow, 2000).

2.1.2. Evolution of Cleaner Production

Li and Chai (2007) classified the phases taking place during the development of environmental technologies into three, which are namely traditional linear economy, end-of-pipe technologies and Cleaner Production. Similarly, according to UNEP (2004) *these phases represent the responses of business to pollution. On the other hand; UNEP divides these ways of responses into four including "the solution to pollution is dilution" which Li and Chai didn't consider. Figure 2.1 illustrates these trends.*

2.1.2.1. Linear Industry Economy Pattern

Industrial development patterns are the reflections of relationship between nature and industry. The first pattern is traditional linear economy in which the industry processes does not consider the overall environmental impact (Figure 2.1). While consumption of resources the focus for the choice is the product. The efficiency of the production is improved only by consuming a large number of raw materials which leads to the generation of the waste without further treatment infinitely.

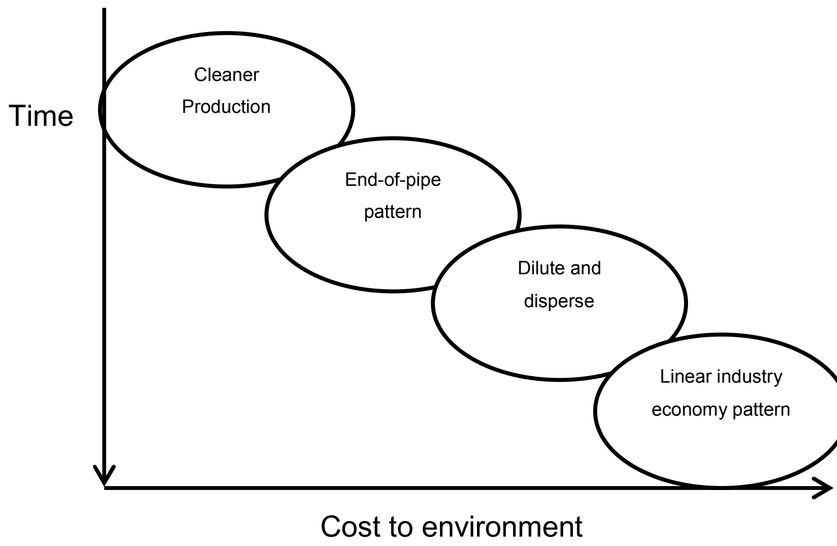


Figure 2.1: Response of Business to Environmental Pollution (UNEP, 2004).

With the further development of industry the large number of wastes emitted by the industry, which exceed the carrying capacity of nature, cause the serious environmental pollution (Figure 2.1). Under the severe condition of the frequent social pollution events and obvious eco-systems damage, the traditional industry pattern was abandoned soon (Li & Chai, 2007).

2.1.2.2. End-of-Pipe Pattern

Since the 1970s many countries have begun to deal with the GHG Emissions, wastewater and solid waste disposal/treatment in order to reduce the pollution to the environment and protect the eco-system. This pollution control strategy is called ‘‘end-of-pipe technologies’’ or “pollution control”. Industrial production is based on the environmental legislation, and treatment equipment is set up at the end of the usual process to decrease the release of pollution or waste. Contrasting with the linear economy pattern the efficiency of resources utilization of this pattern has reached a high standard (Freeman et.al, 1992). On the other hand; the shortcomings are emerging in practice: both the investments and the fees of operation of treatment equipment are high. The simple treatment may not necessarily protect the environment; it can only satisfy the standard of emission (Li & Chai, 2007). The end-of-pipe pattern cannot eradicate pollution, and only transforms pollution between different phases.

2.1.2.3. Cleaner Production Pattern

The concept of process industry Cleaner Production as we know it today began to emerge in the mid 1970's in response to the growing complexity and stringency of environmental requirements. Leading global companies in the process industry, in particular those headquartered in the USA, began to critically assess their approach to environmental issues. The concepts of '*pollution prevention*' and *'waste minimisation'* came through as clearly the most economical and environmentally effective means of addressing environmental challenges (Berkel, 2000) A leading pioneer for the preventive approach to industrial environmental management was 3M that launched its Pollution Prevention Pays (3P program) in 1975 (Zosel, 1990). 3P created a tremendous drive for employee initiated innovation to reduce costs as well as the creation of wastes and pollutants. Similar corporate pollution prevention programs were in the early days for instance launched by Dow, DuPont, and several others (Freeman et al., 1992).

In recent years, much of the attention of environmentally conscious industries has focused around the need for end-of-pipe solutions, particularly in relation to the treatment of waste and the control of emissions into the atmosphere, watercourses or landfill sites. Such solutions, however, do not in themselves promote efficiency gains or improvements in productivity (O'Brein, 1999). Now significant attention and emphasis have been given to Cleaner Production, which is the third pattern of the industrial development. It goes beyond prevention and is a product oriented approach to environmental management. It recognizes that most environmental problems stem from unsustainable production and consumption practices.

The milestones in evolution process of Cleaner Production can be listed as;

- *1987-Brutland Report (Our Common Future):* The concept of sustainable development was proposed. The true challenge of sustainable development was how to put the theory into practice. Cleaner Production provided a practical way to take clues from the conceptual framework of sustainable development towards action. It was more of a preventative strategy and not a curative or reactive approach to address the global pollution problem (WCED, 1987; UNEP, 2002).

- *1989-UNEP Cleaner Production Programme:* United Nations Environmental Program, Department of Technology, Industry and Economy (UNEP-DTIE) took first significant step by launching Cleaner Production Program. The main goal was to raise awareness regarding subject, form a structure and disseminate sustainable development studies by stressing its benefits. Cleaner Production concept that has been adopted by many countries, agencies and institutions has obtained a global qualification from that day on (UNEP, 2002).

- *1992-Rio Declaration on Environment and Development & Agenda 21:* Rio Summit as important strategies to take forward the concept of sustainable development and Agenda 21 made significant references to Cleaner Production. Agenda 21 has in fact served as a guiding framework for the implementation of Cleaner Production (UNEP 1992).

- *1998-The International Declaration on Cleaner Production*: In order to obtain a commitment to Cleaner Production across a wide cross-section of stakeholders, an International Declaration on Cleaner Production was launched by the UNEP in 1998. The Declaration is not limited to national governments but may also be signed by companies, associations and individuals (UNEP, 1998).

- *2002-World Summit on Sustainable Development:* The full implementation of Agenda 21 and the Programme for further implementation of Agenda 21, were strongly reaffirmed as the means to reconcile economic growth and environmental protection (UNEP, 2002)

Development of the Cleaner Production concept has been generally started by raising awareness on the concept and continued by capacity building studies including pilot projects in the production and services sectors. Cleaner Production applications were disseminated by forming partnerships, information sharing networks, financial mechanisms and then carrying out necessary political reforms. However, typical “bottom to the top” development process (Figure 2.2) can be realized in “top to the bottom” or different structures due to local, cultural and so forth reasons (UNEP, 2002).

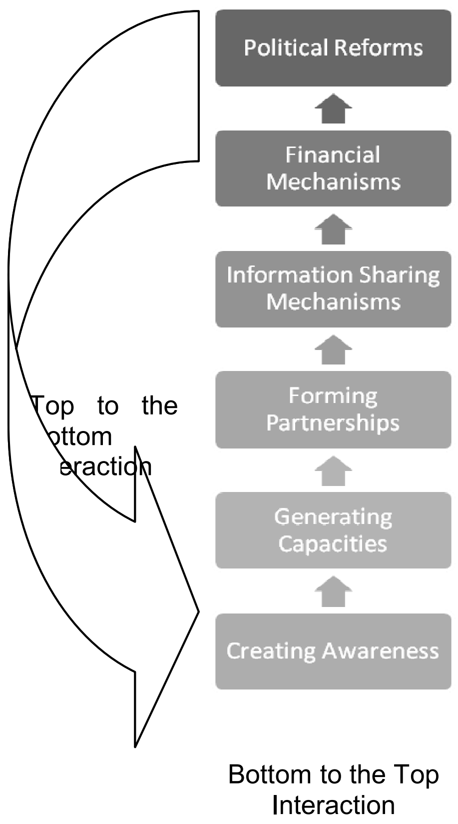


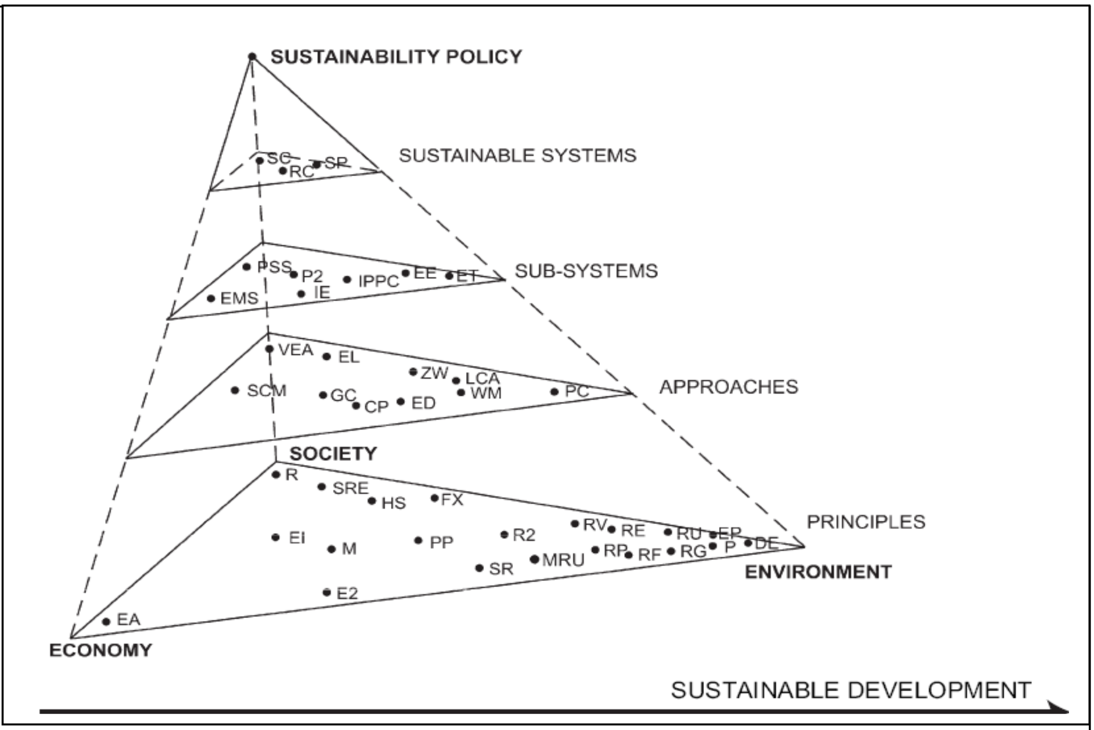
Figure 2.2: Typical Development Process of Cleaner Production Concept in a Country (UNEP, 2002)

2.1.3. From Cleaner Production to Sustainable Production

Studies on “sustainability” have been recently increased in different disciplines and this leads to increase of different concept and terminology use. Cleaner Production is interdisciplinary concept due to its nature. Geographical and cultural differences and rapidly increasing number of concepts lead to variety difficulties in understanding of the Cleaner Production studies and cooperation of concepts and terminologies (TTGV, 2010).

If related disciplines do not sufficiently understand each other, this can create a significant obstruction in front of the development in their field of work. One of the latest comprehensive scientific studies that were conducted to address this problem is “Analysing Sustainability Terms and Definitions” article published in Cleaner Production Journal by “Elsevier Science” (2007). This article has been prepared to provide a contribution for overcoming above mentioned communication difficulty about the sustainability concept. UNEP, US EPA, European Environment Agency (EEA), Organization for Economic Co-operation and Development (OECD), Journal of Cleaner Production and other related sources have been used as references in this study.

The most commonly used 41 terms in sustainability studies have been selected in this article. They have been multi-dimensionally classified by considering their interrelationships. These dimensions consist of environmental/ecological, economic and social ones beside sustainability policies, sustainability system and sub-systems, sustainability approaches and principles (Figure 2.3) (Glavic et al., 2007).



APPROACHES

CP: Cleaner production
ED: Eco-design
EL: Environmental legalization
GC: Green chemistry
LCA: Life cycle assessment
PC: Pollution control
SCM: Supply chain
VEA: Voluntary environmental agreement
WM: Waste minimization
ZW: Zero waste

SUB – SYSTEMS

EE: Environmental engineering
EMS: Environmental management strategy
ET: Environmental technology
IE: Industrial ecology
IPPC: Integrated pollution prevention control
P2: Pollution prevention
PSS: Product service system

PRINCIPLES

DE: Degradation
E2: Eco- efficiency
EA: Environmental accounting
EI: Ethical investment
FX: Factor x
HS: Health and Safety
M: Mutualism
MRU: Minimization resource of usage
P: Purification
PP: “Polluter pays” principle
R: Reporting to the stakeholders
R2: Renewable resources
RE: Recycling
RF: Remanufacturing
RG: Regeneration
RP: Repair
RU: Reuse
RV: Recovery
SR: Source reduction

Figure 2.3: Classification of Terms on Sustainability (Glavic et al., 2007)

This study has provided important contribution to make sustainability terms clear to be understood and used. In addition to this below mentioned tasks have been stated independently while their interactions with Agenda 21, Rio Agreement, European Union Millennium Development Goals, Climate Change, Melbourne Principles and so forth sustainability policies have been indicated (Glavic & Lukman, 2007)

As mentioned in this article, rapid amendment of the sustainability terms in last years requires to be made additional working in order to be easily understood of studies that will be made from now on. “Cleaner Production” concept which has been used in many countries has been evolved to “sustainable production” in the last 5 years (Narayanaswami, 2007). “Cleaner Production” concept is still used by many related institutions while “sustainable production” concept has been rapidly adopted. Sustainable production concept has been defined as “*making production in such a way that processes and systems are non-polluting for long and short term; natural sources shall be protected; it shall be economically feasible; it shall be reliable and healthy for workers, producers and all society; it shall be constructive for stakeholders and provide social benefit*.” (Glavic & Lukman., 2007).

Consequently, studies to be carried out after today shall be based on current Cleaner Production literature. Under this framework, in order to achieve a conceptual simplicity, to cover both concepts’ history and today, to catch up with the concepts used internationally and not to cause a conceptual confusion, it is decided to use “cleaner (sustainable) production” term in the rest of this study.

2.1.4. Benefits Provided by Cleaner (Sustainable) Production

While explaining cleaner (sustainable) production benefits, it may be more convenient to show the differences of cleaner (sustainable) production from pollution control strategies first. Main differences between these two concepts are given in Table 2.1 in detail.

Table 2.1: Main Differences between Cleaner (Sustainable) Production and Pollution Control Approaches (Demirer, 2003)

Pollution Control Approaches	Cleaner (Sustainable) Production Approaches
Pollutants are controlled by filters and waste treatment techniques and technologies; in fact negativities arising from problems are tried to be solved rather than problem itself.	Generation of the pollutants is prevented at the source with integrated precautions.
Pollution control is an application coming after the process and product development to solve the existing pollution problems.	Pollution control is inseparable part of process and product development, therefore it is more efficient.
Environmental rehabilitations to be carried out with pollution control are seen as additional cost.	Pollutants and wastes are seen as potential resources to be recycled to useful products and by-products.
Application of pollution control technologies are the duty of environmental specialists, waste managers, etc.	Performing environmental rehabilitations and cleaner (sustainable) production are duty of all personnel including design and process engineers of the institution.
Environmental rehabilitations require technical and technological applications.	Environmental rehabilitations include both technical and non-technical approaches.
Environmental rehabilitation precautions are provided to comply with standards specified by the authorities.	Cleaner (sustainable) production is a continuous process that aims better environmental standards.
Quality is defined as to respond to customer demands.	Quality is defined as minimizing the effect on the human health and environment besides responding to customer demand.
Technologies used for pollution control have a continuous cost which increases in time.	The cost of the cleaner (sustainable) production approach to solve the same problem can be high at the beginning, however implementation, operation and maintenance costs will be lower in the long term; since the consumption of input such as raw material, water and energy decrease after cleaner (sustainable) production applications.

Cleaner (sustainable) production offers a series of advantages when compared to pollution control approaches that make it preferable for environmental management in business.

a. *Cleaner (sustainable) production as an integral management strategy*

Cleaner (sustainable) production is a business management strategy that goes beyond any specific goals that may arise an occasion and entails a policy taking all of productive processes into account (Natrass & Altomore, 1999). Pollution control, on the other hand, only deals with specific effects without confronting the origin. It also adopts a position that just tags along behind any problem that arises (CP/RAC, 2000).

Pollution control approaches accept the production and design phases as unchangeable factors; therefore pollution is seen as an inevitable result of these phases and solutions are sought after pollution occurs (Rejinders, 1998). On the other hand, cleaner (sustainable) production approaches accept the pollution as a result of deficiencies and inefficiencies during design, raw material utilization and production processes; and aim to find solution by providing necessary developments during these processes. Cleaner (sustainable) production has a close relation with sustainability beside development of a new product, process, system and services (Glavic et al., 2007).

b. *Cleaner (sustainable) production as a source of opportunities*

Cleaner (sustainable) production optimises processes taking place in the company; it enhances the adaptation to new trends towards process efficiency and facilitates the company's growth and competitiveness through improvements to its operating conditions (Berkel, 1994). Pollution control approaches, on the contrary, offers no new opportunities to businesses, as it only repose to mitigating the waste flows that are generated. Cleaner (sustainable) production can be said to promote the *software* and provides an analysis, opportunities, and a more efficient way of operating within the business. Whereas, end-of-pipe treatment is based only on the *hardware*, on actions with no added value, such as investment in equipment, or external treatment (CP/RAC, 2002).

c. *Cleaner (sustainable) production as an adaptable strategy*

As a strategy incorporated with the production processes as a whole, cleaner (sustainable) production automatically responds to process variations (increase in productivity, increase in usage of certain materials etc) according to the needs and possibilities of the company (Zosel, 1999). End-of-pipe treatment is less adaptable as it is only conceived as a supplementary phase of production process and can therefore not respond to easily to changes occurring in the process (CP/RAC, 2002).

Pollution control approaches are used to comply with current laws and regulations. Thus, several potential developments are ignored by this approach. Moreover, firms can be caught unprepared to changes in relevant legislation and desired improvements shall only be achieved with high costs. On the other hand, cleaner (sustainable) production provides that institution can increase their environmental performance continuously and therefore these developments are not restricted by the requirement of any static subject such as law and regulations. Institutions which adopt pollution prevention approaches increase their environmental performances to higher position than required by these law and regulations. Therefore they shall not have difficulty to adapt to the stricter law and regulations when needed (Demirer et al., 1999 and 2000). Additionally UNEP has indicated that cleaner (sustainable) production has an important role on responsibilities of countries regarding international agreements (UNEP, 2006).

d. *Cleaner (sustainable) production and economic benefit*

Through the application of viable cleaner (sustainable) production measures, in the cost of waste flow treatment saving can be made while fostering of more efficient measures leads to reductions in the water, energy, raw material etc. consumptions. At the same time, the optimization of production processes by cleaner (sustainable) production can lead to an increase in a business' productivity. End-of-pipe treatment does not anticipate any cost savings for the business. On the contrary, it does involve an additional cost that is constant and which grows as business production increases and as the result of any new regulation that may appear (Rowledge et. al, 1999)

e. *Cleaner (sustainable) production and the environmental benefits*

Cleaner (sustainable) production is a more positive option for the environment in that it prevents the generation of pollution and brings about a more efficient use of resources. End-of-pipe treatment is also an option reducing the pressure of contamination on the receiving medium, although it acts only after this has been generated and does not bring about the more efficient use of natural resources (Freeman et.al, 1992; CP/RAC, 2000).

f. Cleaner (sustainable) production as an integral policy of involvement

Cleaner (sustainable) production improves and optimises the working structure and level of technical development in a business. Moreover, it is a strategy that is adopted by the entire workforce of a company, form machines operators to the managing director. It involves a prior learning and awareness process that is reflected in better environmental and production practices. Pollution control approaches involve the conscious action of the company director who proposes the measure and of the specialist who implements it (Fussler & James, 1996). But it does not promote responsible actions that includes the involvement or benefits that derive from the entire workforce (CP/RAC, 2000).

g. *Cleaner* (sustainable) *production and the corporate image*

Any strategy incorporating environmental criteria is beneficial to the corporate image. Cleaner (sustainable) production and treatment of waste flows comply with this requirement, although present trends show that prevention is better than correction, in both environmental and economic terms. Cleaner (sustainable) production is hence the best option for corporate image of a business (CP/RAC, 2002).

2.1.5. Options for Cleaner (Sustainable) Production

Cleaner (sustainable) production options can be grouped into (UNEP, 2004) (Figure 2.4);

i. Waste reduction at source
ii. Recycling
iii. Product modifications

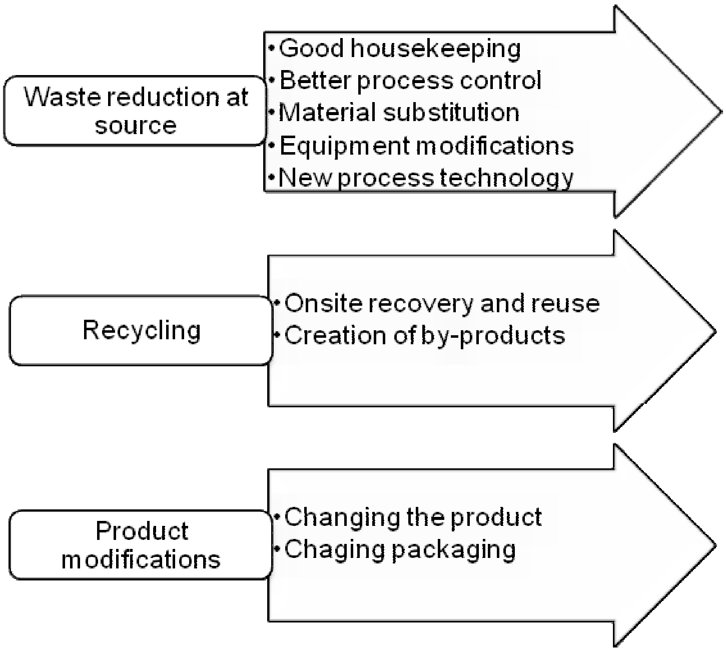


Figure 2.4: General Options for Cleaner (Sustainable) Production (UNEP, 2004)

i. Waste reduction at source: Going to the source of pollution is the fundamental idea of cleaner (sustainable) production.

- *Good housekeeping* is the simplest type of the cleaner (sustainable) production options. Good housekeeping requires no investments and can be implemented as soon as the options are identified (Zosel, 1994). Even though good housekeeping is simple, it requires focus from the management and training of staff.

- *Better process control* is to ensure that the process conditions are optimal with respect to resource consumption, production and waste generation. Process parameters such as temperature, time, pressure, pH, processing speed, etc. have to be monitored and maintained as close to the optimum as possible. As with good housekeeping, better process control requires improved monitoring and management focus (Berkel, 2000).

- *Material substitution* is to purchase higher quality materials that give a higher efficiency. Often there is a direct relation between the quality of the raw materials and the amount and quality of the products. Material substitution is furthermore to replace existing materials with some that are environmentally better

- *Equipment modification* is to improve the existing equipment so less material is wasted. Equipment modification can be to adjust the speed of an engine, to optimise the size of a storage tank, to insulate hot and cold surfaces, or to improve the design of a crucial part of the equipment (Berkel, 1994).

- *New process technology* is to install modern and more efficient equipment, e.g. a highly efficient boiler or a jet dyeing machine with a low liquor ratio. New process technology requires higher investments than the other cleaner (sustainable) production options and should therefore be considered carefully. However, the potential savings and quality improvements often pays back the investment in a very short time (Dunn & Bush, 2001).

ii. Recycling: Waste streams that are unavoidable might be recycled within the company or might be sold as by-products.

- *On-site recovery and reuse* is to collect "waste" and reuse it in the same or a different part of the production. One simple example is to reuse rinse water from one process to another cleaning process (Gavrilescu et. al, 2008).

- *Creation of by-products* is to collect (and treat) "waste streams" so they can be sold to consumers or to other companies (Bass, 1998).

iii. Product Modifications: Improving the products so they pollute less is also a fundamental idea of cleaner (sustainable) production (Graham & Berkel, 2007).

- *Changing the product* is to re-think the product and the requirements to the product Improved product design can result in large savings on material consumption and use of hazardous chemicals.

- *Changing packaging* can be just as important. The key word is to minimise the packaging and maintaining the protection of the product.

2.1.6. Case Studies for Cleaner (Sustainable) Production Implementations in Manufacturing Industry

In this part, different case studies focusing on the cleaner (sustainable) production implementations in manufacturing industry are presented. Manufacture of beverages, manufacture of textiles, manufacture of ceramics, manufacture of electrical machines and manufacture of chemicals and cosmetics are the sub-sectors in which the cleaner (sustainable) production case studies are examined in this study. Two of the case studies (on beverages industry and textile industry) are about the pilot projects implemented within the framework of "UNIDO Eco-efficiency (Cleaner Production) Programme". In the context of this programme cleaner production demonstration projects are implemented in the Seyhan River Basin Area (Adana, Kayseri and Niğde) in addition to national capacity development activities. As the demonstration projects, eco-efficiency (cleaner production) applications which improves environmental and economical performance were implemented in 6 industrial facilities analyzing production processes, water consumption and wastewater generation. As a result of applications, 784,550 m^3 of water were saved annually besides 4,947,000 kWh savings achieved in energy consumption. (TTGV, 2012)

2.1.6.1. Water Saving in a Beverages Industry (Turkey)[1] (TTGV, 2011)

Company Name:	GÜLSAN Gıda Sanayi ve Ticaret A.Ş. (MEYSU)
Field of Activity/Sector:	Manufacture of soft drinks

a. Environmental situation before the cleaner (sustainable) production implementations:

<u>Manufacture of concentrated fruit juice:</u> Fruits are converted to concentrated fruit juice after washing, pre-treatment and pasteurization processes. In the production of concentrated fruit juice, groundwater is used in coo ling process with an amount of 346,000 m^3.

[1] This project has been conducted within the UNIDO Eco-efficiency (Cleaner Production) Programme

Soft drink production: In the production line concentrated fruit juice is mixed with water and other additional ingredients and converted to soft drinks. In soft drink production 173,000 m^3 groundwater is consumed for cooling purposes.

Company sent its wastewater to central wastewater treatment plant of organized industrial zone. Due to increased activity in fruit processing, amount of water consumed and amount of wastewater generated also increase especially in summer period. This situation causes some difficulties in the wastewater treatment plant of organized industrial zone due its limited capacity. On the other hand, such high water consumption is an important cost element for the company.

b. *Summary of actions*: Two different systems are put into practice for the recovery and reuse of cooling water used in concentrated fruit juice and soft drink production lines. Instead of one-through system used before CP implementations, closed loop cooling system including cooling tower, stainless steel water pump and pipes, invertors and control panel has been installed

c. *Results of implementations*: Table 2.2 shows the water consumption amount of different processes of the company before and after the cleaner (sustainable) production implementations.

Table 2.2: Water Consumption Amount of Different Processes before and after the Cleaner (Sustainable) Production Implementations

Production Line	**Operation**	**Before implementations (m^3/year)**	**After implementations (m^3/year)**
Fruit processing	Fruit washing	11,500	11,500
	Cooling	346,000	18,000
	Cleaning	36,000	36,000
Soft drink production	Cooling	173,000	28,000
	Cleaning	36,000	36,000
	In product	55,000	55,000
Utility Services	Steam production etc.	14,000	14,000
Other	Domestic use, in product etc.	180,000	180,000
	TOTAL	**851,500**	**378,500**

From Table 2.3, benchmarking of specific water consumption amount between the companies former and latter situation and the amounts listed in the literature for the same sector can be seen.

Table 2.3: Benchmarking of water consumption based on water consumed per product

Reference	**Specific Water Consumption** (m^3 water/ton product)
Binnie, 1987b	2.3
Gumbo et al., 2003	3.5
Hsine et al., 2005	2.5 – 3.5
Environment Report, 2006	1.5
IFC, 2007	6.5
ETBPP, 2009	2.3 – 6.1
Company- before implementation	23.6
Company- after implementation	10.6

Via the implementations conducted for water saving in cooling processes, water consumption in this process has been decreased from 519,000 m^3 to 46,000 m^3. Implementations have decreased the water consumption in cooling processes by 91%. Total water consumption of the company has decreased from 851,000 m^3 to 378,500 m^3. In other words total water consumption of the company reduced at a rate of 56%. As a result of the implementations, the capacity problem in central wastewater treatment plant of organized industrial zone has also been solved due decreased wastewater amount of the company.

2.1.6.2. Water and Energy Saving in a Textile Industry (Turkey)[2] (TTGV, 2012)

Company Name:	ÖZEL Tekstil Sanayi ve Tic. Ltd. Şti
Field of Activity/Sector:	Manufacture of Textile Products: Textile Dyeing and Finishing

[2] This project has been conducted within the UNIDO Eco-efficiency (Cleaner Production) Programme

a. *Environmental situation before the cleaner (sustainable) production implementations:* Company which includes wet processes like dyeing and finishing has a high water and energy consumption. Depending on the production amount total annual water consumption is about 300,000 m^3, 80-85% of which is consumed in dyeing and finishing processes. On the other hand, total annual energy (natural gas and electricity) requirement of the company is about 1,300,000 m^3 natural gas & 4,250,000 kWh electricity.

b. *Summary of actions:* With the cleaner (sustainable) production approach, implementations were carried out in dyeing and finishing processes in which the water consumption is about 260,000 m^3. In addition to this ion exchange system used for soft water production was renovated.

Actions taken in dyeing and finishing processes are as follows:

- Better control of water consumption amounts for each process and examination of the adequate water amounts (high water consumption is identified in fabric washing, washing after dyeing units and cloth expanding machine)
- Renovation of valves in the inputs and outputs replaced in the cooling water part of dyeing machines
- Reuse of tumbler dryer cooling water in the system
- Reuse of nap trimming cooling water in the system

c. *Results of implementations:* Water saving resulted from the cleaner (sustainable) production implementations were monitored in the company. Before the project, water consumption per product is 111.7-129.4L/kg, this amount decreased to 50.9 L/kg with the project implementations (See Figure 2.5).

With the realized activities nearly 162.000 m^3 has been saved and total water consumption of the company has decreased by 54%. Together with water saving, 22% energy efficiency in the production of hot water has been achieved and total natural gas and electricity consumption has decreased 4,780,000 kWh. Thus total CO_2 emission has decreased by 879.6 ton/year. On the other hand, with renovation of ion exchange system 192 ton/year salt (NaCl) saving has been achieved. With the savings of implementations having an investment cost of 18,500 Dollars, the project has paid back itself less than two months.

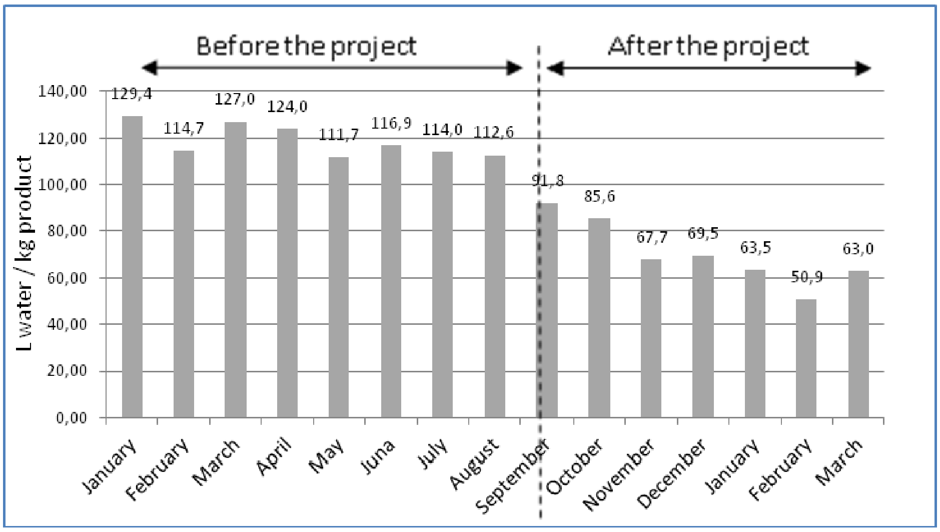


Figure 2.5: Changes in Specific Water Consumption with the Cleaner (Sustainable) Production Implementations

2.1.6.3. Energy Saving in a Ceramic Kiln (France) (CP/RAC, 2008)

Company Name: Porcelaine de Sologne
Field of Activity/Sector: Manufacture of chinaware and decorative ceramics

a. *Environmental situation before the cleaner (sustainable) production implementations:* Ceramic kilns consume large amount of energy especially gas. Firing ceramic products requires a kiln operating at determined setting of each type of product, based on established temperature curves. Porcelaine de Sologne was previously using a conventional kiln operating according to pre-calibrated firing regimes. After a series of problem in the operation of kiln, company was forced to install a new one. Furthermore, it is decided to implement good housekeeping practices in order to optimize energy consumption in the process.

b. *Summary of Actions:* The Company has decided to install a new feed forward control system in the new kiln. This system improves the control and adjustment of firing temperatures, making the kiln more flexible it its operations and hence optimizing energy consumption. The advantage over a conventional is that the new system features a sensor which monitors oxygen content in the firing chamber, allowing it to be adjusted in real time. Moreover, this system makes it possible to calculate the necessary gas amount for efficient firing.

c. *Results of implementations:* With the renovation of ceramic kiln gas consumed in firing ceramic products decreased from 5,371 MWh/year to 4,571 MWh/year. Payback period of the implementations having initial investment cost of 60,990 Euros is 2.5 years.

2.1.6.4. Resource Recovery in Oil and Fats Company (Egypt) (CP/RAC, 2008)

Company Name: Tanta Oil and Soap Company
Field of Activity/Sector: Manufacture of oil and soap

a. *Environmental situation before the cleaner (sustainable) production implementations:* Some of the main environmental impacts generated throughout the production process were due to oil, ghee (clarified oil) as well as fatty matter leakage and spillages. Likewise large volumes were lost from the production discharged as effluent. In a cleaner (sustainable) production audit a list of possible cleaner (sustainable) production opportunities some of which were implemented were listed.

b. *Summary of Actions:* Cleaner (sustainable) production opportunities implemented are listed as follows:

- Upgrading loading and unloading procedures: Improved procedural instructions and transfer operations eliminated the significant levels of leakage and spillages of oil, ghee and fatty matter.
- Recovery oil, ghee and fatty matter: Gravity oil separators were installed on the oil washing line, immediately after the water was discharged from the batch reactors of oil and ghee refining to recover oil and ghee that had been

discharged and lost to the refinery effluent. Furthermore, new underground separators were installed replacing the existing units that recovered the mucilage produced during neutralisation and fatty matter from the refinery effluents in oil separators.

- Recovery or fodder ingredients: The installation of a cyclone vacuum eliminated heavy dust emissions by the animal fodder production unit during the loading and unloading of raw material system. The vacuum collected the suspended matter and transferred it directly to the raw material intake system.

- Water Saving: Huge volumes of water were being discharged since cooling water was not being reused closed circuit system. This was addressed by segregating the cooling water, vacuum water and process water from one another in parallel with the rehabilitation of cooling systems.

c. *Results of implementations*: Through the implementation of the measures mentioned above, the company achieved significant benefits;

- Annual recovery oil, ghee, fats and animal feed totalled 150,250 euro
- Water consumption was reduced by 23%.
- Oil and grease concentration and BOD load in the final effluent were reduced by 99% and 75% respectively.
- Investment needed for the industrial wastewater treatment plant reduced by 145,310 euro (related to the point above).
- Payback period of implementation is about one year.

2.2. Multiple Criteria Decision Making

Decision making is the process of selecting a possible course of action from all available alternatives. In many cases, multiplicity of criteria for judging the alternatives is prevalent. Often the decision maker wants to attain more than one objective or goal in selecting a course of action, while satisfying constraints dictated by environment, processes and resources (Lai & Hwang, 1996). MCDM analysis is a method widely used in decision making problems covering most of the economical, industrial financial or political decisions that are a multi-criteria nature. MCDM is a structured framework for analysing decision problems characterized by complex multiple objectives (Nijkamp et al., 1990; Zeleney, 1984). MCDM can also deal with long-term time horizons, uncertainties, risks and complex value issues. The MCDM process typically defines objectives, chooses the criteria to measure the objectives, specifies alternatives, transforms the criteria scales into commensurable units, assigns weights to the criteria that reflect their relative importance, selects and applies a mathematical algorithm for ranking alternatives, and chooses an alternative (Howard, 1991; Keeney, 1992; Hajkowicz & Prato, 1998; Massam, 1988). Two key advantages of MCDM are that it allows greater stakeholder involvement and provides greater transparency to the decisions being made at all levels of appraisal (Risk and Policy Analysts Ltd [RPA], 2004)

2.2.1. Components of MCDM

Although MCDM methods may be widely diverse, many of them have certain aspects in common (Chen & Hwang, 1992). These are the notions of alternatives, criteria and attributes.

- *A set of alternatives:* Alternatives, also seen as actions, courses of action, states, feasible solutions, and so forth, constitute the candidate set over which decisions are to be made (Jin, 1996). Alternatives are represented generally as A = {A_1, A_2, An}, and the number of alternatives n is countable. These are supposed to be screened, prioritized and eventually ranked among different criteria by MCDM methods (Triantaphyllou, 2000).

- *A set of criteria***:** More than one criteria has to be present in a MCDM problem. A Criterion in general is one aspect of interest, against which the decision maker wants to learn about the alternatives (Jin, 1996). Bouyssou (1990) expressed criteria as a particular significance axis or point of view allowing for comparison of alternatives. Henig & Buchanan (1996) stated that criteria are usually "general, abstract and often ambiguous" and could even be "independent of the alternatives." To this end, "criteria," as opposed to "attribute" (which will be introduced next) is a more decision maker-sided concept. Situation subjected to decision making process can be associated with several different criteria. Many MCDM methods require the weighing of the criteria according to their importance with respect to each other (Triantaphyllou, 2000).

- *A corresponding set of attributes.* It is critical to be aware of the distinctness and correlation between "attribute" and "criteria." An attribute is usually a quantitative (e.g. interval or ratio scale) or qualitative (e.g. verbal, nominal, or ordinal scale) measure on the target alternatives, which is selected or devised in such a way that it reflects the attainment level of a pre-specified criteria (Jin, 1996).

- *A decision matrix:* A MCDM problem can be easily expressed in a matrix format. A decision matrix A is a m x n matrix in which element a_{ij} indicates the performance of Alternative A_i when it is evaluated in terms of decision criteria C_j (for i= 1, 2, 3, ..., m, and j= 1, 2, 3, ..., n). It is also assumed that the decision maker has determined the weights of the relative performance of the decision criteria (denoted as w_j, for j= 1, 2, 3, ..., n) (Triantaphyllou, 2000). This information is summarized in Figure 2.6.

	Criteria			
	C_1	**C_2**	**…$_3$**	**C_n**
Alternatives	(w_1	w_2		w_n)
A_1	a_{11}	a_{12}	...	a_{1n}
A_2	a_{21}^{*}	a_{13}	...	a_{2n}
...	...	...	...	...
A_m	a_{m1}	a_{m3}	...	a_{mn}

Figure 2.6: Typical Decision Matrix (Triantaphyllou, 2000)

In the decision matrix given in Figure 2.6;

A: Alternatives

m: Number of alternatives

C: Criteria

n: Number of criteria

w: Weighting factor of the criteria

a_{21}^*: Result of evaluation of the second alternative (A_2) with respect to the first criteria (C_1)

2.2.2. Classification of MCDM Techniques

Hajkowicz et al. (2000) classify MCDM methods under two major groupings namely continuous and discrete methods, based on the nature of the alternatives to be evaluated (Janssen, 1992). Continuous methods aim to identify an optimal quantity, which can vary infinitely in a decision problem. Techniques such as linear programming, goal programming and aspiration-based models are considered continuous. Discrete MCDM methods can be defined as decision support techniques that have a finite number of alternatives, a set of objectives and criteria by which the alternatives are to be judged and a method of ranking alternatives, based on how well they satisfy the objectives and criteria (Hajkowicz et al., 2000). Discrete methods can be further subdivided into weighting methods and ranking methods (Nijkampet al., 1990). These categories can be further subdivided into qualitative, quantitative, and mixed methods. Qualitative methods use only ordinal performance measures. Mixed qualitative and quantitative methods apply different decision rules based on the type of data available. Quantitative methods require all data to be expressed in cardinal or ratio measurements (Hajkowicz et al., 2000).

2.2.2.1. Criteria Weighting Methods

It is apparent that all of the criteria that are used in MCDM analysis do not have the same importance. Measure of the relative importance of criteria is the weight. (Pomerol & Romero, 2000). Therefore, criteria should be weighted based on their importance level in order to make a more accurate assessment. Criteria weighing methods used within the scope of this study are explained below.

2.2.2.1.1. Entropy Method

In this method, values of the weights are determined without the direct involvement of the decision maker, in terms of the values a_{ij} in decision matrix. The essential ideas is that the importance relative to a criteria j , measured by the weight w_j, is a direct function of the information conveyed by the criteria relative to the whole set of alternatives (Pomerol & Romero, 2000). Entropy Method shows how the criterion reflects the information in the system and the uncertainty of it (Wang et. al, 2009). In concrete terms the lower the entropy (greater the dispersion) in the evaluations of the alternatives a_j for j, the more important the criteria j. Thus, the most important criteria are those which have the greatest discriminating power between alternatives (Pomerol & Romero, 2000).

Weighing factor calculation with Entropy Method is done as follows,

i. Data belonging to criteria are normalized by using the Formula below,

$$\text{Normalized value} = \frac{a_{ij}}{\sum a_{ij}} \tag{2.1}$$

ii. Entropy (E_j) is calculated for each criteria. Entropy shows the proximity between data of related criteria. Data of criteria with high entropy is numerically close to each other. So, it is assumed that these types of criteria are not distinguishing for alternatives.

$$E_j = -k \sum a_{ij} \log (a_{ij}) \tag{2.2}$$

Where *k* is a constant which is adjusted so that for all *j* we have $0 \leq E_j \leq 1$; $k=1/\log(m)$.

iii. Measure of dispersion which shows the importance value of the criteria is calculated. When the dispersion is large, the values are widely scattered; when it is small they are tightly clustered.

$$D_j = 1 - E_j \tag{2.3}$$

iv. Finally sum of the weights are normalized and criteria weights are calculated.

$$w_j = D_j / \sum D_j \tag{2.4}$$

2.2.2.1.2. Simple Ranking Method

Simple ranking is one of the Direct Evaluation Methods. Decision maker directly assign values to criteria by this method. The only information asked of the decision maker is his/her order of preference for ranking the criteria. The most important criteria will take place in the first rank; on the other hand the least important criteria will come up in the last. As a result of this ranking, according to importance scores for each criteria is given and these scores are normalized (Pomerol & Romero, 2000).

2.2.2.1.3. Eigen Value Method

This method is based on filing the decision matrix by pair wise comparison of criteria (Pomerol & Romero, 2000). The aim of this method is to derive quantitative weights from qualitative statements on the relative importance of criteria obtained from comparison of all pairs of criteria (Janssen, 1992). Saaty (1980) proposes the following nine-point scale to express differences in importance (Table 2.4).

With the calculation of eigenvalue and eigenvector, weighting factors of criteria are identified. Inconsistency is an acceptable problem in these matrices only up to some degree. Therefore, method suggests an inconsistency ratio less than 0.1 (Pomerol & Romero., 2000).

Table 2.4: Weighting Scale for Eigen Value Method

Weighing value	When criteria i compared with j is:
1	Equally important
3	Slightly more important
5	Strongly more important
7	Demonstrably more important
9	Absolutely more important
1/3	Slightly less important
1/5	Strongly less important
1/7	Demonstrably less important
1/9	Absolutely less important

*The intermediate values 2, 4, 6 and 8 can also be used if necessary

2.2.2.2. MCDM Analysis Methods

There are many MCDM methods for decision making process (Weighted Sum Method, Weighted Product Method, analytical Hierarchy Process, ELECTRE etc.) Common property of these methods is the analysis of the alternatives based on the determined criteria. Details of Weighted Sum Method and Analytical Hierarchy Process that are used in this study are explained below.

2.2.2.2.1. Weighted Sum Method (WSM)

WSM is one of the oldest and most widely used methods of MCDM. Score of each alternative in this method is calculated as below:

$$P_i=\sum_i^j a_{ij}\, w_j \qquad i=1,2,3,\ldots m \text{ and } j=1,2,3,\ldots n \tag{2.5}$$

P_i *:* score of i^{th} alternative according to WSM

n: number of criteria

m: number of alternatives

a_{ij} : value of i^{th} alternative with respect to j^{th} criteria

w_j: weighting factor of j^{th} criteria

2.2.2.2.2. Analytical Hierarchy Process (AHP)

AHP method, developed by Thomas Saaty in 1970, is a decision making method used for the solution of complex problems composed of more than one criterion (Kuruüzüm & Atsan, 2001). AHP is used when making a choice among a large number of alternatives in a multi-purpose case in which many decision makers are included. AHP provides decision makers to model the complex problems according to main objective of the problem, criteria and relation between alternatives in a hierarchical structure. The most important feature of AHP is that both objective and subjective opinions of decision makers can be included in the process.

For the weighting of the criteria used in AHP, “Eigen Value Method” is utilized. After the determination of criteria weights, alternative scores with respect to criteria are calculated as in the method of WSM (Kuruüzüm & Atsan, 2001).

2.2.3. Integration of MCDM into Environmental Decision Making

Environmental decisions are often complex, multi-faceted and involve many different stakeholders with different priorities and objectives. Effective environmental decision making requires an explicit structure for coordinating joint consideration of the environmental, ecological, technological, economic, and socio-political factors relevant to evaluating and selecting among management alternatives. Each of these factors includes multiple sub-criteria, making the process inherently multi-objective. However, current decision process offers little guidance on how to integrate or judge the relative importance of information from each factor. Furthermore, information comes in different forms. While modelling and monitoring, results are usually presented as quantitative estimates, while risk assessment and cost-benefit analysis may incorporate a higher degree of qualitative judgement. Integrating this heterogeneous information with respect to human aspirations and technical applications demands a systematic and understandable framework to organize the people, processes, and tools for making a structured and defensible decision (Kiker et al, 2005).

The field of MCDM includes methods that can help to develop a decision analytic framework useful for environmental management. MCDM tools can be applied to assess value judgments of individual decision makers or multiple stakeholders. For individuals, risk-based decision analysis quantifies value judgments, scores different project alternatives on the criteria of interest, and facilitates selection of a preferred course of action.

Successful environmental decision making in complex settings will depend on the extent to which 3 key components are integrated within the process: people, process, and tools. A systematic decision framework is proposed by Kiker (2005) (Figure 2.7) which is intended to give a generalized road map to the environmental decision process.

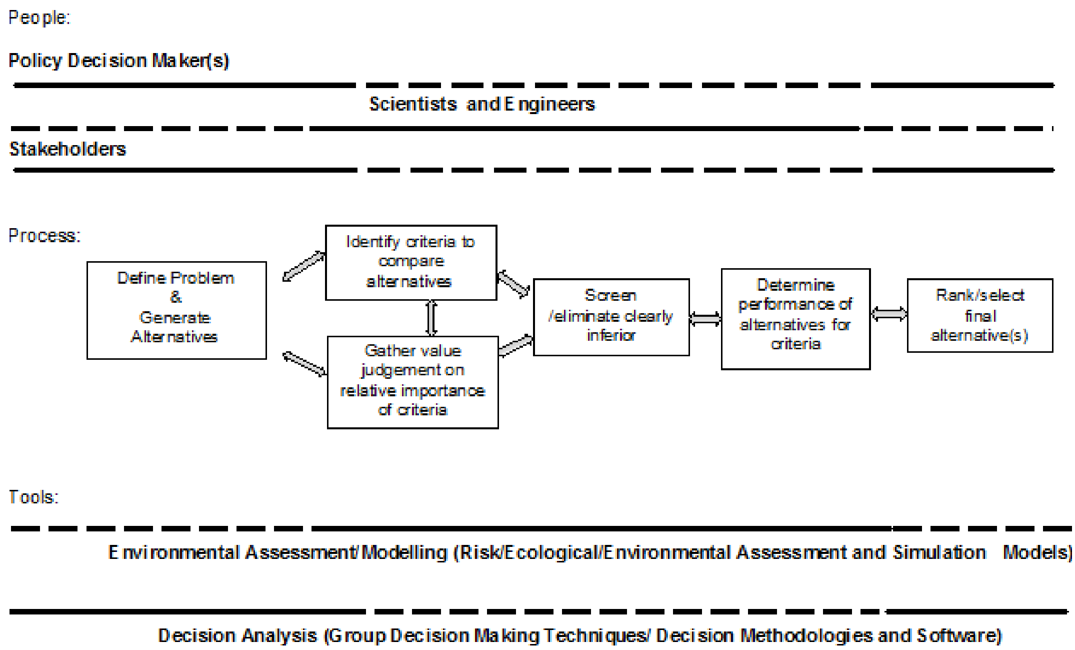


Figure 2.7: Synthesis of decision making ingredients (Kiker, 2005)

In Figure 2.7, the tools used within group decision making and scientific research are essential elements of the overall decision process. Similar to people, the applicability of the various tools is symbolized by solid lines (representing direct, or high, utility) and dotted lines (representing indirect, or lower, utility). Decision analysis tools help generate and guide the preferences of stakeholder groups, as well as individual value judgments, into organized structures that can be linked with the other technical tools from risk analysis, modelling/monitoring, and cost estimations. The decision analysis software also provides useful graphical techniques and visualization methods to express the gathered information in understandable formats. When changes occur in the requirements or decision process, decision analysis tools can respond efficiently to reprocess and iterate with the new inputs.

The MCDM applications are relevant to environmental management, stakeholder involvement, and the management of contaminated sites. The use of MCDM is more strongly evident within the broad area of environmental management and stakeholder involvement. It should be noted that MCDM has also been applied in many other related policy development areas, such as natural resource management (Schmold et al., 2001; Brown et al., 2001; Kangas et al, 2001); environmental/remedial technology selection (Hamalainen et al, 2001); environmental impact assessment (Rogers & Bruen, 1998); climate change (Bell et al. 2003); energy policy (Hobbs and Meier 2000) and etc.

Table 2.5 listed some of environmental management decision studies in which MCDM methods were integrated.

Table 2.5: Application of MCDM Tools for Environmental Management Studies

Area of Evaluation	Method	Reference
Landfill siting for a fast growing urban region	Fuzzy MCDM	Chang et al., 2008
Multi-contaminant industrial network design	TOPSIS	Boix et. al, 2011
Forestry planning	AHP	Kangas et al., 2001
Natural park management	AHP	Schmoldt et al, 1994
Highway environmental appraisal	ELECTRE	Rogers & Bruen, 1998
Environmental/remedial technology selection	AHP	Hamalainen et al, 2001
Management of marine protected area	Weighting	Brown et al, 2001
Post-emergency management of radioactively contaminated land	MCDM-GIS	Salt & Dunsmore., 2000
Improving and controlling air quality	AHP	Ananda & Herath, 2009
Selection of hydrothermal pre-treatment conditions of waste sludge destruction	PROMETHEE	Khalil et al., 2004
Necessities and priorities in Cleaner (Sustainable) Production	WSM	Ghazinoory, 2004
Evaluation of Bio-Electricity Production		Rozakis et al, 2001
Integrated assessment of climate change	AHP, ELECTRE	Bell et al., 2003
Incorporating sustainability Into Transportation Planning	WSM, MACBETH	Jeon, 2007

Although number of studies integrating MCDM methods into environmental decision making process in Turkey is very limited, Table 2.6 shows that diverse usage of these methods in various environmental fields becoming more common after 2000.

Table 2.6: Application of MCDM Tools for Environmental Management Studies in Turkey

Area of Evaluation	Method	Reference
Energy Planning	TOPSIS	Kaya & Kahraman, 2010
Selection of solid waste collection methods	TOPSIS	Ulukan & Kop, 2009
Water resource management	WSM,TOPSIS	Yilmaz & Harmancıoğlu, 2010
Current energy resources for Turkish manufacturing industry	ANP	Önüt et al, 2008
Selection of a municipal landfill site	ANP	Banar et al., 2007
Determination of appropriate energy policies	ANP	Ulutaş, 2004
Evaluation of alternative fuels for residential heating	ANP	Erdoğmuş et al., 2006
Environmental assessment of wind energy systems	OWA	Aydın et al., 2010
Health care waste management	OWA, TOPSIS	Dursun et al., 2011
Evaluating fuel alternatives for electricity generation	AHP, ANP	Halis, 2009

2.2.4. Case Studies on Integration of MCDM into Environmental Decision Making

2.2.4.1. A Multi-objective Optimization Framework for Multi-Contaminant Industrial Water Network Design (Boix, 2011)

The optimal design of multi-contaminant industrial water networks according to several objectives is carried out in this study. The general formulation of the water allocation problem was given as a set of nonlinear equations with binary variables representing the presence of interconnections in the network. For optimization purposes, three antagonist objectives were considered: F1, the freshwater flowrate at the network entrance, F2, the water flow-rate at inlet of regeneration units, and F3, the number of interconnections in the network. The multiobjective problem was solved via a lexicographic strategy, where a mixed-integer nonlinear programming procedure was used at each step.

2.2.4.2. Multiple Criteria Evaluation of Current Energy Resources for Turkish Manufacturing Industry (Önüt et. al, 2008)

Energy is the main component of natural resources of developing, as well as developed, countries like Turkey. Because of economic and social developments, the demand for energy, in general, has increased considerably in Turkey. Since Turkey is not an oil or natural gas producing country, the energy resource usage for energy consumption should be effective. The Turkish industrial sector comprises approximately 36% of Turkey's primary energy consumption and the manufacturing industry is the largest industrial sector. In this study, the focus was on the manufacturing industry as the major energy consuming sector in Turkey and it was analyzed in terms of efficient use of energy resources. The most widely used energy resources in the Turkish manufacturing industry, namely fuel-oil, coal, electricity, LPG and NG were taken into account. Evaluation and selection of current energy resources in this selected industry can be viewed as a MCDM problem, including human judgments, tangible and intangible criteria and priorities and tradeoffs between goals and criteria. The analytic network process one of the MCDM methods was used to evaluate the most suitable energy resources for the manufacturing industry in this study.

2.2.4.3. Combining GIS with Fuzzy Multicriteria Decision-Making for Landfill Sitting in a Fast-Growing Urban Region (Chang et al., 2008)

Landfill sitting is a difficult, complex, tedious, and protracted process requiring evaluation of many different criteria. In this study, a fuzzy multicriteria decision analysis is presented alongside with a geospatial analysis for the selection of landfill sites. It employs a two stage analysis synergistically to form a spatial decision support system for waste management in a fast-growing urban region, south Texas.
The first-stage analysis makes use of the thematic maps in Geographical information system (GIS) in conjunction with environmental, biophysical, ecological, and socioeconomic variables leading to support the second-stage analysis using the fuzzy multicriteria decision-making as a tool. It differs from the conventional methods of integrating GIS with MCDM for landfill selection because the approach follows two sequential steps rather than a full-integrated scheme. The case study was made for

the city of Harlingen in south Texas, which is rapidly evolving into a large urban area due to its vantage position near the US–Mexico borderlands. The purpose of GIS was to perform an initial screening process to eliminate unsuitable land followed by utilization of FMCDM method to identify the most suitable site using the information provided by the regional experts with reference to five chosen criteria. Research findings show that the proposed SDSS may aid in recognizing the pros and cons of potential areas for the localization of landfill sites in any study region. Based on initial GIS screening and final FMCDM assessment, one of the sites (site 1) was selected as the most suitable site for the new landfill in the suburban area of the City of Harlingen. Sensitivity analysis was performed using Monte Carlo simulation where the decision weights associated with all criteria were varied to investigate their relative impacts on the rank ordering of the potential sites in the second stage. Despite variations of the decision weights within a range of 20%, it shows that the same site (site 1) remains its comparative advantage in the final site selection process

2.2.4.4. Cleaner (Sustainable) Production in Iran: Necessities and Priorities (Ghazinoory, 2005)

The purpose of this study is to underscore the necessity for implementing a cleaner (sustainable) production strategy in order to achieve sustainable development for Iran's industries. While reviewing the reasons for the need to adopt the strategy of cleaner (sustainable) production for the industries of developing countries, the special features of Iranian society which makes the use of cleaner (sustainable) production necessary were also studied.

It is important to develop a model or method for developing a priority for industrialists to work with in initiating cleaner (sustainable) production activities. This was done in Iran using the MCDM. This included, among other things, interviewing the relevant experts and directors, for each industrial group. A relative ranking score was developed and based upon it, the priority of each group was determined. Within this process, the industrial groups of “textiles apparel and leather industries” were given the highest priority and the industrial group of “manufacture of wood and wood products, including furniture” were given the lowest priority.

CHAPTER 3

METHODOLOGY AND RESEARCH DESIGN

3.1. Study Approach

Purpose of this study is to prioritize manufacturing industry sub-sectors in Turkey (national level) and in İzmir (regional level) for cleaner (sustainable) production applications. Steps followed for this purpose are listed below;

a. Selection of the sectoral classification codes: Economic activities including manufacturing industry sub-sectors can be classified according to various topics. There are different statistical classifications and coding systems (Statistical Classification of Economic Activities in the European Community [NACE], International Standard Industrial Classification [ISIC], etc.) developed for this purpose. Within the scope of this study ISIC Rev.3.1 classification system which is the most common used one for the existing data sets was used (See Section 3.2).

b. Selection of important criteria affecting cleaner (sustainable) production: While comparing and prioritizing manufacturing industry sub-sectors for cleaner (sustainable) production applications, criteria that underpin to this approach are required. In this study, important criteria for the mentioned purpose was selected by taking international, national (for Turkey) and regional (for İzmir) framework conditions into account. For the prioritization of manufacturing industry sub-sectors for cleaner (sustainable) production in Turkey, nine different criteria were selected (Section 3.3.1), whereas this number is twelve in İzmir (Section 3.4.1) for analyzing related regional conditions. These criteria were used to evaluate the environmental performance, contribution to national/regional economy and cleaner (sustainable) production potential of the sectoral structure.

c. Weighting the selected criteria: It is apparent that all of the criteria that were used for the prioritization of manufacturing industry sub-sector in terms of cleaner (sustainable) production do not have the same importance. Therefore, criteria should be weighted based on their importance level in order to make a more accurate assessment. In this study, during the determination of weighting factors of selected criteria for cleaner (sustainable) production applications, three different weighting methods were used (Entropy Method, Simple Ranking Method, Eigen Value Method) (Section 3.3.2, Section 3.4.2). During the determination of weighting factors of selected criteria by Simple Ranking Method and Eigen Value Methods, feedbacks from stakeholders through the questionnaires were used as input.

d. Feedbacks of stakeholder for the determination of weighting factors of the selected criteria: Weighting of the criteria is directly depends on the decision maker (for Simple Ranking Method and Eigen Value Method). In order to minimize the subjectivity that may be reflected to the results, all of the related stakeholders (public bodies, universities, research agencies, non-governmental organizations, chambers of commerce and industrial zones) were included in the decision making process. Stakeholders included in the decision making process were selected according to the relation of their area of activities with the mentioned concepts. Variety in their area of activities is another aspect while selecting the stakeholders that were included in the decision making process. Questionnaires given in Appendix E were sent to 37 stakeholders for the case in Turkey and to 21 stakeholders for İzmir. Stakeholders were asked to prioritize the listed criteria from the cleaner (sustainable) production point of view. Feedbacks of the stakeholders (filled questionnaires) were used as input for Simple Ranking Method and Eigen Value Method. List of stakeholders provided feedback (22 stakeholders for Turkey, 18 stakeholders for İzmir) were listed in Appendix A.

e. Research and determination of the data sets used for selected criteria: In order to prioritize manufacturing industry sub-sectors for cleaner (sustainable) production based on selected criteria, quantitative data sets on selected criteria are required. For this purpose, different statistics/data sets from different sources were searched for each criterion and the most recent ones were selected to use in the analysis. At this stage, statistics which is periodically collected and organized by Turkish Statistical Institute (TÜİK) were generally tried to be used (Section 3.3.2, Section 3.4.2). Information relied on other sources were only used when information from TÜİK were insufficient or out-of-date. Summary of data sources were given in Table 3.1.

Table 3.1: Summary Data Sources

Criteria	**TURKEY**	**İZMİR**
Sectoral employment	TÜİK	SGK
Export share	TÜİK	TÜİK
Water consumption	TÜİK	TÜİK
Energy consumption	TÜİK	TÜİK
Amount of discharged wastewater	TÜİK	TÜİK
Amount solid waste generated	TÜİK	TÜİK
Amount hazardous waste generated	TÜİK	TÜİK
GHG Emissions	TÜİK, UNFCC	TÜİK, UNFCC
Suitability to cleaner (sustainable) production	GRECO	GRECO
Herfindahl-Hirschman Index	-	SGK, TÜİK
Number of companies	-	BTSB
Added value	-	TÜİK

f. Prioritization of manufacturing industry sub-sectors for cleaner (sustainable) production: Data regarding each criteria and each sector are placed to the MCDM matrix and all data sets were normalized (See Sections 3.3.2.1, 3.4.2.1). Normalized values of the criteria were multiplied by weighting factors assigned by the mentioned methods (See Sections 3.3.2, 3.4.2). For the purpose of identifying the priority sectors for cleaner (sustainable) production, two different MCDM methods were used. They are Weighted Sum Method (See Sections 3.3.3.1, 3.4.3.1.) and Analytical Hierarchy Method. Results (See Sections 3.3.3.2, 3.4.3.2) of the prioritization analysis were compared between each other and with the results of prioritization studies conducted for different purposes.

g. Sensitivity analysis: Sensitivity analysis was performed on the input data of MCDM matrices. For sensitivity analysis a methodology specific to MCDM Methods was followed (Triantaphyllou & Sanchez, 1997). (See Sections 3.3.4 and 3.4.4 for the methodology and Sections 4.1.4 and 4.2.4 for the results).

3.2. Sectoral Classification

In economic evaluations, sectors can be classified according to various topics particularly production activities, products and external trade. Target in activity classification is to group economic activities in homogenous categories and to enable international comparisons to be made. For this purpose, different statistical classifications and coding systems (NACE, ISIC, etc.) have been developed. “International Standards Industrial Classification (ISIC)”, prepared by United Nations, is one of the most common used classification and coding systems. Within the scope of this study data of TÜİK is utilized while doing sectoral prioritization for cleaner (sustainable) production practices. So, taking into account the existing data structure of TÜİK, ISIC Rev. 3.1 is the classification system for industrial sectors is selected to be used in this study.

ISIC general activities classification covered all activities in the economy (agriculture, fishing, mining, manufacturing, electricity, gas and water supply, etc.). Industry sector covers mining and energy sector in addition to manufacturing industry. In this study, manufacturing industry on which the cleaner (sustainable) production practices is focused on, was examined. According to ISIC Rev. 3.1, manufacturing industry is composed of 23 two-digit code sub-sectors. In this study, all sub-sectors except recycling are included. Classification of manufacturing industry sub-sectors according to ISIC Rev. 3.1 is provided in Table 3.2. A more detailed ISIC Rev. 3.1 manufacturing industry classification including three and four digit sub-sectors is given in Appendix B, Table B.1.

Table 3.2: International Standard Industrial Classification of All Economic Activities Manufacturing Classification (ISIC, Rev. 3.1)

D- Manufacturing Industry Main Manufacturing Industry Group	Code
Man. (Manufacture) of food products and beverages	15
Man. of tobacco products	16
Man. of textiles	17
Man. of wearing apparel	18
Tanning and dressing of leather	19
Man. of wood and of products of wood and cork, except furniture	20
Man. of paper and paper products	21
Publishing, printing and reproduction of recorded media	22
Man. of coke, refined petroleum products and nuclear fuel	23
Man. of chemicals and chemical products	24
Man. of rubber and plastics products	25
Man. of other non-metallic mineral products	26
Man. of basic metals	27
Man. of fabricated metal products, except machinery and equipment	28
Man. of machinery and equipment nec.*	29
Man. of office, accounting and computing machinery	30
Man. of electrical machinery and apparatus nec.	31
Man. of radio, television and communication equipment and apparatus	32
Man. of medical, precision and optical instruments, watches and clocks	33
Man. of motor vehicles, trailers and semi-trailers	34
Man. of other transport equipment	35
Man. of furniture, Manufacturing nec.	36

*nec.: not elsewhere classified

3.3. Prioritization of Manufacturing Industry Sub-Sectors for Cleaner (Sustainable) Production in Turkey

3.3.1. Important Criteria for Cleaner (Sustainable) Production (Turkey)

While comparing and prioritizing manufacturing industry sub-sectors for cleaner (sustainable) production applications, criteria that underpin to this approach are required.

Enclosing of all related components (environmental, economical, managerial etc.) of cleaner (sustainable) production is important for the accuracy of the results and the success of the implementations based on these results. In this context, nine criteria were selected to be used in prioritization of manufacturing industry sub-sectors for cleaner (sustainable) production applications in Turkey (See Sections 3.3.1.1 - 3.3.1.9). These criteria were used to evaluate the environmental performance, contribution to national economy and cleaner (sustainable) production potential of the sectoral structure.

Selected criteria can be listed as follows:

- Water consumption
- Energy consumption
- Amount of discharged wastewater
- Amount of solid waste generated
- Amount of hazardous waste generated
- GHG Emissions
- Sectoral employment
- Export share
- Suitability to cleaner (sustainable) production

In order to evaluate the manufacturing industry according to identified criteria, quantitative data is required. For this reason, statistics which is periodically collected and organized by TÜİK were used. Information relied on other sources were only used for calculations and conversions when information from TÜİK were insufficient (Green House Gas Emissions). Tables summarizing these calculations are given in Appendix C Table C.6.

Although there are some other criteria (waste management costs, compliance with EU Legislation etc.) that could be used in prioritization analysis, they cannot be used in the analysis due to lack of relative data in these criteria for all sectors investigated and integration problem of criteria to the MCDM methods.

Criteria and related data that were used while conducting the sectoral analysis and prioritizing these sectors for cleaner (sustainable) production are explained below.

Water consumption amounts of manufacturing industries sub-sector are given in Appendix C, Table C.1.

3.3.1.2. Energy Consumption

According to the results of “Sectoral energy consumption survey of TÜİK 2005”, the highest energy consumption belongs to manufacturing industry by 72.8% share (TÜİK, 2008b). It is stated that there are negative different environmental impacts arisen from production to consumption of energy. The most common pollution type is air pollution originated from usage of fossil fuels such as petroleum, natural gas and coal (DPT, 2007).

Energy consumption is another parameters that is frequently considered in cleaner (sustainable) production studies (Ozalp et al., 2010; CP/RAC, 2007; UNEP, 2007a; Ghazinoory, 2005). Therefore, the energy consumed in industries is selected as a criteria that needs to be considered in the prioritization analysis for cleaner (sustainable) production.

According to the sectoral distribution of energy consumption in Turkey (Figure 3.2) Manufacture of non-metallic mineral products has the highest energy consumption amount among the manufacturing industry sub-sectors with a share of 27%. It is followed by manufacture of basic metals (26%) and manufacture of textiles (13%).

According to the sectoral distribution of hazardous waste generation in Turkey (Figure 3.5) manufacture of chemical and chemical products has the highest hazardous waste amount among the manufacturing industry sub-sectors with a share of 41%. It is followed by manufacture of basic metals (25%) and manufacture of non-metallic mineral products (8%).

Amount of hazardous waste generated by manufacturing industry sub-sectors are given in Appendix C, Table C.5.

3.3.1.6. Greenhouse Gas Emissions

Mistakes made in the selecting the location of the industries and insufficient enforcement of the relevant legislations resulted in the increase the local air pollution problems that were solved in the beginning of 1960’s in the world (ÇOB, 2007). Emissions from electricity production and emissions from industrial processes are the ones that have the highest contribution to the increase in CO_2 emissions in 1990-2003 (DPT, 2007). GHG emissions is one of the important criteria in cleaner (sustainable) production practices (Jawjit et al., 2010; CP/RAC, 2007). So GHG emissions are also included in the list of criteria examined within the scope of this study.

According to the sectoral distribution of GHG emissions in Turkey (Figure 3.6) Manufacture of basic metal has the highest emission amount among the manufacturing industry sub-sectors with a share of 29%. It is followed by manufacture of non-metallic mineral products (24%) and manufacture of chemicals and chemical products (13%).

Yearly export share values of manufacturing industry sub-sectors are given in Appendix C, Table C.8.

3.3.1.9. Suitability to Cleaner (Sustainable) Production

Within the scope of this criteria, results of possible cleaner (sustainable) production practices are evaluated with respect various aspects. Concept of suitability to cleaner (sustainable) production is defined based on initial investment, rate of return of the investment and abatement of environmental impact of manufacturing processes etc. In this study initial investment, rate of return of the investment and abatement of environmental impact are taken into account. For this purpose, information in “Green Competitiveness in the Mediterranean Report” which is prepared by Regional Activity Centre for Cleaner Production and GRECO Initiative was used (CP/RAC, 2007).

This report seeks to understand cleaner (sustainable) production benefits in the Mediterranean Region. Analysis of cleaner (sustainable) production case studies in Mediterranean Region is based on data from CP/RAC MCID. This database identified 176 cleaner (sustainable) production techniques from 100 companies from different manufacturing industry sub-sectors.

This document includes the results of cleaner (sustainable) production implementation in manufacturing industry sub-sectors in terms of initial investment, rate of return of the investment and abatement of environmental impact. These results for three different aspects were integrated for each manufacturing industry sub-sector including 100 companies from Mediterranean Region and scored accordingly. Although results from 100 companies seem to be enough for such a comparison, more case studies from all around the world should be included for a much more detailed analysis. Figure 3.9 shows the comparison of manufacturing industry sub-sectors with respect to initial investment, payback period and environmental impact abatement of cleaner (sustainable) production projects.

3.3.2.1. Entropy Method

In this method values of the weights were determined without the direct involvement of the decision maker. The essential ideas is that the importance relative to a criteria, measured by the weight, is a direct function of the information conveyed by the criteria relative to the whole set of alternatives (Pomerol & Romero, 2000).

The steps followed for the determination of criteria weights via Entropy Method are as follows:

i. Normalization: Data listed in Appendix C, Table C.1 – Table C.9 were normalized via Formula (2.1). MCDM matrix for prioritization was formed with these normalized values.

ii. Entropy Calculation: For each criterion, entropy was calculated by using Formula (2.2). Calculated entropy values are given in Table 3.3.

iii. Dispersion Calculation: For each criterion, dispersion was calculated by using Formula (2.3). Calculated dispersion values are given in Table 3.3. Furthermore, via "EasyFit Software", normalized criteria values are fitted into normal distribution (Figure 3.10- Figure 3.14) and standard deviation values are calculated for making a comparison with dispersion values (Table 3.3).

iv. Weight Calculation: Criteria weights calculated by using entropy and dispersion values according to Formula (2.4) are given in Table 4.1.

Table D.1 for questionnaire). 67 experts filled these questionnaires representing 22 institutions in total. Response rate to the questionnaire is 60%. Feedbacks of the stakeholders (filled questionnaires) were used as an input for Simple Ranking Method. Results were integrated based on institutional scale. (List of stakeholders participating to the questionnaire can be seen from Appendix A).

Criteria ranks came from the stakeholders were firstly converted to scores. In Table 3.4, conversion between rankings and scores is given.

Table 3.4: Conversion between Ranking and Scores for Simple Ranking Methods

Ranking	1	2	3	4	5	6	7	8	9
Scores	9	8	7	6	5	4	3	2	1

After the calculation of scores' averages for each criterion, criteria weights were determined for each stakeholder and afterwards they were integrated for a single set of criteria weights. Criteria weights calculated by Simple Ranking Method are given in Section 4.1.1.2.

3.3.2.3. Eigen Value Method

In Eigen Value Method, weighting of the criteria also directly depends on the decision maker. In order to minimize the subjectivity that may be reflected to the results, related stakeholders (public bodies, universities, research agencies, non-governmental organizations, chambers of commerce and industrial zones) were included in the decision making process. Another important reason of this application is reflection of the related institutions' opinions to the decision making process. Stakeholders included in the decision making process were selected according to the relation of their area of activities with the mentioned concepts. Variety in their area of activities is another aspect while selecting the stakeholders that were included in the decision making process.

In order to determine the weights of criteria by Eigen Value Method, a matrix including a pair wise comparison of criteria should be filled. Questionnaire in Appendix D in Table D.2 was sent to 37 stakeholders. Stakeholders were asked to fill this matrix by comparing the criteria pair wise. 67 experts filled these questionnaires representing 22 institutions in total. Response rate to the questionnaire was 60%. Feedbacks of the stakeholders (filled questionnaires) were used as an input for Eigen Value Method. Results were integrated based on institutional scale. List of stakeholders participating to the questionnaire can be seen from Appendix A.

From the pair wise comparison matrix, weights assigned to each criteria were computed as the Eigen vector corresponding to the maximum eigenvalue of the matrix. Calculation of Eigen vector and eigenvalues in this study were done by “Expert Choice” software based on AHP. Expert Choice software provides a structured approach process for prioritization and decision-making. It is commonly used software for project and product management (America Online and National Aeronautics Space Administration-NASA), Strategic Planning and Budgeting (US Department of Housing and Urban Development), vendor and human resource management (3M Company) (Expert Choice, 2012).

As priorities make sense only if derived from consistent or near consistent matrices, an inconsistency check was also applied. The inconsistency ratio (I.R) indicates how consistent the comparison matrix with decision makers’ answers. A higher number means matrix is less consistent, whereas a lower number means that the matrix is more consistent (Pomerol & Romero, 2000). In general, if the I.R. is 0.10 or less, the decision maker’s answers are relatively consistent. I.R. values for matrices in this study were calculated by “Expert Choice” software program based on AHP. At this stage, results are interpreted in two ways. In the first way, results of the matrices that of I.R.s are larger than 0.1 was not included while calculating the averages (Pomerol & Romero, 2000). In the second one, all weighting factors coming from all matrices were included in the averages without considering the I.R. values

Criteria weights and I.R.s calculated by Eigen Value Method is given in Section 4.1.1.3.

3.3.3. Identification Priority Sector for Cleaner (Sustainable) Production in Turkey

For the purpose of identifying the priority manufacturing industry sub-sectors for cleaner (sustainable) production, two different MCDM methods were used. They are Weighted Sum Method and Analytical Hierarchy Method. Both methods are explained below.

3.3.3.1. Weighted Sum Method (WSM)

While the priority sectors were identified with WSM, normalized values inserted into MCDM matrix were used (See Appendix D, Table D.5 and Table D.6). These data were multiplied by the weights that were calculated by Entropy Method (Section 3.3.2.1) and Simple Ranking Method (Section 3.3.2.2) separately. Total scores for each alternative sector were calculated by using Formula (2.5). According to these calculated values, sectors were ranked from the sector with the highest score to the sector with the lowest score.

3.3.3.2. Analytical Hierarchy Process (AHP)

While the priority sectors were identified with AHP, normalized values inserted into MCDM matrix were used (See Appendix D, Table D.7). These data were multiplied by the weights that were calculated by Eigen Value Method (Section 3.3.2.3). According to these calculated values, sectors were ranked from the sector with the highest score to the sector with the lowest score via “Expert Choice Software”.

3.3.4. Sensitivity Analysis for the Prioritization Results (Turkey)

Often data in MCDM problems are imprecise and changeable. Therefore an important step in many applications of MCDM problems is to perform a sensitivity analysis on the input data. Sensitivity analysis approach determines how critical the various performance measures of the alternatives (in terms of a single decision criterion) are in the ranking of alternatives (Triantaphyllou & Sanchez, 1997).

The steps followed for sensitivity analysis in order to determine the most critical measure of performance are as follows:

i. The threshold value is the minimum change that has to occur on the current value of a_{ij} such that the current ranking between alternatives A_i and A_k will change. The threshold value for each measure of performance (aij) was determined by using Formula (3.2).

$$T_{i,j,k} = \frac{(P_i - P_k)}{\left|P_i - P_k + w_j\,(a_{kj} - a_{ij} + 1)\right|} \times \frac{100}{a_{ij}} \tag{3.2}$$

$T_{i,j,k}$: Threshold value of a_{ij} (where $1 \leq i < k \leq M$ and $1 \leq j \leq N$)
P_i : Score calculated for an alternative with the used method

ii. Criticality degree is the smallest amount (%) by which the current value of a_{ij} must change, such that the existing ranking of alternative A_i will change (Formula 3.3). Criticality degree of all alternatives was calculated in terms of each criterion.

$$Criticality\ degree = \min_{k \neq i}\{|T_{i,j,k}|\}\ for\ some\ N \geq k \geq i \tag{3.3}$$

iii. Most sensitive alternative, the one associated with the smallest criticality degree is identified (Formula 3.4)

$$Most\ sensitive\ alternative\ = \min_{M \geq i \geq 1}\left\{\min_{N \geq j \geq 1}\ Criticality\ degree\right\} \tag{3.4}$$

3.4. Prioritization of Manufacturing Industry Sub-Sectors for Cleaner (Sustainable) Production in İzmir

3.4.1. Important Criteria for Cleaner (Sustainable) Production (İzmir)

While comparing and prioritizing industrial sectors for cleaner (sustainable) productions, criteria that underpin to this approach are required. Enclosing of all related components (environmental, economical, managerial etc.) of cleaner (sustainable) production is important for the accuracy of the results and the success of the implementations based on these results. Criteria selected for the prioritization analysis for İzmir differ from the criteria selected for the prioritization analysis in Turkey. Additional criteria were selected that reflects the regional properties to the result of prioritization. In this context, 12 criteria were determined to be used in sectoral comparisons (See Sections 3.4.1.1 - 3.4.1.12). These criteria were used to evaluate the environmental performance, contribution to regional economy and cleaner (sustainable) production potential of the sectoral structure.

Selected criteria can be listed as follows:

- Herfindahl–Hirschman Index
- Water consumption
- Energy consumption
- Amount of discharged wastewater
- Amount of solid waste generated
- Amount of hazardous waste generated
- Greenhouse Gas Emissions (GHG)
- Sectoral employment
- Number of companies
- Export share
- Added value
- Suitability to cleaner (sustainable) production

In order to evaluate the manufacturing industry according to identified criteria, quantitative data is required. . For this purpose different statistics/data sets specific to İzmir from different sources were searched for each criteria and the most recent ones were selected to use in the analysis. For sectoral employment export share, number of companies, added value and Herfindahl–Hirschman Index statistical (measure of market concentration, See Section 3.4.1.1) statistics specific to İzmir were used from different sources (TÜİK, IZKA, Ministry of Industry and Trade [STB], and Social Security Institution [SGK]). On the other hand, environmental statistics (water consumption, energy consumption, wastewater discharge, solid waste, and hazardous waste and GHG emissions) were not available for İzmir for each manufacturing industry sub-sector. Values for these criteria were calculated from the environmental statistics used for Turkey by using Herfindahl–Hirschman Index as a ratio.

Criteria and related data that were used while conducting the sectoral analysis and prioritizing these sectors for cleaner (sustainable) production are explained below.

3.4.1.1. Herfindahl–Hirschman Index

Herfindahl–Hirschman Index is a commonly used statistical measure of market concentration. It measures the size of firms in relation to the industry and an indicator of the amount of competition among them. The Herfindahl–Hirschman Index takes into account the relative size and distribution of the firms in a market. The Herfindahl–Hirschman Index can be calculates from the Formula (3.1) below.

$$Herfindahl - Hirchman\ Index = \sum \left(\frac{E_{ij}}{E_j}\right)^2 \qquad (3.1)$$

where;
E_{ij}: employment in i region in j sector
E_j : employment in j sector in total

It is an economic approach widely applied in competition law, antitrust and also technology management. In addition to usage of this index in international and national strategy documents (U.S. Department of Justice and the Federal Trade Commission, 2010; U.S. Department of Commerce, 2002; European Commission, 2010; Kurul, 2011) , Herfindahl–Hirschman Index is also used in İzmir region for the determination of strategic rising sectors (İZKA, 2009a, South Aegean Development Agency [GEKA], 2011). Therefore, Herfindahl–Hirschman Index of each manufacturing industry sub-sector is selected as a criteria that needs to be considered in the prioritization analysis for cleaner (sustainable) production.

In addition, due to lack of specific data sets for İzmir regarding some criteria (water and energy consumption, solid waste, hazardous waste, GHG emissions), Herfindahl-Hirschman Index was also used for the projection of these criteria from national level (Turkey) to regional level (İzmir). Square root of this index shows the ratio of a manufacturing industry sub-sector in İzmir with respect to the same sector in Turkey.

According to the sectoral distribution of Herfindahl–Hirschman Index in İzmir (Figure 3.15); manufacture of tobacco products has the highest index value among the

Yearly water consumption values for manufacturing industry in İzmir were calculated from the values for that in Turkey (Appendix C, Table C.1) by using square root of Herfindahl–Hirschman Index as a ratio.

3.4.1.3. Energy Consumption

As it is also stated in Section 3.3.1.2, from production to consumption of energy, there are negative different environmental impacts. The most common pollution type is air pollution originated from usage of fossil fuels such as petroleum, natural gas and coal (DPT, 2007). In İzmir nearly 60% of total energy consumption belongs to industry (İZKA, 2008).

Energy consumption is another parameter that is frequently considered in cleaner (sustainable) production studies (Dovi et al.,2009; CP/RAC, 2007; UNEP, 2007a; Ghazinoory, 2005). Furthermore, energy consumption is one the most discussed subject also in the strategy documents prepared specific to İzmir (İBB, 2010; İZKA, 2010; İZKA 2008; ÇOB 2009a; ÇMO, 2008).To illustrate in “Activity Report of İzmir Metropolitan Municipality” activities regarding the dissemination of renewable energy usage were identified.(İBB, 2010). Therefore, the energy consumed in industries is selected as a criteria that needs to be considered in the prioritization analysis for cleaner (sustainable) production.

According to the sectoral distribution of energy consumption in İzmir (Figure 3.17) Manufacture of basic metals has the highest energy consumption amount among the manufacturing industry sub-sectors with a share of 33%. It is followed by manufacture of other non-metallic mineral products (23%) and manufacture of coke and refined petroleum (17%).

According to the sectoral distribution of the added value in İzmir (Figure 3.26) manufacture of coke and refined petroleum has the highest rate of added value among the manufacturing industry sub-sectors with a share of 24%. It is followed by manufacture of chemicals and chemical products (16%) and manufacture of tobacco products (14%).

The added value of each manufacturing industry sub-sector in İzmir is given in Appendix C, Table C.13

3.4.1.12. Suitability to Cleaner (Sustainable) Production

Rankings of the manufacturing industry sub-sectors in Section 3.3.1.9 were used.

3.4.2. Weighting of Important Criteria for Cleaner (Sustainable) Production for İzmir

As it is also explained in Section 3.3.2 criteria selected for prioritization of manufacturing industry sub-sectors for cleaner (sustainable) production in İzmir should be weighted based on the comparisons with other criteria in order to make a more accurate assessment. In this study, selected criteria were weighted according to their degree of importance by using different methods (Entropy Method, Simple Ranking Method, and Eigen Value Method).

3.4.2.1. Entropy Method

In this method values of the weights were determined without the direct involvement of the decision maker.

The steps followed for the determination of criteria weights via Entropy Method are as follows:

i. Normalization: Data figured out in Section 3.4.1.1-Section 3.4.1.12 were normalized via Formula (2.1). MCDM matrix for prioritization was formed with these normalized values.

ii. Entropy Calculation: For each criterion, entropy was calculated by using Formula (2.2). Calculated entropy values are given in Table 3.5.

iii. Dispersion Calculation: For each criterion, dispersion was calculated by using Formula (2.3). Calculated dispersion values are given in Table 3.5.

iv. Weight Calculation: Criteria weights calculated by using entropy and dispersion values according to Formula (2.4) are given in Table 4.1.

Table 3.5: Entropy, Dispersion and Weighting Values of Criteria (İzmir)

Criteria	**Entropy** $E_j = -k\, a_{ij} \log(a_{ij})$	**Dispersion** $D_j = 1 - E_j$
Sectoral employment	0.805533	0.194467
Number of companies	0.888454	0.111546
Export share	0.866502	0.133498
Additional value	0.807544	0.192456
Herfindahl–Hirschman Index	0.996961	0.003039
Water consumption	0.405986	0.594014
Energy consumption	0.654437	0.345563
Wastewater	0.336499	0.663501
Solid waste	0.381528	0.618472
Hazardous waste	0.546356	0.453644
Greenhouse Gas Emissions	0.596566	0.403434
Suitability to Cleaner Production	0.944816	0.055184
		D_j = 3.768817

Criteria weights calculated by Entropy Method are given in Section 4.2.1.1.

3.4.2.2. Simple Ranking Method

In Simple Ranking Method, weighting of the criteria directly depends on the decision maker. As it is also stated in Section 3.3.2.2, in order to minimize the subjectivity that may be reflected to the results, related stakeholders (public bodies, universities, research agencies, non-governmental organizations, chambers of commerce and industrial zones.) were included in the decision making process. Stakeholders included in the decision making process were selected according to the relation of their area of activities with the mentioned concepts. Variety in their area of activities is another aspect while selecting the stakeholders that were included in the decision making process.

Questionnaires, asking to sort the criteria according to importance level from cleaner (sustainable) production perspective, were filled by 18 stakeholders in face to face meetings (See Appendix D, Table D.3 for questionnaire). List of stakeholders participating to the questionnaire can be seen from Appendix A, Table A.2.

Criteria ranks came from the stakeholders were firstly converted to scores. (Table 3.4). Criteria weights calculated by Simple Ranking Method are given in Section 4.2.1.2.

3.4.2.3. Eigen Value Method

As it is in Simple Ranking Method, weighting of the criteria directly depends on the decision maker in Eigen Value Method as well. In order to minimize the subjectivity that may be reflected to the results, related stakeholders (public bodies, universities, research agencies, non-governmental organizations, chambers of commerce and industrial zones.) were included in the decision making process. Stakeholders included in the decision making process were selected according to the relation of their area of activities with the mentioned concepts. Variety in their area of activities is another aspect while selecting the stakeholders that were included in the decision making process.

In order to determine the weights of criteria by Eigen Value Method, a matrix including a pair wise comparison of criteria should be filled. Questionnaire in Appendix D in Table D.4 was sent to 18 stakeholders. Stakeholders were asked to fill this matrix by comparing the criteria pair wise. (List of stakeholders participating to the questionnaire can be seen from Appendix A).

From the pair wise comparison matrix, weight attached to each criterion was computed as explained in Section 3.3.2.3. Criteria weights by Eigen Value Method are given in Section 4.2.1.3.

3.4.3. Identification Priority Sector for Cleaner (Sustainable) Production in İzmir

For the purpose of identifying the priority manufacturing industry sub-sectors for cleaner (sustainable) production, two different MCDM methods were used. They are Weighted Sum Method and Analytical Hierarchy Method. Both methods are explained below.

3.4.3.1. Weighted Sum Method (WSM)

While the priority sectors were identified with WSM, normalized values inserted into MCDM matrix were used (See Appendix D, Table D.8 and Table D.9). These data were multiplied by the weights that were calculated by Entropy Method (Section 3.4.2.1) and Simple Ranking Method (Section 3.4.2.2) separately. Total scores for each alternative sector were calculated by using Formula (2.5). According to these calculated values, sectors were ranked from the sector with the highest score to the sector with the lowest score.

3.4.3.2. Analytical Hierarchy Process (AHP)

While the priority sectors were identified with AHP, normalized values inserted into MCDM matrix were used (See Appendix D, Table D.10). These data were multiplied by the weights that were calculated by Eigen Value Method (Section 3.4.2.3). According to these calculated values, sectors were ranked from the sector with the highest score to the sector with the lowest score via “Expert Choice Software”.

3.4.4. Sensitivity Analysis for the Prioritization Results (İzmir)

Same steps listed in Section 3.3.4 were followed for sensitivity analysis.

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter, the results obtained from prioritization analysis of manufacturing industry sub-sector for cleaner (sustainable) production implementations in Turkey and in İzmir are presented. Results of three different criteria weighting methods (Entropy Method, Simple Ranking Method, and Eigen Value Method) used for assigning weights to selected criteria are given in Sections 4.1.1 and 4.2.1. Differences in these results were discussed by comparing the weights assigned to the criteria. Results obtained from the prioritization analysis of manufacturing industries in Turkey and in İzmir conducted by WSM, AHP are given in Sections 4.1.2 and 4.2.2 and results of these analyses were discussed comparatively.

4.1. Prioritization of Manufacturing Industry Sub-Sectors for Cleaner (Sustainable) Production in Turkey

4.1.1. Weighting of Important Criteria for Cleaner (Sustainable) Production MCDM (Turkey)

4.1.1.1. Entropy Method

In this method, the values of the weights were determined without the direct involvement of the decision maker. Figure 4.1 and Table 4.1 shows the results of entropy analysis. As it can be seen from the results, water consumption has the highest weighting factor (0.182) due highest dispersion value of its data set. Wastewater, solid waste and hazardous waste criteria follows it. Although it is directly related criterion, suitability to cleaner (sustainable) production has the least weighting factor (0,018). As it explained in Section 2.2.2.1.1, importance (higher weighting factor) of the criteria is an indication of its discriminating power between alternatives. Discriminating power of suitability to cleaner production criterion is lower with respect to others due to lower dispersion value (data points are very close to mean and to each other). Thus, suitability to cleaner production takes the least weighting factor based on Entropy Method results as oppose to water consumption.

Table 4.1: Entropy, Dispersion and Weighting Factor Results of Criteria with Entropy Method (Turkey)

Criteria	**Entropy** $E_j = -k\ a_{ij} \log (a_{ij})$	**Dispersion** $D_j = 1 - E_j$	**Weighting Factor** $w_j = (D_j / D_j)$
Water Consumption*	0.476*	0.524*	0.182*
Wastewater	0.560	0.440	0.153
Solid Waste	0.589	0.411	0.143
Hazardous Waste	0.594	0.406	0.141
GHG Emissions	0.599	0.401	0.140
Energy consumption	0.681	0.319	0.111
Export Rate	0.839	0.161	0.056
Suitability to CP	0.948	0.052	0.018
Sectoral Employment	0.843	0.157	0.055
		$D_j = 2.872$	$w_j = 1$

*Sample calculation for water consumption criterion was shown in Appendix E, Section E.1.

As it can be seen from Table 4.1 higher the dispersion value of a criteria, higher the weight calculated by Entropy Method. It can be concluded from these results that while a prioritization analysis for manufacturing industry sub-sectors for cleaner (sustainable) production based on the results of Entropy Method, sectors with higher water consumption, higher wastewater discharge and higher amount of solid waste are the potential alternatives to be priority sectors.

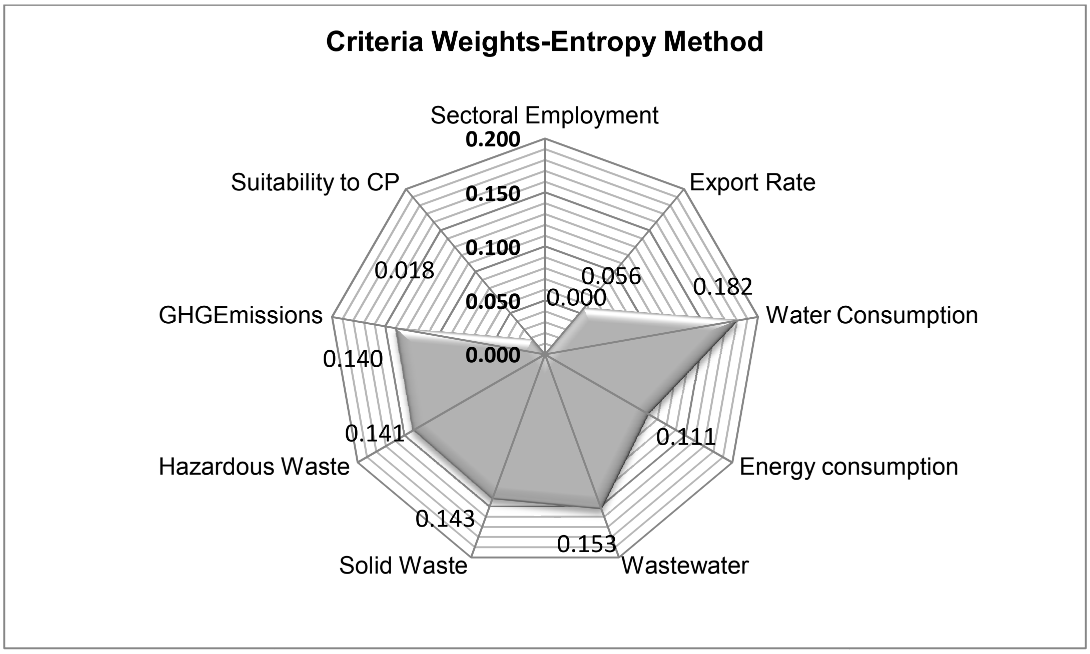


Figure 4.1: Criteria Weights Calculated by Entropy Method (Turkey)

4.1.1.2. Simple Ranking Method

In Simple Ranking Method, weighting of the criteria is directly depends on the decision maker. Table 4.2 and Figure 4.2 and show the results of Simple Ranking Method analysis. As it can be seen from the results, hazardous waste has the highest weighting factor (0.156) according to the rankings of decision makers. Energy consumption, water consumption and wastewater criteria follow hazardous waste criteria. Sectoral employment with the weighting factor of 0.051 takes place at the last rank.

As it can be seen from Table 4.2 higher the score assigned to a criterion by decision makers, higher the weight calculated by Simple Ranking Method. It can be concluded from these results that while a prioritization analysis for based on the results of Simple Ranking Method, sectors with higher amount of hazardous waste, higher energy consumption and higher water consumption are the potential alternatives to be priority sectors.

Table 4.2: Weighting Factor Results for Simple Ranking Method (Turkey)

Criteria	Score	Weight
Hazardous Waste	7.045	0.156
Energy consumption	6.216	0.138
Water Consumption	5.943	0.132
Wastewater	5.420	0.120
GHG Emissions	5.289	0.117
Solid Waste	5.135	0.114
Suitability to Cleaner (Sustainable) Production	5.010	0.111
Export Rate	2.742	0.061
Sectoral Employment	2.304	0.051
Number of Institutions		**22**

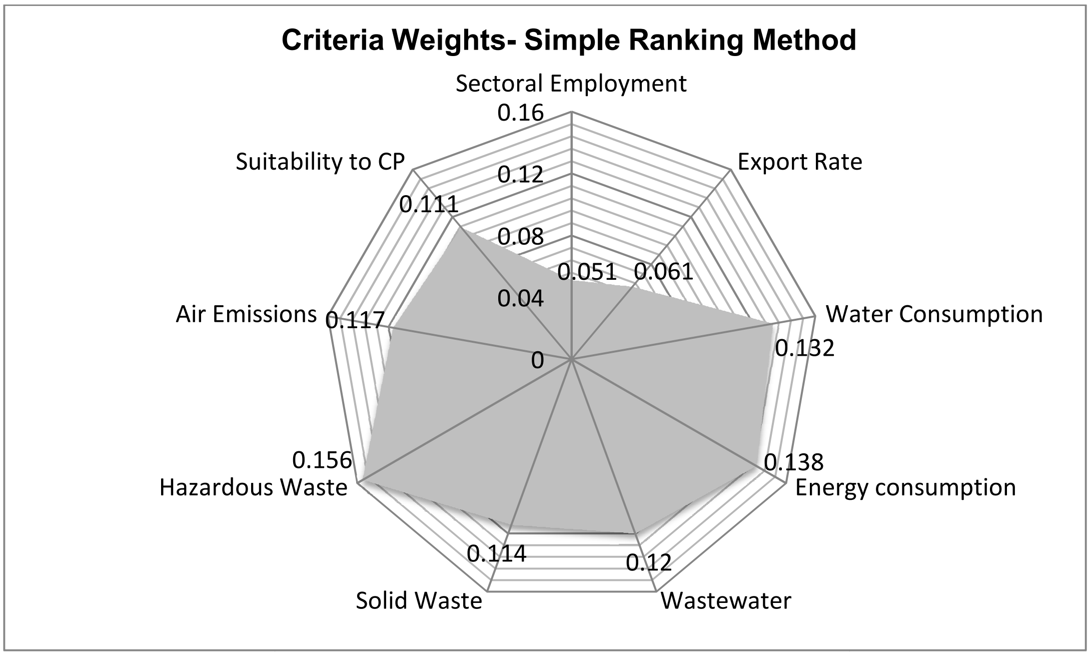


Figure 4.2: Criteria weights calculated by Simple Ranking Method (Turkey)

4.1.1.3. Eigen Value Method

As it is in Simple Ranking Method, weighting of the criteria is directly depends on the decision maker in Eigen Value Method also. For this method, results are interpreted in two ways. In the first way, results of the matrices whose I.R.'s are larger than 0.1

were not included while calculating the averages (Pomerol & Romero., 2000). In the second one, all weighting factors coming from all matrices were included in the averages without considering the I.R's. (Table 4.3).

Table 4.3: Weighting Factor Results According to Eigen Value Method (Turkey)

Criteria	**Weights**	
	I	**II**
Energy consumption	0.190	0.151
Hazardous Waste	0.182	0.189
GHG Emissions	0.171	0.155
Water Consumption	0.165	0.141
Suitability to Cleaner (Sustainable) Production	0.151	0.147
Solid Waste	0.106	0.096
Wastewater	0.104	0.098
Export Rate	0.065	0.076
Sectoral Employment	0.053	0.069
Number of Institutions	**14**	**22**

I: Questionnaires having I.R less than 0.1 were evaluated.

II: All of the questionnaires were evaluated.

As it can be seen from Table 4.3, both criteria weights and rankings are different for I and II. When the inconsistency ratios are taken into consideration, the most important criteria is appeared as energy consumption with a weighting factor of 0.190. In the second case in which the inconsistency ratios are not taken into consideration, hazardous waste is seen as the most important criteria with a weighting factor of 0.189. Differences in these results show that consistency in matrices is a critical issue and should be taken into account during the prioritization analysis. To be more accurate in the results of prioritization, weights of Eigen Value Method (I) is more convenient to use.

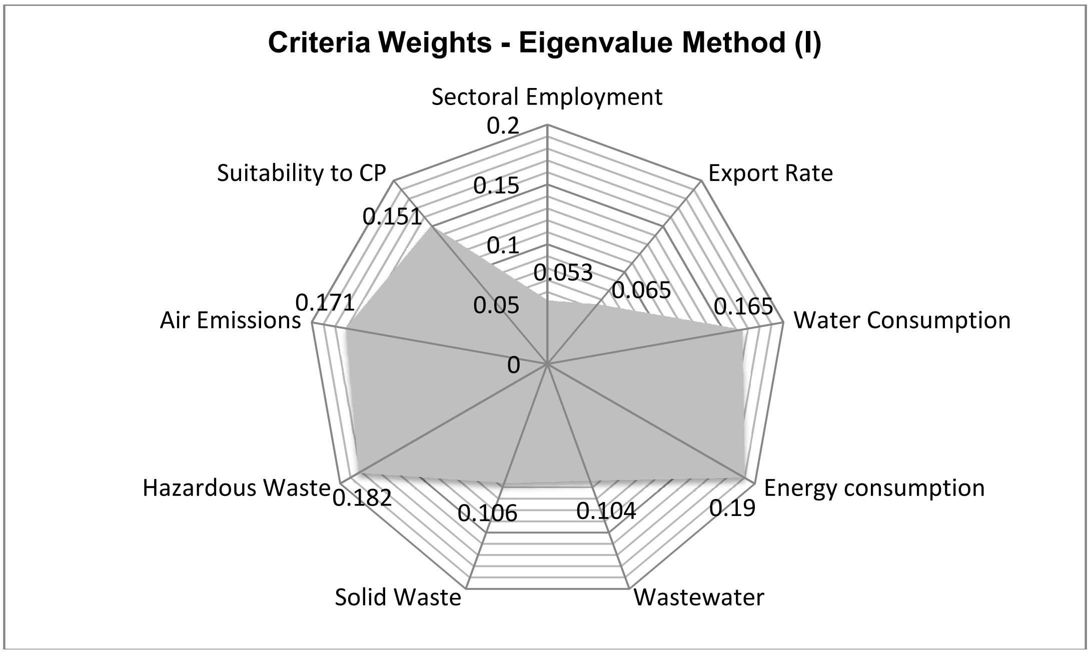


Figure 4.3: Criteria Weights Calculated by Eigen Value Method I (Turkey)

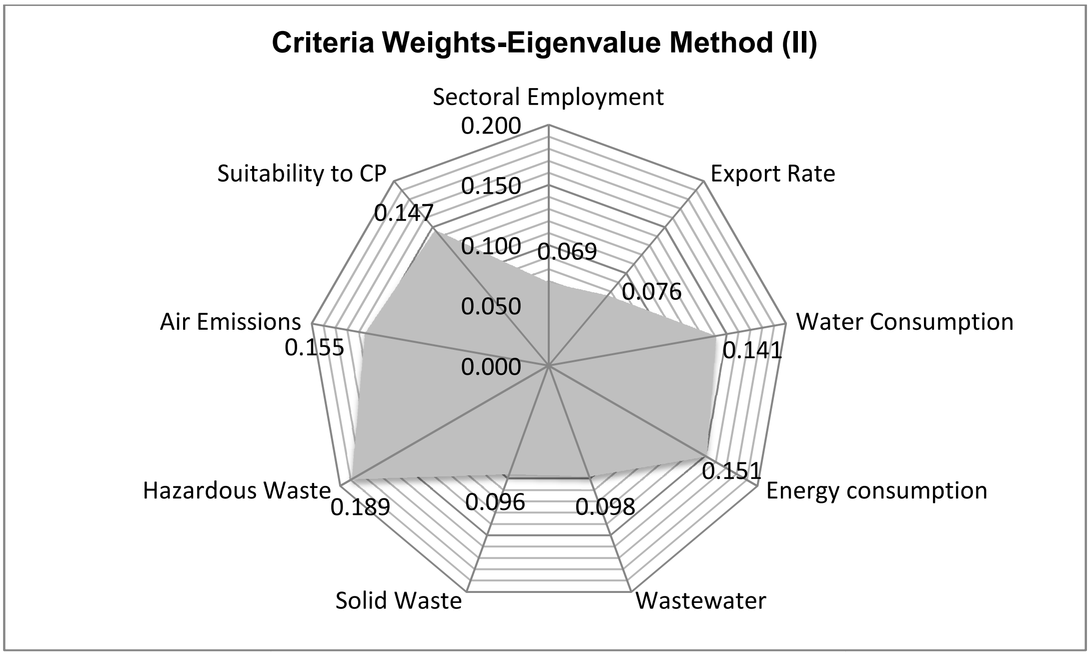


Figure 4.4: Criteria Weights Calculated by Eigen Value Method II (Turkey)

It can be concluded from the results given in Table 4.3 and Figure 4.3 that while a prioritization analysis based on the results of Eigen Value Method (I) sectors with higher energy consumption, higher amount of hazardous waste and higher water consumption are the potential alternatives to be priority sectors.

4.1.1.4. Comparison of Criteria Weighting Method Results (Turkey)

Comparison of the criteria weights calculated with Entropy, Simple Ranking and Eigen Value (I &II) Methods is given in Table 4.4 and Figure 4.5.

Table 4.4: Comparison of Criteria Weights (Turkey)

Criteria	Entropy Method	Simple Ranking Method	Eigen Value Method (I)	Eigen Value Method (II)
Sectoral Employment	0.055	0.051	0.053	0.069
Export Rate	0.056	0.061	0.065	0.076
Water Consumption	0.182	0.132	0.165	0.141
Energy consumption	0.111	0.138	0.190	0.151
Wastewater	0.153	0.12	0.104	0.098
Solid Waste	0.143	0.114	0.106	0.096
Hazardous Waste	0.141	0.156	0.182	0.189
GHG Emissions	0.140	0.117	0.171	0.155
Suitability to Cleaner (Sustainable) Production	0.018	0.111	0.151	0.147
Number of Institutions	**-**	**22**	**14**	**22**

I: Questionnaires having I.R less than 0.1 are evaluated;

II: All questionnaires are evaluated

As it can be seen from Table 4.4 and Figure 4.5, depending on the used method not only criteria weights but also the ranking of criteria differs. Although the criterion with highest weighting factor in Entropy Method is water consumption, it is hazardous waste in Simple Ranking Method and energy consumption in Eigen Value Method. Differences in these results will affect the prioritization analysis based on the results of these criteria weighting methods. For this reason all of the criteria weighting method results were used in the following steps (prioritization analysis of manufacturing industry sub-sectors). Criteria weights calculated by Entropy Method the other hand, weighting factors of criteria were assigned by decision makers in Simple Ranking and Eigen Value Method. As it can be seen from Table 4.4 and Figure 4.5, suitability to cleaner (sustainable) production criterion has the largest difference in the results between Entropy and other weighting methods (Simple Ranking and Eigen Value). The main reason for this is the usage of dispersion values in Entropy Method without the involvement of decision makers. As it is also explained in Section 4.2.1.3, this criterion has the least weighting factor due to its much lower dispersion value with respect to others.

Although both Simple Ranking Method and Eigen Value Method involve same decision makers in the criteria weighting process, results regarding criteria weighting factors differ between these two methods. In Simple Ranking Method decision makers were asked to rank selected criteria from 1 to 9 according to their importance level from cleaner (sustainable) production point of view. So, in this method, all 9 criteria were assessed together and decision makers provided only ordinal information that was converted to scores and weights by the analyst (Pomerol & Romero, 2000). However, in Eigen Value Method decision makers were asked to compare each criterion with those which follow (pair-wise comparison) by using a 9 point weighting scale (See Section 2.2.2.1.3). Furthermore, in Eigen Value Methods criteria weighting factors were determined according to eigenvector and eigenvalues of the matrices (Bouyssou et.al, 2006). Differences in the criteria weighting methodology of these two methods also affect the results obtained from them.

4.1.2. Identification of Priority Sectors for Cleaner (Sustainable) Production in Turkey

For the purpose of identifying the priority sectors for Cleaner (Sustainable) production, two of MCDM methods were used. They are Weighted Sum Method and Analytical Hierarchy Method. Results for both methods are explained below.

4.1.2.1. Weighted Sum Method (WSM)

While the priority sectors were identified with WSM, normalized values inserted into MCDM matrix were used. These data were multiplied by the weights that were calculated by Entropy Method (Section 4.1.1.1) and Simple Ranking Method (Section 4.1.1.2) separately. Total scores for each alternative sector were calculated by using (2.5). Prioritization results delivered from WSM are given in Table 4.5 and Table 4.6.

Table 4.5: WSM Prioritization Results (Criteria Weighting Method: Entropy Method)

Main Manufacturing Sector	Score	Ranking
Man. of basic metals	0.3989	1
Man. of food products and beverages	0.1478	2
Man. of chemicals and chemical products	0.1035	3
Man. of other non-metallic mineral products	0.0694	4
Man. of textiles*	0.0691*	5*
Man. of coke, refined petroleum products and nuclear fuel	0.0335	6
Man. of motor vehicles, trailers and semi-trailers	0.0296	7
Man. of machinery and equipment nec.	0.0269	8
Man. of wearing apparel	0.0238	9
Man. of fabricated metal products, except mach. Equip.	0.0211	10
Man. of electrical machinery and apparatus nec.	0.0173	11
Man. of paper and paper products	0.0147	12
Man. of rubber and plastics products	0.0109	13
Man. of furniture, Manufacturing nec.	0.0080	14
Man. of wood and of products of wood and cork, except furniture	0.0048	15
Man. of other transport equipment	0.0046	16
Man. of radio, television and communication equip.	0.0040	17
Man. of tobacco products	0.0036	18
Publishing, printing and reproduction of recorded media	0.0034	19
Tanning and dressing of leather	0.0028	20
Man. of medical, precision and optical instruments,	0.0009	21
Man. of office, accounting and computing machinery	0.0004	22

*Sample calculation for water consumption criterion was shown in Appendix E, Section E.2

As shown in Table 4.5, according to the prioritization results of WSM with Entropy Method as a criteria weighting method, manufacture of basic metals is in the first rank among other manufacturing industries with a score of 0.3889. It is followed by manufacture of food products and beverages, manufacture of chemicals and chemical products. Manufacture of basic metals has a much higher score than the others. The main reason behind this result is the manufacture of basic metal industry has the highest water consumption, the highest amount of wastewater discharge and the highest amount of solid waste criteria with respect to other manufacturing industry sub-sectors (Section 3.3.1.1, Section 3.3.1.3, and Section 3.3.1.4). These criteria in which the manufacturing of basic metals has a highest share among others were the criteria with highest weighting factors obtained with Entropy Method (Section 4.1.1.1).

Table 4.6: WSM Prioritization Results (Criteria Weighting Method: Simple Ranking Method)

Main Manufacturing Sector	**Simple Ranking**	
	Score	**Ranking**
Manufacture of basic metals	0.3482	1
Manufacture of food and beverages	0.1406	2
Manufacture of chemicals and chemicals products	0.1048	3
Manufacture of non-metallic products	0.0726	4
Manufacture of textiles	0.0698	5
Manufacture of coke, refined petroleum	0.0361	6
Manufacture of motor vehicles and trailers	0.0359	7
Manufacture of wearing apparel	0.0270	8
Manufacture of fabricated metal products	0.0263	9
Manufacture of electrical machinery nec	0.0257	10
Manufacture of machinery and equipment nec	0.0247	11
Manufacture of paper and paper products	0.0170	12
Manufacture of rubber and plastics products.	0.0148	13
Manufacture of furniture; manufacturing nec	0.0117	14
Manufacture of other transport equipment	0.0102	15
Manufacture of leather and footwear	0.0074	16
Manufacture of wood products and cork	0.0072	17
Printing and Publishing	0.0064	18
Manufacture of radio, TV, communication equipment	0.0052	19
Manufacture of tobacco products	0.0047	20
Manufacture of medical and optical instruments	0.0022	21
Manufacture of office, accounting and computing. machinery	0.0017	22
Number of Institutions		**22**

As shown in Table 4.6, according to the prioritization results of WSM with Simple Ranking Method as a criteria weighting method, manufacture of basic metals is in the first rank among other manufacturing industries with a score of 0.3482. It is followed by manufacture of food products and beverages, manufacture of chemicals and chemical products. As it is in WSM-Entropy Method, manufacture of basic metals has a much higher score than the others. The main reason behind this result is the manufacture of basic metal industry has the highest water consumption, higher energy consumption and higher amount of hazardous waste with respect to other manufacturing industry sub-sectors (Section 3.3.1.1, Section 3.3.1.2, and Section 3.3.1.5). These criteria in which the manufacturing of basic metals has a higher share among others were the criteria with highest weighting factors obtained with Simple Ranking Method (Section 4.1.1.2).

4.1.2.2. Analytical Hierarchy Process (AHP)

The first step of prioritization with AHP is the determination of criteria weights by a pair-wise comparison. These weights were determined with Eigen Value Method. Next step is the multiplication of normalized values with criteria weights and analysis of them as in the WSM. Scores and the ranking of the sectors according AHP method are given in Table 4.7 and Table 4.8.

Table 4.7: AHP Prioritization Results (I) (Criteria Weighting Method: Eigen Value Method)

Main Manufacturing Sector	Score (I)	Ranking (I)
Manufacture of basic metals	0.4063	1
Manufacture of food and beverages	0.1652	2
Manufacture of chemicals and chemicals products	0.1245	3
Manufacture of non-metallic products	0.0918	4
Manufacture of textiles	0.0811	5
Manufacture of coke, refined petroleum	0.0436	7
Manufacture of motor vehicles and trailers	0.0425	6
Manufacture of fabricated metal products	0.0323	10
Manufacture of electrical machinery nec	0.0317	9
Manufacture of wearing apparel	0.0305	8
Manufacture of machinery and equipment nec	0.0276	11
Manufacture of paper and paper products	0.0208	12
Manufacture of rubber and plastics products.	0.0181	13
Manufacture of furniture; manufacturing nec	0.0142	14
Manufacture of other transport equipment	0.0130	15
Manufacture of leather and footwear	0.0096	16
Manufacture of wood products and cork	0.0092	17
Printing and Publishing	0.0082	18
Manufacture of radio, TV, communication equipment	0.0062	19
Manufacture of tobacco products(	0.0057	20
Manufacture of medical and optical instruments	0.0028	21
Manufacture of office, accounting and computing. machinery	0.0022	22
Number of Institutions		**14**

I: Questionnaires having I.R less than 0.1 are evaluated

As shown in Table 4.7 and Table 4.8, according to the prioritization results of AHP with Eigen Value Method as a criteria weighting method, manufacture of basic metals is in the first rank among other manufacturing industries with a score of 0.3701. It is followed by manufacture of food products and beverages, manufacture of chemicals and chemical products. As it is in other methods explained before (See Section 4.1.2.1), manufacture of basic metals has a much higher score than the others. The main reason behind this result is the manufacture of basic metal industry has the higher energy consumption, higher amount of hazardous waste and the highest GHG emissions with respect to other manufacturing industry sub-sectors (Sections 3.3.1.2, 3.3.1.5, and 3.3.1.6). These criteria in which the manufacturing of basic metals has a higher share among others were the criteria with highest weighting factors obtained with Entropy Method (Section 4.1.1.1).

Table 4.8: AHP Prioritization Results (II) (Criteria Weighting Method: Eigen Value Method)

Main Manufacturing Sector	Score (II)	Ranking (II)
Manufacture of basic metals	0.3701	1
Manufacture of food and beverages	0.1573	2
Manufacture of chemicals and chemicals products	0.1187	3
Manufacture of non-metallic products	0.0811	4
Manufacture of textiles	0.0773	5
Manufacture of motor vehicles and trailers	0.0438	6
Manufacture of coke, refined petroleum	0.0416	7
Manufacture of wearing apparel	0.0325	8
Manufacture of electrical machinery nec	0.0320	9
Manufacture of fabricated metal products	0.0315	10
Manufacture of machinery and equipment nec	0.0276	11
Manufacture of paper and paper products	0.0191	12
Manufacture of rubber and plastics products	0.0179	13
Manufacture of furniture; manufacturing nec	0.0143	14
Manufacture of other transport equipment	0.0130	15
Manufacture of leather and footwear	0.0096	16
Manufacture of wood products and cork	0.0086	17
Printing and Publishing	0.0078	18
Manufacture of radio, TV, communication equipment	0.0064	19
Manufacture of tobacco products	0.0057	20
Manufacture of medical and optical instruments	0.0028	21
Manufacture of office, accounting and computing machinery	0.0022	22
Number of Institutions		**22**

II: All questionnaires are evaluated

4.1.3. Comparison and Evaluation of Sectoral Analysis Results (Turkey)

In this study, manufacturing industry sub-sectors were prioritized based on selected criteria via different MCDM methods (WSM-Entropy Methods, WSM-Simple Ranking Method, AHP-Eigen Value Method) for cleaner (sustainable) production in Turkey by including the feedbacks of the stakeholders. Comparative results of these prioritizations are given in Table 4.9. AHP (II) results are not taken into consideration due to having inconsistency values larger than 0.1.

As it can be seen from Table 4.9, although results of different methods (WSM-Entropy Methods, WSM-Simple Ranking Method, and AHP-Eigen Value Method) vary in some rankings, it is observed that results from these different methods mainly overlap. When the three different analysis results are considered, it is seen that sectors in the first five ranks does not differ. Accordingly, priority sectors for cleaner (sustainable) production practices in Turkey are as follows:

- Basic metal industry
- Manufacture of food products and beverages
- Manufacture of chemical and chemical products
- Manufacture of non-metallic mineral products
- Manufacture of textiles

The main reason behind this coincidence is the higher share of the first five ranked manufacturing industry sub-sectors in the criteria with highest weighting factors obtained by Entropy Method, Simple Ranking Method and Eigen Value Methods. In other words, all of the 5 sectors above have higher water consumption, higher energy consumption, higher amount of solid waste and hazardous waste and higher GHG emissions in addition to higher share in other criteria with respect to other manufacturing industry sub-sectors.

In the case of a cleaner (sustainable) production investment in Turkey, these five sectors should be taken into account primarily. Sectors taking in the first five ranks also coincide with the priorities of other national and international institutions/ organizations. For example, within the scope of UNIDO Eco-efficiency (Cleaner Production) Program, sectors prioritized based on water consumption are indicated as follows; manufacture of textiles and leather, manufacture of food products and beverages, manufacture of chemical and chemical products, manufacture of paper and paper products. Among these sectors, leather, paper and paper products manufacturing does not take place in the priority list within the scope of this study. One of the main reasons for this situation is that; water consumption is the only criteria that the analysis of the UNIDO is based on whereas in this study nine criteria enclosing both environmental and economical considerations were used. Furthermore, in EU's Competitiveness & Innovation Program, manufacturing of food and beverages sector is identified in the list of priority sector for eco-efficiency investments.

Table 4.9: Comparative Ranking of Sectoral Prioritization

MCDM Method **Weighting Method**	**WSM** **Entropy**	**WSM** **Simple ranking**	**AHP** **Eigen value (I)**
Man. of basic metals	1	1	1
Man. of food products and beverages	2	2	2
Man. of chemicals and chemical products	3	3	3
Man. of other non-metallic mineral products	4	4	4
Man. of textiles	5	5	5
Man. of coke, refined petroleum products and nuclear fuel	6	6	7
Man. of motor vehicles, trailers and semi-trailers	7	7	6
Man. of machinery and equipment nec.	8	11	10
Man. of wearing apparel	9	8	9
Man. of fabricated metal products, except mach. Equip.	10	9	8
Man. of electrical machinery and apparatus nec.	11	10	11
Man. of paper and paper products	12	12	12
Man. of rubber and plastics products	13	13	13
Man. of furniture, Manufacturing nec.	14	14	14
Man. of wood and of products of wood and cork, except furniture	15	17	15
Man. of other transport equipment	16	15	16
Man. of radio, television and communication equip.	17	19	17
Man. of tobacco products	18	20	18
Publishing, printing and reproduction of recorded media	19	18	19
Tanning and dressing of leather	20	16	20
Man. of medical, precision and optical instruments,	21	21	21
Man. of office, accounting and computing machinery	22	22	22
Number of Institutions	-	**22**	**14**

production capacity, export potential, supply to other sectors. Production capacity of this sector is 2.5 million tons in 1980s and increased ten times in 2007 (STB, 2011). Basic metal industry has importance by taking place among the highest export share industries also.

Food products and beverages sector, in the second rank, is one of the biggest industries in Turkey. This sector creating significant employment has a positive impact on economy by providing added-value. Furthermore, it takes place in the highest rank among the sectors having highest foreign investment (STB, 2011).

Chemical and chemical products industry appears in the third ranked based on cleaner (sustainable) production approach in this study. This sector provides raw material to other industrial sectors such as; plastics, cosmetic, pharmaceuticals, paint (TÜSİAD, 2007). Besides, highest investment is put into chemical and chemical products sector in Turkey (STB, 2011).

Manufacture of non-metallic other mineral products industry, in fourth rank, includes cement industry as a sub-sector. Capacity of and investment on cement industry increased (STB, 2011). Furthermore, glass industry listed under heading of non-metallic mineral products sector is qualified as “priority sector” and “sensitive sector” in the world due to its high added value per employee, interactions with other sectors, creation of work capacity, high technology usage, besides its structural and economical properties (ÇOB, 2007).

Textile sector ranked in the fifth place among the priority sectors has a critical importance in Turkey’s economy when the current installed capacity, export share and sectoral employment criteria are taken into consideration. National product and employment provided by this sector are very important in addition to having the largest production capacity and being an important part of the country exports (STB, 2011). Furthermore, first legal document regarding cleaner (sustainable) production in Turkey was published for textile industry. Notification on “Integrated Pollution Prevention and Control (IPPC) for Textile Industry” was published on December 2011 and requires to prepare and implement cleaner (sustainable) production plans in textile industry companies (Ministry of Environment and Urban Planning, 2011).

As can be seen from the given examples, although the analysis for the prioritization of the sectors predicated on the cleaner (sustainable) production, results from this analysis overlap with other priority lists of other institutions/organizations based on different criteria.

After these primary sectors, sectors ranked between fifth and tenth secondary sectors take place. These sectors can be listed as, coke coal, refined petroleum products, nuclear fuel manufacturing, manufacture of machinery and equipment nec., manufacture of wearing apparel, manufacture of fabricated metal products, manufacture of electrical machinery and apparatus. In “Industry for Continuous and Balanced Development” section of “Turkey National Agenda 21 Report” prepared by Ministry of Environment and Forestry (2007), it is stated sustainable industrialization policy will especially affect the industries having high water, raw material and energy consumptions such as paper packaging, chemical and petrochemical industries. Ranking of these sectors varies according to method used and it changes between six and ten. As stated before, for the analysis of sectors nine set of data are used for nine criteria, details of which are given in section 3.3. For these sectors to conduct a more accurate and detailed prioritization, an analysis with more data sets should be done. But, results of this analysis,

- Prioritize industrial sectors in Turkey based on cleaner (sustainable) production practices,
- Offer input for future policies,
- Form a basis for similar future studies that will be done with more comprehensive data sets and opinions of related stakeholder institutions/ organizations.

4.1.4. Sensitivity Analysis for Sectoral Prioritization Results (Turkey)

Often data in MCDM problems are imprecise and changeable. Therefore an important step in many applications of MCDM problems is to perform a sensitivity analysis on the input data. Sensitivity analysis approach determines how critical the various performance measures of the alternatives (in terms of a single decision criterion) are in the ranking of alternatives (Triantaphyllou & Sanchez, 1997).

Sensitivity analysis for the results obtained from WSM (Section 4.2.2.1) was performed. First threshold values of each a_{ij} were calculated. Afterwards criticality degree of each alternative was determined. Based on the obtained results most sensitive alternative was identified.

Threshold values for each alternative regarding each criterion were calculated by using Formula (3.2). During this process, MCDM matrices given in Appendix D, Table D.8 (WSM-Entropy) were used. Corresponding criticality degrees (%) (Minimum threshold values for each aij) were given in Table 4.10.

Entries in Table 4.10 indicate the minimum amount of changes for the aij values required for a change in the rankings of alternatives. To help interpret the entries in Table 4.10f consider anyone of them; say entry for the second alternative (with the ISIC Code 15) regarding export share criterion (4482). This entry indicates that criticality value for second alternative (ISIC Code: 15) based on the export share criterion is equal to % 482. That is the measure of performance of aij must be decreased by % 482 from its current value, in order for third alternative (ISIC Code: 26) to become more preferred than second alternative (ISIC Code: 15). A similar interpretation holds for the rest of the entries. Negative changes in the entries mean that the regarding aij values should increase for a change in the rankings.

From Table 4.10.it can be concluded that most sensitive alternative (lowest criticality value) is alternative with the ISIC Code 29 (Manufacture of machinery and equipment not elsewhere classified. This is true because alternative corresponds to the minimum criticality degree (equal to 158) among all values in Table 4.10.

Table 4.10: Criticality degrees of Alternatives for WSM (Entropy) Method

ISIC Code	Employment	Export	Water Cons.	Energy Cons.	Wastewater	Solid waste	Hazardous waste	GHG Emissions	Suitability to CP
27	10,771	13,497	1,410	2,454	796	846	3,137	3,768	6,447
	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)	(15)
15	20,784	482*	6,136	3,976	4,862	2,428	1,056	3,654	2,245
	(26)	(26)	(26)	(26)	(26)	(26)	(26)	(26)	(26)
26	2,514	2,066	3,020	2,372	1,784	1,398	13,6704	3,886	918
	(17)	(17)	(17)	(17)	(17)	(17)	(17)	(17)	(17)
17	-3,053	-2,454	2,571	2,026	1,518	1,196	11,649	3,303	782
	(26)	(26)	(23)	(23)	(23)	(23)	(23)	(23)	(23)
23	9,023	6,915	15,430	717	8,497	21,316	5,405	1,307	5,752
	(34)	(34)	(34)	(34)	(34)	(34)	(34)	(34)	(34)
34	569	896	1,106	1,472	1,578	1,477	2,693	1,286	2,814
	(29)	(29)	(29)	(29)	(29)	(29)	(29)	(29)	(29)
29	**158**	726	9,469	1,398	3,080	1,348	2,526	1,501	942
	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)	(18)
18	904	716	286	5,483	1,547	2,447	7,154	1,483	1,563
	(28)	(28)	(28)	(28)	(28)	(28)	(28)	(28)	(28)
28	237	1,156	1,051	680	494	334	438	453	3,365
	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)	(31)
31	5,013	2,398	6,171	2,967	3,578	3,498	2,012	1,978	851
	(21)	(21)	(21)	(21)	(21)	(21)	(21)	(21)	(21)

* Sample calculation was shown in Appendix E, Section E.3

Table 4.10: Criticality degrees of Alternatives for WSM (Entropy) Method (Cont'd)

ISIC Code	Employment	Export	Water Cons.	Energy Cons.	Wastewater	Solid waste	Hazardous waste	GHG Emissions	Suitability to CP
21	6,838	3,083	3,014	4,283	1189,200	1,483	784,800	2,458	3,560
	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)	(25)
25	6,014	13,919	9,072	4,734	5,875	2,838	1,086	4,117	2,718
	(36)	(36)	(36)	(36)	(36)	(36)	(36)	(36)	(36)
36	3,132	1,823	4,436	6,740	7,787	1,240	2,136	6,148	9,722
	(26)	(26)	(26)	(26)	(26)	(26)	(26)	(26)	(26)
20	-6,025	-8,137	201	2,869	4,814	6,122	11,651	2,164	1,179
	(36)	(36)	(35)	(35)	(35)	(35)	(35)	(35)	(35)
35	3,534	5,881	10,402	9,534	1,735	12,428	5,881	3,346	4,922
	(32	(32)	(32)	(32)	(32)	(32)	(32)	(32)	(32)
32	6,178	2,882	7,069	3,617	4,141	1,190	1,214	1,183	1,205
	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
16	1,386	344	9,768	6,014	4,175	2,614	6,055	7,254	1,206
	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)	(22)
22	-715	-1,294	-7,487	-1,883	-1,547	-2,526	-4,318	-2,042	4,565
	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)	(16)
19	1,438	4,757	1,183	2,014	4,094	2,495	4,158	3,694	1,244
	(34)	(34)	(34)	(34)	(34)	(34)	(34)	(34)	(34)
33	-3,108	-13,643	-6,730	-3,912	-5,483	-6,247	-1,740	-631	-1,284
	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)	(19)

4.2. Prioritization of Manufacturing Industry Sub-Sectors in İzmir for Cleaner (Sustainable) Production (İzmir)

4.2.1. Weighting of Important Criteria for Cleaner (Sustainable) Production MCDM

4.2.1.1. Entropy Method

In this method values of the weights were determined without the direct involvement of the decision maker. Table 4.11 and Figure 4.7 show the results of entropy analysis. As it can be seen from the results, wastewater discharge with the weighting factor of 0.176 take place at the highest rank (with highest dispersion values); solid waste and water consumption criteria follow it. At the last rank, Herfindahl - Hirschman Index takes place. Reason for this criterion to take the least weighting factor (0.001) is lowest dispersion value of its data set. As it explained in Section 2.2.2.1.1, importance (higher weighting factor) of the criteria is an indication of its discriminating power between alternatives. Discriminating power of Herfindahl - Hirschman Index criterion is lower with respect to others due to lower dispersion value (data points are very close to mean and to each other). Thus, Herfindahl - Hirschman Index takes the least weighting factor based on Entropy Method results as oppose to wastewater.

As it can be seen from Table 4.11 higher the dispersion value of a criteria, higher the weight calculated by Entropy Method. It can be concluded from these results that while a prioritization analysis based on the results of Entropy Method, sectors with, higher wastewater discharge, higher amount of solid waste and higher wastewater discharge are the potential alternatives to be priority sectors.

Table 4.11: Entropy, Dispersion and Weighting Factors of Criteria (İzmir)

Criteria	**Entropy** $E_j = -k\ a_{ij} \log (a_{ij})$	**Dispersion** $D_j = 1 - E_j$	**Weighting Factor** $w_j = (D_j / D_j)$
Wastewater	0.336	0.664	0.176
Solid waste	0.382	0.618	0.164
Water consumption	0.406	0.594	0.158
Hazardous waste	0.546	0.454	0.120
Greenhouse Gas Emissions	0.597	0.403	0.107
Energy consumption	0.654	0.346	0.092
Sectoral employment	0.806	0.194	0.052
Additional value	0.808	0.192	0.051
Export share	0.867	0.133	0.035
Number of companies	0.888	0.112	0.030
Suitability to Cleaner (Sustainable) Production	0.945	0.055	0.015
Herfindahl - Hirschman Index	0.997	0.003	0.001
		$D_j = 3.767$	$w_j = 1$

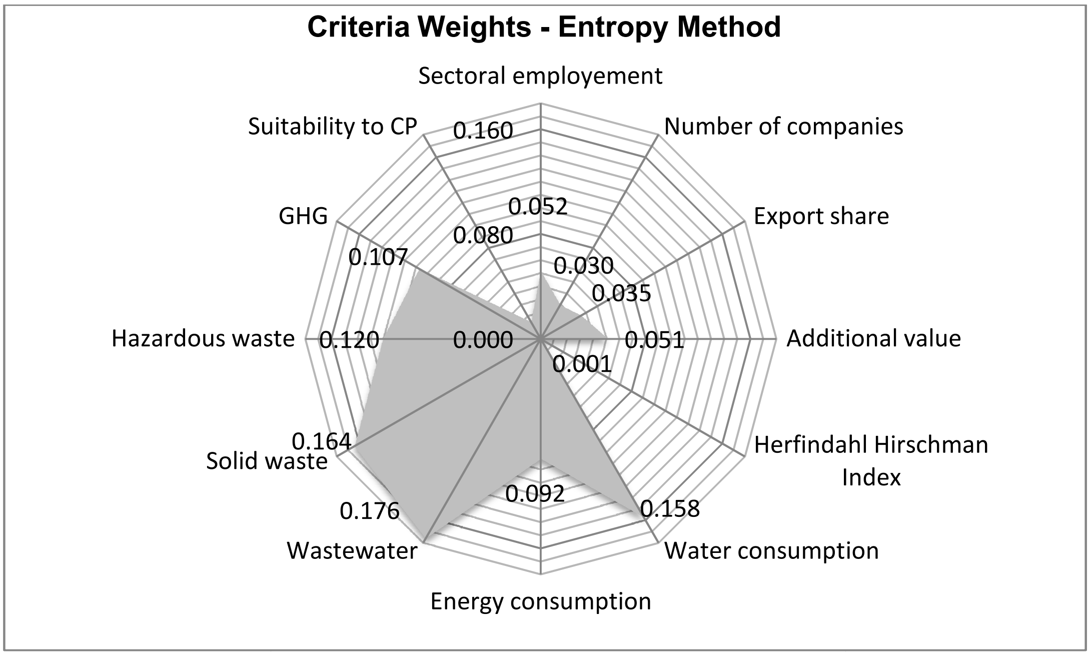


Figure 4.7: Criteria Weights Calculated by Entropy Method (İzmir)

4.2.1.2. Simple Ranking Method

In Simple Ranking Method, weighting of the criteria is directly depends on the decision maker. Table 4.12 and Figure 4.8 show the results of Simple Ranking Method analysis. As it can be seen from the results, hazardous waste has the highest weighting factor (0.123) according to the rankings of decision makers. Water consumption, energy consumption and wastewater criteria follow hazardous waste criteria. Sectoral employment with the weighting factor of 0.051 takes place at the last rank.

Table 4.12: Weighting Factor Results for Simple Ranking Method (İzmir)

Criteria	Score	Weighting Factor
Hazardous waste	9.78	0.123
Water consumption	9.08	0.114
Energy consumption	8.91	0.112
Wastewater	7.45	0.093
Greenhouse Gas Emissions	7.21	0.091
Solid waste	6.81	0.086
Suitability to Cleaner (Sustainable) Production	6.03	0.076
Number of companies	5.2	0.065
Export share	5.17	0.065
Additional value	5	0.063
Herfindahl-Hirschman Index	4.9	0.062
Sectoral employment	4.1	0.051
Number of Institutions		**18**

As it can be seen from Table 4.12 higher the score assigned to criteria by decision makers, higher the weight calculated by Simple Ranking Method. It can be concluded from these results that while a prioritization analysis based on the results of Simple Ranking Method, sectors with higher amount of hazardous waste, higher water consumption and higher energy consumption are the potential alternatives to be priority sectors.

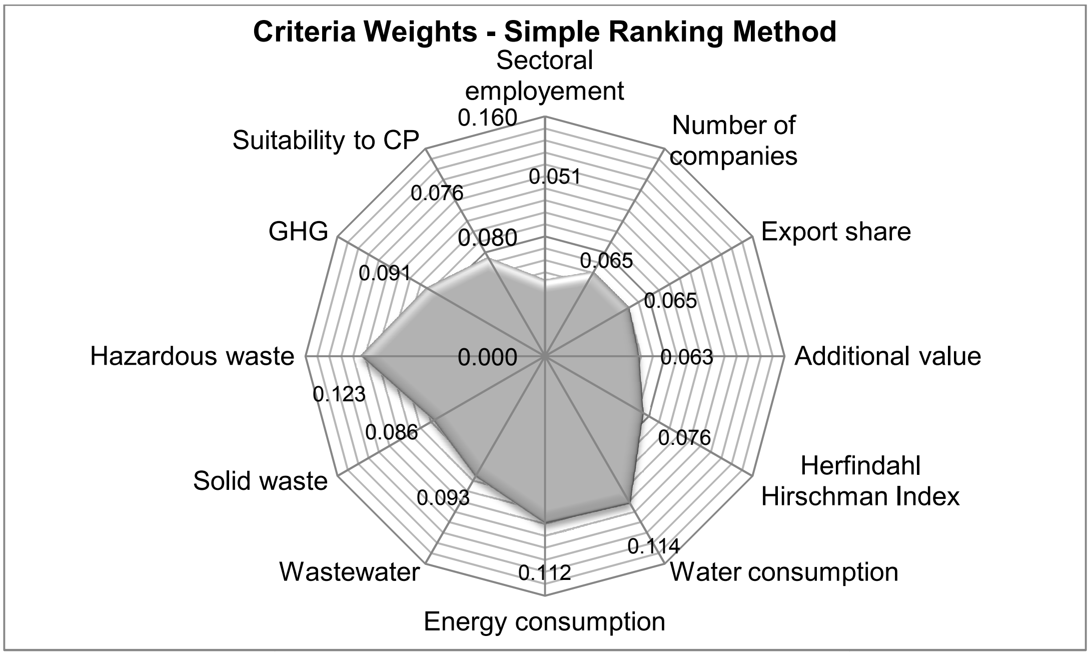


Figure 4.8: Criteria Weights Calculated by Simple Ranking Method (İzmir)

4.2.1.3. Eigen Value Method

Similar to Simple Ranking Method, weighting of the criteria is directly depends on the decision maker in Eigen Value Method also. As it can be seen from the results, energy consumption has the highest weighting factor (0.167) according to the rankings of decision makers. Hazardous waste, water consumption and wastewater criteria follow it. Sectoral employment with the weighting factor of 0.022 takes place at the last rank.

It can be concluded from the results given in Table 4.13 and Figure 4.9 that while a prioritization analysis based on the results of Eigen Value Method (I) sectors with higher energy consumption, higher amount of hazardous waste and higher water consumption are the potential alternatives to be priority sectors.

Table 4.13: Weighting Factors Calculated by Eigen Value Method (İzmir)

Criteria	Weighting Factor
Energy consumption	0.167
Hazardous waste	0.143
Water consumption	0.130
Wastewater	0.106
Greenhouse Gas Emissions	0.092
Suitability to Cleaner (Sustainable) Production	0.090
Solid waste	0.083
Additional value	0.054
Herfindahl-Hirschman Index	0.041
Number of companies	0.037
Export share	0.036
Sectoral employment	0.022
Number of Institutions	**18**

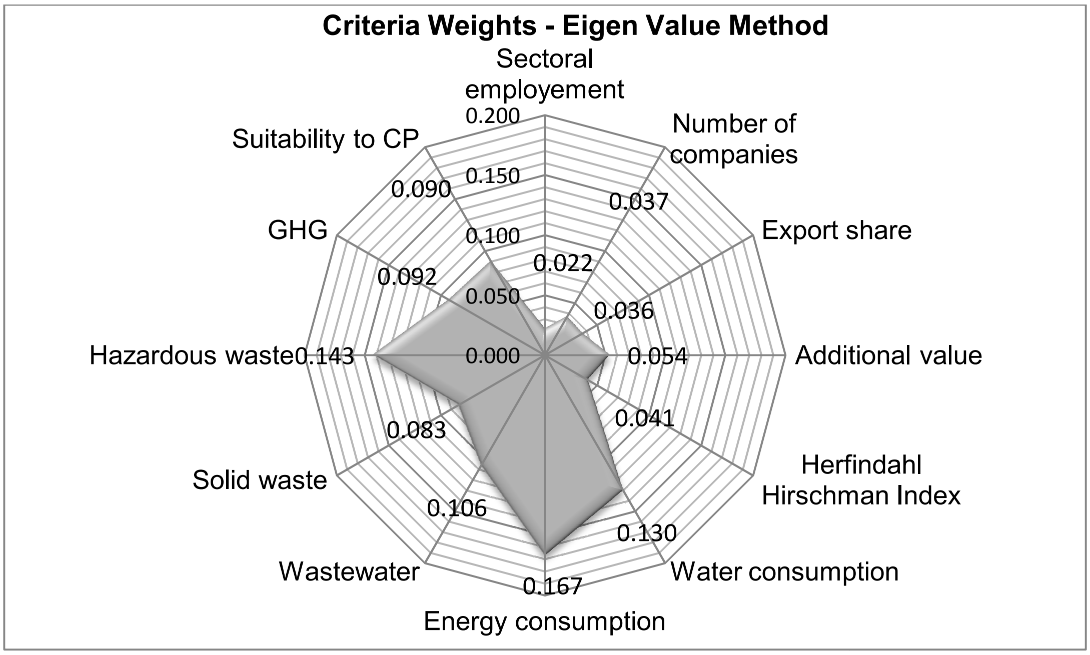


Figure 4.9: Criteria Weights Calculated by Eigen Value Method (İzmir)

4.2.1.4. Comparison of Criteria Weighting Method Results (İzmir)

Comparison of the criteria weights calculated with Entropy, Simple Ranking and Eigen Value Methods is given in Table 4.14 and Figure 4.10.

Table 4.14: Comparison of Criteria Weights (İzmir)

Criteria	Entropy Method	Simple Ranking Method	Eigenvalue Method
Sectoral employment	0.052	0.051	0.022
Number of companies	0.030	0.065	0.037
Export share	0.035	0.065	0.036
Additional value	0.051	0.063	0.054
Herfindahl-Hirschman Index	0.001	0.076	0.041
Water consumption	0.158	0.114	0.130
Energy consumption	0.092	0.112	0.167
Wastewater	0.176	0.093	0.106
Solid waste	0.164	0.086	0.083
Hazardous waste	0.120	0.123	0.143
Greenhouse Gas Emissions	0.107	0.091	0.092
Suitability to Cleaner (Sustainable) Production	0.015	0.076	0.090

As it can be seen from Table 4.14 and Figure 4.10, depending on the used method not only criteria weights but also the ranking of criteria differs. Although the criterion with highest weighting factor in Entropy Method is wastewater, it is hazardous waste in Simple Ranking Method and energy consumption in Eigen Value Method. Differences in these results will affect the prioritization analysis based on the results of these criteria weighting methods. For this reason all of the criteria weighting method results were used in the following steps (prioritization analysis of manufacturing industry sub-sectors). Criteria weights calculated by Entropy Method and Simple Ranking Method were used for WSM. On the other hand criteria weights calculated by Eigen Value Method were used for AHP.

criteria have lower weighting factors due to their much lower dispersion value with respect to others.

4.2.2. Identification of Priority Sectors for Cleaner (Sustainable) Production in İzmir

For the purpose of identifying the priority sectors for cleaner (sustainable) production, two of MCDM methods were used. They are Weighted Sum Method and Analytical Hierarchy Method. Results for both methods are explained below.

4.2.2.1. Weighted Sum Method (WSM)

While the priority sectors were identified with WSM, normalized values inserted into MCDM matrix were used. These data were multiplied by the weights that were calculated by Entropy Method (Section 4.2.1.1) and Simple Ranking Method (Section 4.2.1.2) separately. Total scores for each alternative sector were calculated by using Formula (2.5)

As shown in Table 4.15, according to the prioritization results of WSM with Entropy Method as a criteria weighting method, manufacture of basic metals is in the first rank among other manufacturing industries with a score of 0.4838. It is followed by manufacture of chemicals and chemical products and manufacture of non-metallic mineral products. Manufacture of basic metals has a much higher score than the others. The main reason behind this result is the manufacture of basic metal industry has the highest amount of wastewater discharge, the highest amount of water consumption and the highest amount of solid waste criteria with respect to other manufacturing industry sub-sectors (Section 3.4.1.2, Section 3.4.1.4, and Section 3.3.1.5). These criteria in which the manufacturing of basic metals has a highest share among others were the criteria with highest weighting factors obtained with Entropy Method (Section 4.2.1.1).

Table 4.15: WSM Prioritization Results (Criteria Weighting Method: Entropy Method)

Main Manufacturing Sector	Entropy	
	Score	Ranking
Manufacture of basic metals	0.4838	1
Manufacture of chemicals and chemicals products	0.1230	2
Manufacture of non-metallic products	0.0728	3
Manufacture of food and beverages	0.0664	4
Manufacture of coke, refined petroleum	0.0576	5
Manufacture of wearing apparel	0.0251	6
Manufacture of machinery and equipment nec	0.0251	7
Manufacture of electrical machinery nec	0.0219	8
Manufacture of textiles	0.0200	9
Manufacture of motor vehicles and trailers	0.0197	10
Manufacture of paper and paper products	0.0159	11
Manufacture of tobacco products	0.0120	12
Manufacture of fabricated metal products	0.0097	13
Manufacture of furniture; manufacturing nec	0.0094	14
Manufacture of office, communication, medical equip.	0.0089	15
Manufacture of rubber and plastics products	0.0083	16
Manufacture of other transport equipment	0.0065	17
Manufacture of leather and footwear	0.0034	18
Manufacture of wood products and cork	0.0029	19
Printing and Publishing	0.0020	20
Number of institutions		**18**

As shown in Table 4.16, according to the prioritization results of WSM with Simple Ranking Method as a criteria weighting method, manufacture of basic metals is in the first rank among other manufacturing industries with a score of 0.3323. It is followed by manufacture of chemicals and chemical products and manufacture of food products and beverages. As it is in WSM-Entropy Method, manufacture of basic metals has a much higher score than the others. The main reason behind this result is the manufacture of basic metal industry has higher amount of hazardous waste, the highest water consumption, the highest energy consumption with respect to other manufacturing industry sub-sectors (Sections 3.3.1.2, 3.3.1.3, and 3.3.1.6). These criteria in which the manufacturing of basic metals has a higher share among others were the criteria with highest weighting factors obtained with Simple Ranking Method (Section 4.2.1.2).

Table 4.16: WSM Prioritization Results (Criteria Weighting Method: Simple Ranking Method)

Main Manufacturing Sector	Simple Ranking	
	Score	Ranking
Manufacture of basic metals	0.3323	1
Manufacture of chemicals and chemicals products	0.1078	2
Manufacture of food and beverages	0.0780	3
Manufacture of non-metallic products	0.0666	4
Manufacture of coke, refined petroleum	0.0551	5
Manufacture of machinery and equipment nec	0.0438	6
Manufacture of wearing apparel	0.0422	7
Manufacture of electrical machinery nec	0.0356	8
Manufacture of motor vehicles and trailers	0.0330	9
Manufacture of textiles	0.0286	10
Manufacture of tobacco products	0.0280	11
Manufacture of fabricated metal products	0.0243	12
Manufacture of paper and paper products	0.0219	13
Manufacture of office, communication, medical equip.	0.0209	14
Manufacture of furniture; manufacturing nec	0.0203	15
Manufacture of rubber and plastics products.	0.0194	16
Manufacture of other transport equipment	0.0183	17
Manufacture of leather and footwear	0.0141	18
Manufacture of wood products and cork	0.0071	19
Printing and Publishing	0.0068	20
Number of Institutions		**18**

4.2.2.2. Analytical Hierarchy Process

The first step of prioritization with AHP is the determination of criteria weights by a pair-wise comparison. These weights were determined with Eigen Value Method. Next step is the multiplication of normalized values with criteria weights and analysis of them as in the WSM. Scores and the ranking of the sectors according AHP method are given in Table 4.17

Table 4.17: AHP Prioritization Results (Criteria Weighting Method: Eigen Value Method)

Main Manufacturing Sector	Eigen Value	
	Score	Ranking
Manufacture of basic metals	0.3878	1
Manufacture of chemicals and chemicals products	0.1016	2
Manufacture of food and beverages	0.0777	3
Manufacture of non-metallic products	0.0649	4
Manufacture of coke, refined petroleum	0.0440	5
Manufacture of machinery and equipment nec	0.0382	6
Manufacture of wearing apparel	0.0366	7
Manufacture of electrical machinery nec	0.0339	8
Manufacture of textiles	0.0302	9
Manufacture of motor vehicles and trailers	0.0286	10
Manufacture of fabricated metal products	0.0238	11
Manufacture of paper and paper products	0.0212	12
Manufacture of furniture; manufacturing nec	0.0182	13
Manufacture of rubber and plastics products.	0.0180	14
Manufacture of other transport equipment	0.0171	15
Manufacture of tobacco products	0.0168	16
Manufacture of office, communication, medical equip.	0.0146	17
Manufacture of leather and footwear	0.0141	18
Manufacture of wood products and cork	0.0071	19
Printing and Publishing	0.0067	20
Number of Institutions		**18**

As shown in Table 4.17, according to the prioritization results of AHP with Eigen Value Method as a criteria weighting method, manufacture of basic metals is in the first rank among other manufacturing industries with a score of 0.3878. It is followed by manufacture of chemicals and chemical products and manufacture of food products and beverages. As it is in other methods explained before (Section 4.2.2.1), manufacture of basic metals has a much higher score than the others. The main reason behind this result is the manufacture of basic metal industry has the highest energy consumption, higher amount of hazardous waste and the highest water consumption with respect to other manufacturing industry sub-sectors (Sections 3.3.1.2, 3.3.1.3 and 3.3.1.6). These criteria in which the manufacturing of basic metals has a higher share among others were the criteria with highest weighting factors obtained with Entropy Method (Section 4.2.1.3).

4.2.3. Comparison and Evaluation of Sectoral Analysis Results

In this part of the study, manufacturing industry sub-sectors were prioritized based on selected criteria via different MCDM methods (WSM-Entropy Methods, WSM-Simple Ranking Method, AHP-Eigen Value Method) for cleaner (sustainable) production in İzmir by including the feedbacks of the stakeholders. Comparative results of these prioritizations are given in Table 4.18.

As it can be seen from Table 4.18 and Figure 4.11, although results of different methods (WSM-Entropy Methods, WSM-Simple Ranking Method, and AHP-Eigen Value Method) vary in some rankings, it is observed that results from these different methods mainly overlap. Accordingly, priority sectors for cleaner (sustainable) production practices are as follows:

- Basic metal industry
- Manufacture of chemical and chemical products
- Manufacture of food products and beverages
- Manufacture of non-metallic mineral products
- Manufacture of coke and refined petroleum

Third and fourth rank of WSM-Entropy results and results of other methods (WSM-Simple Ranking, AHP-Eigen Value) are different. For this reason finalized ranking was done based on the results of WSM-Simple Ranking and AHP-Eigen Value due to consistency between them.

Table 4.18: Comparative Ranking of Sectoral Prioritization for İzmir

MCDM Method Weighting Method	WSM Entropy	WSM Simple ranking	AHP Eigen value
Manufacture of basic metals	1	1	1
Manufacture of chemicals and chemicals products	2	2	2
Manufacture of non-metallic products	3	4	4
Manufacture of food and beverages	4	3	3
Manufacture of coke, refined petroleum	5	5	5
Manufacture of wearing apparel	6	7	7
Manufacture of machinery and equipment nec	7	6	6
Manufacture of electrical machinery nec	8	8	8
Manufacture of textiles	9	10	9
Manufacture of motor vehicles and trailers	10	9	10
Manufacture of paper and paper products	11	13	12
Manufacture of tobacco products	12	11	16
Manufacture of fabricated metal products	13	12	11
Manufacture of furniture; manufacturing nec	14	15	13
Manufacture of office, communication, medical equip.	15	14	17
Manufacture of rubber and plastics products	16	16	14
Manufacture of other transport equipment	17	17	15
Manufacture of leather and footwear	18	18	18
Manufacture of wood products and cork	19	19	19
Printing and Publishing	20	20	20
Number of Institutions	**-**	**18**	**18**

The main reason behind this coincidence is the higher share of the first five ranked manufacturing industry sub-sectors in the criteria with highest weighting factors obtained by Entropy Method, Simple Ranking Method and Eigen Value Methods. In other words, all of the 5 sectors above have higher water consumption, higher energy consumption, higher amount of solid waste and hazardous waste in addition to higher share in other criteria with respect to other manufacturing industry sub-sectors.

In the case of a cleaner (sustainable) production investment in İzmir, these five sectors should be taken into account primarily (ranking of sectors can be used interchangeably). Sectors taking in the first five ranks also coincide with the priorities of other regional institutions/ organizations conducted by different institution based on different purposes. To illustrate in “Strategic and Rising Sectors for İzmir” report

According to Ministry of Science, Industry and Technology (BTSB) (2011), manufacturing of chemicals and chemical products, manufacture of coke refined petroleum and manufacture of non-metallic mineral products are among the higher exporting sectors in İzmir. Also, the potential areas for an investment in İzmir include manufacture of basic metals, manufacture of chemical and chemical products, manufacture of food products and beverages (BTSB, 2011).

4.2.4. Sensitivity Analysis for Sectoral Prioritization Results (İzmir)

Often data in MCDM problems are imprecise and changeable. Therefore an important step in many applications of MCDM problems is to perform a sensitivity analysis on the input data. Sensitivity analysis approach determines how critical the various performance measures of the alternatives (in terms of a single decision criterion) are in the ranking of alternatives (Triantaphyllou & Sanchez, 1997).

Sensitivity analysis for the results obtained from WSM (Section 4.2.2.1) was performed. First threshold values of each a_{ij} were calculated. Afterwards criticality degree of each alternative was determined. Based on the obtained results most sensitive alternative was identified.

Threshold values for each alternative regarding each criterion were calculated by using Formula (3.2). During this process, MCDM matrices given in Appendix D, Table D.8 (WSM-Entropy) were used. Corresponding criticality degrees (%) (Minimum threshold values for each aij) were given in Table 4.19

Entries in Table 4.19 indicate the minimum amount of changes for the a_{ij} values required for a change in the rankings of alternatives. To help interpret the entries in Table..., consider anyone of them; say entry for the second alternative (with the ISIC Code 24) regarding number of companies criteria (4,577). This entry indicates that criticality value for second alternative (ISIC Code: 24) based on the number of companies criterion is equal to % 4,577. That is the measure of performance of a_{ij} must be decreased by %4,577 from its current value, in order for third alternative (ISIC Code: 26) to become more preferred than second alternative (ISIC Code: 24). A similar interpretation holds for the rest of the entries. Negative changes in the entries mean that the regarding aij values should increase for a change in the rankings.

Table 4.19: Criticality degrees of Alternatives for WSM (Entropy) Method

ISIC Code	Employment	Number of comp.	Export	Added value	HHI	Water Cons.	Energy Cons.	WW	Solid waste	Hazard. waste	GHG	Suitability to CP
27	10,425 (24)	20,692 (24)	13,232 (24)	34,219 (24)	20,767 (24)	1,382 (24)	2,406 (24)	781 (24)	830 (24)	3,075 (24)	3,694 (24)	6,321 (24)
24	20,578 (26)	4,577* (26)	4,135 (26)	4,388 (26)	8,753 (26)	6,075 (26)	3,937 (26)	4,814 (26)	2,404 (26)	669 (26)	3,618 (26)	2,223 (26)
26	2,095 (15)	699 (15)	1,722 (15)	7,535 (15)	6,261 (15)	2,517 (15)	1,977 (15)	1,487 (15)	1,165 (15)	11,392 (15)	3,239 (15)	765 (15)
15	-3,047 (28)	-895 (28)	-2,449 (28)	1,753 (18)	6,353 (18)	2,566 (18)	2,022 (18)	1,515 (18)	1,194 (18)	11,626 (18)	3,296 (18)	781 (18)
23	9,005 (29)	11,233 (18)	6,901 (18)	1,458 (18)	2,680 (18)	15,399 (18)	716 (18)	8,480 (18)	21,273 (18)	5,394 (18)	1,304 (18)	5,741 (18)
18	364 (29)	**102** (29)	389 (29)	1,144 (29)	553 (29)	6,459 (29)	1,575 (29)	1,474 (29)	2,688 (29)	1,283 (29)	2,808 (29)	883 (29)
29	132 (31)	514 (31)	605 (31)	1,150 (31)	644 (31)	7,891 (31)	1,165 (31)	2,567 (31)	1,123 (31)	2,105 (31)	1251 (31)	785 (31)
31	754 (17)	896 (17)	593 (17)	569 (17)	789 (17)	239 (17)	4,569 (17)	1,289 (17)	2,039 (17)	5,962 (17)	1,236 (17)	15,469 (17)
17	198 (34)	769 (34)	964 (34)	913 (34)	834 (34)	876 (34)	567 (34)	412 (34)	279 (34)	365 (34)	378 (34)	305 (34)
34	2,003 (21)	5,690 (21)	2,369 (21)	11,256 (21)	1,596 (21)	5,698 (21)	3,269 (21)	4,569 (21)	1,236 (21)	1,456 (21)	856 (21)	789 (21)

Table 4.19: Criticality degrees of Alternatives for WSM (Entropy) Method (Cont'd)

ISIC Code	Employm ent	Number of comp.	Export	Added value	HHI	Water Cons.	Energy Cons.	WW	Solid waste	Hazard. waste	GHG	Suitability to CP
21	5,698 (16)	-1,692 (34)	2,569 (16)	4,702 (16)	944 (16)	2,512 (16)	3,569 (16)	991 (16)	1,236 (16)	654 (16)	2,048 (16)	2,967 (16)
16	5,012 (28)	2,076 (28)	11,599 (28)	2,601 (28)	1,098 (28)	7,560 (28)	3,945 (28)	4,896 (28)	2,365 (28)	905 (28)	3,431 (28)	2,265 (28)
28	2,610 (36)	709 (36)	1,519 (36)	7,378 (36)	6,401 (36)	3,697 (36)	5,617 (36)	6,489 (36)	1,033 (36)	1,780 (36)	5,123 (36)	8,102 (36)
36	5,021 (30)	512 (30)	6,781 (30)	1,297 (30)	2,016 (30)	168 (30)	2,391 (30)	4,012 (30)	5,102 (30)	9,709 (30)	1,803 (30)	983 (30)
30	2,945 (25)	11,356 (25)	4,901 (25)	1,590 (25)	5,680 (25)	12,002 (25)	7,945 (25)	1,446 (25)	12,023 (25)	4,901 (25)	2,788 (25)	4,102 (25)
25	5,148 (35)	804 (35)	2,402 (35)	3,782 (35)	2,498 (35)	5,891 (35)	3,014 (35)	3,451 (35)	992 (35)	1,012 (35)	986 (35)	1,004 (35)
35	1,155 (20)	594 (20)	287 (20)	1,112 (19)	2,411 (20)	8,140 (20)	5,012 (20)	3,479 (20)	2,178 (20)	5,046 (20)	6,045 (20)	1,005 (20)
19	-596 (35)	-1,356 (35)	-1,078 (35)	-569 (35)	-5,012 (35)	-6,239 (35)	-1,569 (35)	1,289 (20)	2,105 (20)	3,598 (20)	1,702 (20)	3,804 (20)
20	1,198 (22)	7,069 (22)	3,964 (22)	1,913 (22)	1,534 (22)	986 (22)	1,678 (22)	3,412 (22)	2,079 (22)	3,465 (22)	3,078 (22)	1,037 (22)
22	-2,590 (20)	-11,690 (20)	-11,369 (20)	-10,256 (20)	--9,596 (20)	-5,608 (20)	-3,260 (19)	-4,5695 (19)	-5,206 (19)	-1,450 (19)	-526 (19)	-1,070 (19)

From Table 4.19 it can be concluded that most sensitive alternative (lowest criticality value) is alternative with the ISIC Code 18 (Manufacture of wearing apparel). This is true because alternative correspond to the minimum criticality degree (equal to 102) among all values in Table 4.19.

CHAPTER 5

CONCLUSION

One of the most important factors leading to success of a national cleaner (sustainable) production strategy is sector-focused approach. Due to limited resources, it is a necessity to make a prioritization between sectors for cleaner (sustainable) production practices. Simple cleaner (sustainable) production tools such as Good Housekeeping are developed for implementations in SME's regardless of sector. These tools can provide improvements only in very general issues (prevention of water, raw material losses etc.). Significant gains in large-scale enterprises is only possible with the utilization of more comprehensive and sector-specific cleaner (sustainable) production tools. Due to requirement of more resources and high level of expertise, use of this kind of tools without sectoral prioritization may lead to significant loss of time and resources. In this context, sectoral prioritization has an important role in cleaner (sustainable) production practices (Ulutaş et al., 2011; Böğürcü et al., 2010).

In this study prioritization of manufacturing industry sub-sectors in Turkey (national level) and in İzmir (regional level) for cleaner (sustainable) production applications was conducted. While the prioritization processes two different methods of MCDM were used (WSM, AHP).

Prioritization has been carried out based on the selected criteria that are thought to be important for cleaner (sustainable) production. Important criteria for the mentioned purpose were selected by taking international, national (for Turkey) and regional (for İzmir) framework conditions into account. These criteria were used to evaluate the environmental performance, contribution to national/regional economy and cleaner (sustainable) production potential of the sectoral structure. The criteria used in prioritization of manufacturing industry sub-sectors in Turkey were water and energy consumption, amount of wastewater discharged, amount of solid waste and hazardous waste generated, greenhouse gas emissions, sectoral employment, export share and suitability for cleaner (sustainable) production. In the prioritization analysis for İzmir, Herfindahl-Hirschman Index, number of companies and added value were also used in addition to the listed criteria for Turkey. There are other parameter that are relative to the cleaner (sustainable) production and could be taken into account in decision making process such as; environmental management status of the sectors, research and development activities in the sectors, parameters regarding legislations etc. However due limitation of the data sources and unsuitability of the data properties with the model, other parameter could not be used as criteria for the decision making process.

During the determination of weighting factors of selected criteria for cleaner (sustainable) production applications, three different weighting methods were used (Entropy Method, Simple Ranking Method, Eigen Value Method. In the context of Simple Ranking Method and Eigen Value Methods, feedbacks from stakeholders through the questionnaires were used as input. In order to minimize the subjectivity that may be reflected to the results, all of the related stakeholders (public bodies, universities, research agencies, non-governmental organizations, chambers of commerce and industrial zones.) were included in the decision making process.

According to the results of this study, the top five high priority industrial sectors for cleaner (sustainable) production implementations in Turkey are basic metal industry, food products and beverages, chemicals and chemical products, other non-metallic mineral products and textile industry. In the sectoral prioritization analysis for cleaner (sustainable) production in İzmir coke and refine petroleum takes the place of textile industry. These sectors also coincide with the priorities of other regional, national and international institutions based on different purposes.

Results of this prioritization study offer input for related future regional and national policies. In “Industrial Strategy Plan of Turkey 2011-2014”, adaptation process to European Union Environmental Acquis is specified as the initial step for transition to cleaner (sustainable) production in Turkish Industry. Furthermore, in this strategy document, cleaner (sustainable) production is one of the underlined tools to follow sustainable development principles for Turkish Industry. For this purpose, it stated that activities for transition to cleaner (sustainable) production and low carbon economy will be supported. In addition to these incentives, it is planned to implement a cleaner (sustainable) production programme in country wide in the framework of prepared action plan (STB, 2010). By considering aforementioned plans and activities, it is evident that, related parts of this action plan should be elaborated and sectoral roadmaps should be prepared particularly on the prioritized sectors for cleaner (sustainable) production.

Studies regarding the adaptation of “Directive on Industrial Emissions 2010/75/EU” which codify “IPPC Directive” with other 6 sectoral Directives have been conducted by Ministry of Environment and Urban Planning (European Parliament & Council of the EU, 2010; Ministry of Environment and Urban Planning, 2012). For the implementation of Best Available Techniques (BAT) in Turkish industry, that can be used as a tool for cleaner (sustainable) production implementations as well, related plans and programmes are in the preparation phase. Sector specific studies should be conducted within the scope of this adaptation process as well particularly on the prioritized sectors in this study.

Apart from the mentioned adaptation studies, first legal document regarding cleaner (sustainable) production in Turkey was published for textile industry. As it stated before, textile industry is one of the priority sectors for cleaner (sustainable) production identified within the scope of this study. Notification on “Integrated Pollution Prevention and Control for Textile Industry” was published on December 2011 and requires to prepare and implement cleaner (sustainable) production plans in textile industry companies (Ministry of Environment and Urban Planning, 2011). Legislative adjustment for IPPC and transition to cleaner (sustainable) production should be disseminated to other sectors especially to the prioritized ones in this study.

Together with national policies, these studies should be conducted at regional level as well. Activities regarding cleaner (sustainable) production should be included in regional plans. By considering the existing industrial structure, industrial development trends and region’s environmental conditions, sectors should be prioritized for cleaner (sustainable) production practices. Afterwards, action plans for the whole region including actions for the prioritized industries should be prepared. In the context of this study, manufacturing industry sub-sectors in İzmir were prioritized for cleaner (sustainable) production practices. Within the scope of

"Dissemination of Eco-Efficiency (Cleaner Production) Applications in İzmir" project, pilot implementations for cleaner (sustainable) production will be realized. Results of this study will form a basis in the selection of sectors for the mentioned pilot cleaner (sustainable) production implementations. Furthermore, results also offer input for the "Regional Plan of İzmir 2013-2016" that will be prepared by İZKA.

To conclude, within the scope of this study manufacturing industry sub-sectors were prioritized for cleaner (sustainable) production practices at regional and national level. Results obtained from this study should assist to policy makers in the preparation of related sectoral roadmaps, national and regional action plans. It is evident that much additional work should be conducted for adapting this study to other regions of Turkey. Prioritization analysis for cleaner production should be elaborated based on different sub-sectors, different size of enterprises etc. Furthermore, it is hoped that this study will stimulate further investigations in this field.

REFERENCES

Adams, W. M. (2006). The future of sustainability: re-thinking environment and development in the twenty-first century. Report of the IUCN Renowned Thinkers Meeting, 29–31 January, 2006.

Allen, D., & Rosselot K. S. (1997). Pollution Prevention for Chemical Processes. New York: John Wiley & Sons Inc.

Altrock, C. V., & Krause, B. (1994). Multi-criteria decision making in German automotive industry using fuzzy logic. Fuzzy Sets and System, 14, 77-88.

Ananda, J., & Herath, G. (2009). A critical review of multi-criteria decision making methods with special reference to forest management and planning. Ecological Economics, 68, 2532-2548.

Ashton, W. A., & Ehrenfeld, J. (2002). Best practices in cleaner production promotion and implementation for smaller enterprises. Inter-American Development Bank.

Asian Productivity Organization (APO). (2006). Handbook on green productivity. Canada.

Aydın, N. Y., Kentel, E., & Düzgün, S. (2010). GIS-based environmental assessment of wind energy systems for spatial planning: A case study from Western Turkey. *Renewable and Sustainable Energy Reviews*, *14*, 364-373.

Azapagic, A. (1999). Life cycle assessment and its application to process selection, design and optimisation. *Chemical Engineering Journal, 73*, 1-21.

Baas, L. (1998). Cleaner production and industrial ecosystems: a Dutch experience. *Journal of Cleaner Production, 6*(3-4), 189-197.

Banar, M., Köse, B. M., Özkan, A., & Acar, I. P. (2007). Choosing a municipal landfill site by analytic network process. *Environmental Geology, 52*, 747-751.

Bell, M. L., Hobbs, B. F., & Ellis, H. (2003). The use of multi-criteria decision-making methods in the integrated assessment of climate change: implications for IA practitioners. *Social-Economic Planning Sciences, 37*, 289-316.

Berkel, R. V. (1994). Comparative evaluation of cleaner production working methods. *Journal of Cleaner Production, 2*(3-4), 139-152.

Berkel, R. V. (2000). Cleaner production for process industries: overview of the cleaner production concept and relation with other environmental management strategies. Plenary Lecture, CHEMECA 2000, Perth, Australia, 9-12 July.

Binnie (1987). Water and wastewater management in the soft drink industry. Report no. NATSURV 3 prepared for the Water Research Commission by Binnie and Partners Consulting Engineers, Pretoria.

Böğürcü, M., Ulutas, F., Alkaya, E., & Demirer, G. N. (2010). Sectoral priority analysis for C(S)P applications in Turkey. *Third International Conference on Eco-Efficiency*, 2010 Jun 9–11; Egmond aan zee, The Netherlands.

Boix, M., Montastruc, L., Pibouleau, L., Pantel, C. A., & Domenech, S. (2011). A multi-objective optimization framework for multi-contaminant industrial water network design. *Journal of Environmental Managament, 92*, 1802-1808.

Bouyssou, D. (1990). Building Criteria: A Prerequisite for MCDA. In Costa, B. (Ed) *Readings in Multiple Criteria Decision Aid*. Berlin: Springer.

Brown, B., Neil-Adger, W., Tompkins, E., Bacon, P., Shim, D., & Young, K. (2001). Trade-off analysis for marine protected area management. *Ecological Economics, 37*, 417–434.

Caberera, R. L., & Giraldo, G. E. (2009). A Multiple Criteria Decision Analysis for the FDI in Latin-American Countries. *In Revelling: Industrial Engineering Research Conference*, Poerto Rico.

Chang, N. B., Parvathinathan, G., & Breeden, J. B. (2008). Combining GIS with fuzzy multicriteria decision-making for landfill sitting in a fast-growing urban region. *Journal of Environmental Management, 85,* 139-153.

Chen, S.J., Hwang, C.L. (1992) *Fuzzy multiple attribute decision making: methods and applications*, New York: Springer-Verlag.

Chertow, M. R. (2000). Industrial symbiosis: literature and taxonomy. *Annual Review of Energy and the Environment, 25,* 313-337.

Clay, S., Gibson, D. & Ward, J. (2007). Sustainability Victoria: influencing resource use, towards zero waste and sustainable production and consumption. *Journal of Cleaner Production,* 15, 782, 786.

De Bruijn, T., & P. Hofman (2000). Pollution prevention and industrial transformation: evoking structural changes within companies. *Journal of Cleaner Production, 8,* 215-223.

Demirer G. N., & Mirata M., (1999). Endustriyel kirlilik onleme ya da temiz uretim-i [Industrial pollution prevention or cleaner productiın-I], *Endustri&Otomasyon*, 31, 110-113.

Demirer, G. N. (2003). Kirlilik önleme yaklaşımlarının temel prensipleri [Main principals of pollution prevention approach]. *Çevre ve Mühendis, 25,* 13-20.

Demirer, G. N., & Torunoğlu E. (Eds.) (2000), UCTEAT, Publication of Board of Environmental Engineers, December 2000, Ankara, 3.2-3.18.

Demirer, G. N., & Uludağ-Demirer, S. (2000). Pollution prevention opportunities for local administration services*. Integrated and Preventive Environmental Management Project Handbook for Local Administrations*.

DeSimone, L., & Popov F. (1997). *Eco-Efficiency: the business link to sustainable development.* Cambridge: MIT Press.

Dorfman, M. (1992). Source Reduction: environmental dividends from cutting chemical waste. *Pollution Prevention Review, 1992,* 403-414.

Dovı, V. G.,Friedler, F., Huisingh, D. & Klemes, J. J. (2009). Cleaner energy for sustainable future. *Journal of Cleaner Production*, 17, 889-895.ˇ

Dunn, R. G., & Bush, D. G. (2001). Using process integration technology for cleaner production. *Journal of Cleaner Production, 9*(1), 1-23.

Dursun, M., Karsak, E. E., & Karadayi, M. A. (2011). A fuzzy approach for health-care waste management, *World Academy of Science, Engineering and Technology, 73*.; 858-864.

Ehrenfeld, J., & Gertler N. (1997). Industrial ecology in practice: the evolution of interdependence at Kalundborg. *Journal of Industrial Ecology, 1*(1), 67-79.

Elimelech, E., Ayalon, O. & Flicstein, B. (2011). Hazardous waste management and weight-based indicators-The case of Haifa Metropolis. *Journal of Hazardous Materials.* 185, 626-633.

Environmental Technology Best Practice Programme (ETBPP). (2009). Water use in the soft drinks industry. EG 126 Guide.

Erdoğmuş, Ş., Aras, H., & Koç, E. (2006). Evaluation of alternative fuels for residential heating in Turkey using analytic network process (ANP) with group decision-making. *Renewable and Sustainable Energy Reviews, 10,* 269-279.

European Commission. (2010). *Critical raw materials for the EU*. Brussels: Author.

European Parliament &Council of the European Union. (2010). *Directive on industrial emissions (integrated pollution prevention and control.* Official Journal of the European Union, 334/17.

Expert Choice, *Expert Choice Software Programme*. Retrieved January 15, 2012 from http://www.expertchoice.com/

Freeman, H., Harten, T., Springer, J., Randall, P., Curran, M., & Stone, K. (1992). Industrial pollution prevention: a critical review. J*ournal of the Air and Waste Management Association, 42*(5), 618-656.

Frondel, M., Hiorbach, J., & Rennings, K., (2004). End-of-pipe or cleaner production? An empirical comparison of environmental innovation decisions across OECD countries. Center for European Economic Research, Discussion Paper No. 04-82.

Fussler, C., & James, P. (1996) *Driving eco-innovation: a breakthrough discipline for innovation and sustainability.* London: Pitman Publishing.

Gavrilescu, M., Teodosiu, C., & Lupu, L. (2008). Strategies and practices for sustainable use of water in industrial papermaking processes. *Engineering in Life Sciences, 8*(2), 99-124.

Ghazinoory, S. (2005). Cleaner production in Iran: necessities and priorities. *Journal of Cleaner Production, 13*, 755-762.

Glavic, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. *Journal of Cleaner Production, 15*, 1875-1885.

Graham, A. H., Berkel, R. V. (2007). Assessment of cleaner production uptake: method development and trial with small businesses in Western Australia. *Journal of Cleaner Production, 16*(8-9), 787-789.

Gumbo, B., Mlilio, S., Broome, J., & Lumbroso, D. (2003). Industrial water demand management and cleaner production: a case of three industries in Bulawayo. *Physics and Chemistry of the Earth, 28,* 797-804.

Hajkowicz, S. A., McDonald, G. T., Smith, P. N. (2000). An evaluation of multiple objective decision support weighting techniques in natural resource management. *Journal of Environmental Planning and Management, 43*, 505-518.

Hajkowicz, S. A., Prato, T. (1998). Multiple objective decision analysis of farming systems in Goodwater Creek Watershed, Missouri. Research Report No. 24, Columbia, Missouri: Centre for Agriculture, Resources and Environmental Systems.

Halis, M. (2009). *Evaluating fuel alternatives for electricity generation in turkey through multiple criteria decision support methodologies*. Master of Science Thesis: Gazientep University.

Hamalainen, R. P., Kettunen, E., & Ehtamo, H., (2001). Evaluating a framework for multistakeholder decision support in water resources management. *Group Decision and Negotiation, 10,* 331-353.

Henig, M., & Buchanan, J. T. (1996). Solving MCDM problems: process concept. *Journal of Multi-Criteria Decision Analysis,* 5 (1), 3-21.

Hobbs, B. F., & Meier, P. (2000). *Energy decisions and the environment: A guide to the use of multi-criteria methods.* Boston (MA), USA: Kluwer.

Howard, A. F. (1991). A critical look at multiple criteria decision-making techniques with reference to forestry applications. *Canadian Journal of Forest Research, 21*, 1649-1659.

Hsine, E., Benhammou, A., & Pons, M. N. (2005). Water resources management in soft drink industry: water use and wastewater generation. *Environmental Technology, 26*(12), 1309-1316.

Intergovernmental Panel on Climate Change (IPCC). (2006). Guidelines for national greenhouse gas inventories, Eggleston H. S., Buendia L., Miwa K., Ngara T., & Tanabe K. (Eds.). *National Greenhouse Gas Inventories Programme*, Japan: IGES.

International Finance Corporation (IFC)-World Bank Group (2007). Environmental, Health, and Safety Guidelines for Food and Beverage Processing.

Izmir Development Agency (İZKA). (2008). *İzmir bölgesi (tr31) mevcut durum raporu [İzmir region current situation report],* İzmir: Author.

Izmir Development Agency (İZKA). (2009a). *İzmir için stratejik ve yükselen sektörler. [Strategic and rising sectors for İzmir].* İzmir: Author.

Izmir Development Agency (İZKA). (2009b). *Izmir bölgesel gelişme planı (2009-2013): Yenilenebilir enerji sektörü çalıştayı sonuç raporu [İzmir regional development plan (2010-2013): Final report of renewable energy sector workshop]*, İzmir: Author

İzmir Metropolitan Municipality (İBB). (2010). *2010 faaliyet raporu [2010 Activity Report],* İzmir: Author.

Janssen, R. (1992). *Multiobjective decision support for environmental management.* Dordrecht: Kluwer Academic Publishers.

Jawjit, W., Kroeze, W. & Rattanapan, S. (2010). Greenhouse gas emissions from rubber industry in Thailand. *Journal of Cleaner Production*, 18, 403-411.

Jeon, C. M. (2007). *Incorporating sustainability into transportation planning and decision making: Definitions, performance measures, and evaluation.* Doctoral dissertation, Thesis: Georgia Institute of Technology.

Jin, X. (1996). *Approaching sustainability in engineering design with multiple criteria decision analysis*. Doctoral dissertation, Oklahama State University.

Joubert, A., Steward, J. T., & Eberhard, R. (2003). Evaluation of water supply augmentation and water demand management options for the city of Capetown. *Journal Of Multi-Criteria Decision Analysis, 12,* 17-25.

Kangas, J., Kangas, A., Leskinen, P., & Pykalainen, J. (2001). MCDM methods in strategic planning of forestry on state-owned lands in Finland: Applications and experiences. *Journal of Multi-Criteria Decision Analysis, 10, 257-271.*

Kaya, T., & Kahraman, C. (2011). Multicriteria decision making in energy planning using a modified fuzzy TOPSIS methodology. *Expert Systems with Applications, 38*, 6577- 6585.

Khalil, W. A., Shananbleh, A., Rigby, P., & Kokot, S. (2005). Selection of hydrothermal pre-treatment conditions of waste sludge destruction using multicriteria decision-making. *Journal of Environmental Management, 75*, 53-64.

Kiker, G. A., Bridges, T. S., Varghese, A., Seager, T. P., & Linkov, I. (2005). Application of multi-criteria decision analysis in environmental decision making. *Integrated Environmental Assessment and Management, 1*(2), 95-108.

Klemes, J. & Huising, D.(2008). Economic use of renewable resources, LCA, cleaner batch processes and minimising emissions and wastewater. *Journal of Cleaner Production, 16, 159-163.*

Kurul, D. M. (2011), *Türk bankacılık sektörüne ilişkin yoğunlaşma ve hakimiyet göstergeleri. [Indicators of concentration and dominance of Turkish banking sector]* Ekonomi Notları, No:2011-5, Ankara: Central Bank of the Republic of Turkey.

Kuruüzüm, A., & Atsan, N. (2001). Analitik hiyerarşi yönetmi ve işletmecilik alanındaki uygulamaları [Analytic hierarchy process and its assessments in the field of business]. *Journal of Akdeniz University Faculty of Business Administration,* 1 (1), 83-105.

Lai J. Y., & Hwang C. L. (1996). *Fuzzy multiple criteria decision making: methods and applications.* New York: Springer.

Li, H. B., & Chai, L. H. (2007). Thermodynamic analyses on technical framework of clean production. *Journal of Cleaner Production, 15,* 357-365.

Massam, B. H. (1988). Multi-criteria decision-making techniques in planning. *Progress in Planning, 30,* 1-84.

Meisterling, K., Samaras, C. & Schweizer, V. (2009). Decisions to reduce greenhouse gases from agriculture and product transport: LCA case study of organic and conventional wheat. *Journal of Cleaner Production,* 17, 222-230.

Ministry of Environment and Forestry (ÇOB) (2006), *AB entegre çevre uyum stratejisi. [EU integrated environment approximation strategy]*. Ankara: Author.

Ministry of Environment and Forestry (ÇOB) (2007), *Türkiye çevre durum raporu. [Turkey environmental status Report]*. Ankara: Author.

Ministry of Environment and Forestry (ÇOB) (2009a). *İzmir il çevre durum raporu [İzmir Environmental status Report]*, İzmir: Author.

Ministry of Environment and Forestry (ÇOB) (2009b). Tehlikeli atik istatistikleri: 2009 [Hazardous waste statistics: 2009], *Tehlikeli Atık Bülteni*, Sayı:1.

Ministry of Environment and Urban Planning (2011). *Tekstil Sektörü için Entegre Kirlilik Önleme ve Kontrolü Tebliği [Integrated Pollution Prevention and Control for Textile Industry].* Official Gazette (published on 14/11/2011), Number: 28142.

State Hyrdraulic Works (DSI). (2011). *2010 yılı faaliyet raporu [2010 activity report].* Retrieved February 1, 2012 from http://www2.dsi.gov.tr/faaliyet_raporlari/2010_faaliyet_raporu.pdf

Ministry of Industry and Trade (STB) (2011). *Türkiye Sanayi Stratejisi Belgesi 2010-2014 (AB Üyeliğine Doğru) [Turkey Industry Strategy Document 2010-2014 (Towards EU Membership)]*. Ankara: Author.

Ministry of Industry and Trade (STB). (2010) *Türkiye Sanayi Stratejisi Belgesi (2011-2014)[Turkey Industrial Strategy Document (2011-2014)]*. Retrieved February 1, 2012 from http://www.sanayi.gov.tr/Files/Documents/sanayi_stratejisi_belgesi_2011_2014.pdf

Ministry of Science Industry and Technology (BSTB). (2011). *81 il durum raporu [81 cities situation report].* Ankara: Author.

Narayanaswami, V., & Stone, L. (2007). From cleaner production to sustainable production and consumption in Australia and New Zealand: achievements, challenges, and opportunities. *Journal of Cleaner Production, 15*, 711-715.

Natrass, B., & Altomare, M. (1999). *The natural step for business; wealth, ecology and the evolutionary corporation.* Canada: New Society Publishers.

Nijkamp, P., Rietveld, P., & Voogd, H. (1990). *Multi-criteria evaluation in physical planning.* Amsterdam: North-Holland.

O'Brien, C. (1999). Sustainable production – a new paradigm for a new millennium. *International Journal of Production Economics, 60*, 1-7.

Ozalp, N., Epstein, M. & Kogan, A. (2010). Cleaner pathways of hydrogen, carbon nano-materials and metals production via solar thermal processing. *Journal of Cleaner Production,* 18, 900-907.

Önüt, S., Tuzkaya, U. R., & Saadet, N. (2008). Multiple criteria evaluation of current energy resources for Turkish manufacturing industry. *Energy Conservation and Management, 49,* 1480-1492.

Pohekar, S. D., & Ramachandıran, M. (2004). Application of multi-criteria decision making to sustainable energy planning: a review, *Renewable and Sustainable Energy Reviews, 8,* 365-381.

Pomerol, J., & Romero, S. (2000). *Multi-criterion decision in management: principles and practice.* The Netherlandsl: Academic Publishers.

Ramjeawon, T. (2000). Cleaner production in Mauritian cane-sugar factories. *Journal of Cleaner Production*, 8, 503-510.

Regional Activity Centre for Cleaner Production (CP/RAC). (2000). *Minimization Opportunities Environmental Diagnosis.* Barcelona: Author.

Regional Activity Centre for Cleaner Production (CP/RAC). (2007). *Green competitiveness in the Mediterranean: finding business opportunities through cleaner production*. Barcelona: Author.

Regional Activity Centre for Cleaner Production (CP/RAC). (2008). M*ED clean reports overview*. Barcelona: Author.

Reijnders, L. (1998). The factor X debate: setting targets for eco-efficiency. *Journal of Industrial Ecology, 2*(1), 13-22.

Risk and Policy Analysts Ltd (RPA). (2004). Evaluating a multi-criteria analysis methodology for application to flood management and coastal defence appraisals. Retrieved January 2012, from http://archive.defra.gov.uk/corporate/consult/flood-appraisal/consultation.pdf

Rogers, M., & Bruen, M. (1998). Choosing realistic values of indifference, preference and veto thresholds for use with environmental criteria within ELECTRE. *European Journal of Operational Research, 107,* 542–551.

Rowledge, L., Barton, R., Bradley, K., Fava, J., Ligge, C., & Young, S. (1999). *Mapping the journey: case studies in strategy and action toward sustainable development.* Sheffield: Greenleaf Publishing.

Rozakis, S., Kallivroussis, L., Soldatos, P. G., & Nicolaou, I. (2001). Multiple criteria analysis of bio-energy projects: evaluation of bio-electricity production in farsala plain. *Journal of Geographic Information and Decision Analysis, 5,* 49-64.

Saaty, T. L. (1980). *The analytic hierarchy process: Planning, priority setting, resource allocation,* New York and London: McGraw-Hill International Book Co.

Salt, C. A., & Dunsmore, M. C. (2000). Development of a spatial decision support system for post-emergency management of radioactively contaminated land. *Journal of Environmental Management, 58,* 169-178.

Schliephake, K., Stevens, G. &, Clay, S. (2009). Making resources work more efficiently the importance of supply chain partnerships. *Journal of Cleaner Production*, 17, 1257-1263.

Schmoldt, D. L, Kangas, J., Mendoza G. A., & Pesonen M. (2001). *The analytic hierarchy process in natural resource and environmental decision making*. Amsterdam: Kluwer.

Science-Technology-Industry Discussion Platform. (1999). *Cleaner production-cleaner products environmentally friendly technologies working group industrial sector report*. Retrieved January 2012, from http://kutuphane.tbmm.gov.tr:8088/2000/200004030.pdf

Social Security Institution (SGK). (2008). *Manufacturing Industry employment statistics for İzmir.*

South Aegean Development Agency (GEKA). (2011), *TR32 düzey ii bölgesi'nde kümelenme yaklaşımı. [Clustering approach in TR32 Level II region].Denizli: Author.*

State Planning Organization (DPT) (2007a). *Dokuzuncu kalkınma planı çevre özel ihtisas komisyonu raporu Nninth development plan: specialized commission report on environment], Ankara: DPT.*

State Planning Organization (DPT). (2000). *Sekizinci kalkınma planı [Eighth development plan]*, Ankara: DPT.

Stoop, M. L. M. (2003). Water management of production systems optimised by environmentally oriented integral chain management: case study of leather manufacturing in developing countries. *Technovation*, 23, 265-278.

Technology Development Foundation of Turkey (TTGV). (2010). *Project of determination of framework conditions & research-development needs for the dissemination of cleaner (sustainable) production applications in Turkey*. Ankara: Author.

Technology Development Foundation of Turkey TTGV, (2011). *Sanayide eko-verimlilik (temiz üretim) kılavuzu: yöntemler ve uygulamalar [Guideline on eco-efficiency (cleaner production) in industry: methods and applications]*. Ankara: Author.

Technology Development Foundation of Turkey TTGV, (2012). *Sanayide eko-verimlilik (temiz üretim) kilavuzu: Ek-3 su ürünleri sektörü örnek uygulamalar. [Guideline on eco-efficiency (cleaner production) in industry:Annex-3 water products sector case studies].* Unpublished Guideline, Ankara.

Thrane, M., Nielsen, E. H. & Christensen P. (2009). Cleaner production in Danish fish processing – experiences, status and possible future strategies. *Journal of Cleaner Production, 17,* 3.80-390.

The Scientific and Technological Research Council of Turkey (TÜBİTAK). *Vizyon 2023 [Vision 2023]*. Retrieved January 15, 2012 from http://www.tubitak.gov.tr/home.do?ot=1&sid=472&pid=468

Thomaidis, F., & Mavrakis, D. (2006). Optimum route of the south transcontinental gas pipeline in SE Europe using AHP. *Journal of Multi-Criteria Decision Analysis, 14,* 77-88.

Triantaphyllou, E. (2000) Multi-*criteria decision making methods: a comparative study.* Kluwer Academic Publishers.

Triantaphyllou, E. and Sanchez, A. (1997). A sensitivity analysis approach for some deterministic multi-ceriteria decision making methods. *Decision Sciences,* 28 (1), 151-194.

Turkish Industrialists' and Businessmen's Association (TÜSİAD). (1998). *Dış ticarette çevre koruma kaynaklı tarife dışı teknik engeller ve Türk sanayii için eylem planı [Non-tariff barriers originated from environmental conservation in foreign trade and industry action plan report]*. Istanbul: Author.

Turkish Industrialists' and Businessmen's Association (TÜSİAD). (2008). *Türkiye sanayiine sektörel bakış [Sectoral Look to Turkish industry]. Retrieved January 12, 2012 from* http://www.tusiad.org:7979/FileArchive/sanayi.pdf

Turkish Statistical Institute (TÜİK). (2008). *Manufacturing industry waste statistics.* TÜİK Newsletter. Ankara: Author.

Turkish Statistical Institute (TÜİK). (2010). *Manufacturing industry environmental statistics.* TÜİK Newsletter. Ankara: Author.

Turkish Statistical Institute TÜİK (2002a). *Manufacturing industry employment statistics.* Ankara: Author.

Turkish Statistical Institute TÜİK (2005). *Manufacturing industry energy statistics.* Ankara: Author.

Turkish Statistical Institute TÜİK (2008a). *Manufacturing industry environmental statistics.* Ankara: Author.

Turkish Statistical Institute TÜİK (2008b). *Energy consumption statistics.* TÜİK Newsletter. Ankara: Author.

Turkish Statistical Institute TÜİK (2011). *Manufacturing industry export share statistics.* Ankara: Author.

Turkish Statistical Institute TÜİK (2002). *Manufacturing industry added value statistics.* Ankara: Author.

U.S. Department of Commerce (2006). Concentration Ratios: 2002, 2002 Economic Census, Manufacturing Subject Series, Economics and Statistics Administration, U.S. Census Bureau.

U.S. Department of Justice and the Federal Trade Commission (2010). *Horizontal Merger Guidelines.*

Ulukan, H. Z. & Kop, Y. (2009). Multi-criteria decision making (MCDM) of solid waste collection methods using life cycle assessment (LCA) Outputs. In *Computers and Industrial Engineering International Conference,* Los Angeles 584-589.

Ulutas F., Alkaya E., Böğürcü M., & Demirer G. N., (2011). “Determination of the framework conditions and research-development needs for the dissemination of cleaner (sustainable) production applications in Turkey”, *International Journal of Sustainable Development & World Ecology*, In Press.

Ulutaş, B. H. (2004). Determination of the appropriate energy policy for Turkey. *Energy*, *30,* 1146-1161.

United Nations Environment Programme (UNEP). (1996). *Cleaner production: a training resource package.* Paris: United Nations Publications.

United Nations Environment Programme (UNEP). (2002). *Sustainable consumption and cleaner production global status 2002.* Paris: United Nations Publications.

United Nations Environment Programme (UNEP). (2006). *Environmental agreements and cleaner production: questions and answers.* Paris: United Nations Publications.

United Nations Environment Programme (UNEP). United Nations Industrial Development Organisation (UNIDO). (2004). *Guidence manual: how to establish and operate cleaner production centres*. Vienna.

United Nations Environment Programme (UNEP). (2007a). *Design for sustainability: a practical approach for developing economies.* Paris: United Nations Publications.

United Nations Environment Programme (UNEP). (2007b) *Energizing cleaner production: a guide for trainers*. Retrieved on January 15, 2012 from http://www.unep.fr/scp/publications/details.asp?id=DTI/0922/BA

United Nations Environmental Program (UNEP) (1998), *International declaration on cleaner production*. Retrieved on January 15, 2012 from http://senate.dal.ca/Files/policies/internationaldeclaration.pdf

United Nations Environmental Programme (UNEP) (1992), *Rio declaration on environment and development*. Retrieved on January 15, 2012 from http://www.unep.org/Documents.Multilingual/Default.asp?documentid=78&articleid=1163

United Nations Framework Convention on Climate Change (UNFCCC). (2009). *Turkey Greenhouse Gas Inventory National Report*. Ankara: TÜİK.

US Environmental Agency (US EPA). (2002). Pollution Prevention Act of 1990.

Veleva, V., & Ellenbecker, M. (2001). Indicators of sustainable production: framework and methodology, *Journal of Cleaner Production,* 9, 519–549.

Waits, M. J. (2000) The added value of the industry cluster approach to economic analysis, strategy development, and service delivery. *Economic Development Quarterly, 14*(1) 35-50.

Wang, J., Ying, Y., Zhang, C., & Zhao J. (2009). Review on multi-criteria decision analysis aid in sustainable energy decision-making. *Renewable and Sustainable Energy Reviews, 13,* 2263-2278.

World Business Council for Sustainable Development (WBCSD). (2000). *Eco-efficiency: creating more value with less impact.* Geneva.

World Commission on Environment and Development (WCED). (1987). *Our Common Future.*

Yılmaz, B., & Harmancıoğlu, N. B. (2010). *Multi-criteria decision making for water resource management: a case study of the Gediz River Basin, Turkey.* South African Water Research Commission.

Zeleney, M., (1984). *MCDM: past decade and future trends, a source book of multiple criteria decision-making.* Greenwich: JAI Press Inc.

Zosel, T. (1990). How 3M makes pollution prevention pay big dividends. *Pollution Prevention Review, 1*(1), 67-72.

Zosel, T. (1994). Pollution Prevention in the Chemical Industry. In D. Edgerly (Ed), *Opportunities for Innovation: Pollution Prevention* (pp. 13-25). Gaithersburg: National Institute of Standards and Technology.

APPENDIX A

A. LIST OF STAKEHOLDERS

Table A.1: List of Institution Which Provided Opinion in the Weighting of the Selected Criteria (Turkey)

Public Bodies
Ministry of Environment and Forests
Ministry of Industry and Trade
Izmir Development Agency
KOSGEB(Small and Medium Enterprises Development Organization)
National Productivity Centre
TÜBİTAK-Marmara Research Centre (Environment and Energy Institute)
Universities
Gebze Institute of Technology
Atatürk University
Dokuz Eylül University
İstanbul Technical University
İstanbul University Faculty of Engineering
Middle East Technical University
Süleyman Demirel University
Yıldız Technical University
Associations, Chambers And Organized Industrial Zones
The Union of Chambers and Commodity Exchanges of Turkey- TOBB
Adana Camber of Industry
Ege Chamber of Industry
Eskişehir Chamber of Industry
Gaziantep Chamber of Industry
Bursa Chamber of Industry and Commerce
Mersin Chamber of Industry and Commerce
Non-Governmental Organizations
Regional Environmental Centre (REC-Turkey)
TTGV(Technology Development Foundation of Turkey)

Table A.2: List of Institution Which Provided Opinion in the Weighting of the Selected Criteria (İzmir)

Public Bodies
Metropolitan Municipality of İzmir - Directorate of Environmental Protection and Control
Metropolitan Municipality of İzmir - İZSU
Provisional Directorate of Environment and Urban Planning
Provisional Directorate of Science, Industry and Technology
KOSGEB-İzmir (Small and Medium Enterprises Development Organization)
Universities
Dokuz Eylül University - Environmental Engineering Department
Dokuz Eylül University –EBİLTEM
Ege University - Bio-Engineering Department
Ege University - Centre on Science and Technology Research and Development
İzmir Institute of Technology - Chemical Engineering Department
İzmir Economy University - Department of Sustainable Energy
Associations, Chambers And Organized Industrial Zones
İzmir Chamber of Environmental Engineers
Aegean Region Chamber of Industry
ESBAŞ Industrial Park
İzmir Atatürk Industrial Zone
İzmir Menemen Free Zone

APPENDIX B

B. SECTORAL CLASSIFICATION

Table B.1: International Standards Industrial Classification (ISIC, 3.Rev) Manufacturing Industry

Code	
15	Manufacture of food products and beverages
151	Production, processing and preservation of meat, fish, fruit, vegetables, oils and fats
1511	Production, processing and preserving of meat and meat products
1513	Processing and preserving of fruit and vegetables
1514	Manufacture of vegetable and animal oils and fats
152	Manufacture of dairy products
153	Manufacture of grain mill products, starches and starch products, and prepared animal feeds
1531	Manufacture of grain mill products
1532	Manufacture of starches and starch products
154	Manufacture of other food products
1541	Manufacture of bakery products
1542	Manufacture of sugar
1543	Manufacture of cocoa, chocolate and sugar confectionery
1544	Manufacture of macaroni, noodles, couscous and similar farinaceous products
1549	Manufacture of other food products n.e.c.
155	Manufacture of beverages
1551	Distilling, rectifying and blending of spirits; ethyl alcohol production from fermented materials
1552	Manufacture of wines
1553	Manufacture of malt liquors and malt
1554	Manufacture of soft drinks; production of mineral waters
16	Manufacture of tobacco products
160	Manufacture of tobacco products
1600	Manufacture of tobacco products
17	Manufacture of textiles
171	Spinning, weaving and finishing of textiles
1712	Finishing of textiles
172	Manufacture of other textiles
1721	Manufacture of made-up textile articles, except apparel
1729	Manufacture of other textiles n.e.c
173	Manufacture of knitted and crocheted fabrics and articles
18	Manufacture of wearing apparel ; dressing and dyeing of fur

Table B.1: International Standards Industrial Classification (ISIC, 3.Rev)

Manufacturing Industry (Cont.)

Code	
181	Manufacture of wearing apparel, except fur apparel
1810	Manufacture of wearing apparel, except fur apparel
19	Tanning and dressing of leather ; Manufacture of luggage, handbags,
191	Tanning and dressing of leather ; Manufacture of luggage, handbags, saddlery and harness
1911	Tanning and dressing of leather
1912	Manufacture of luggage, handbags and the like, saddlery and harness
192	Manufacture of footwear
1920	Manufacture of footwear
20	Manufacture of wood and of products of wood and cork, except furniture; Manufacture of articles of straw and plaiting materials
201	Sawmilling and planing of wood
2010	Sawmilling and planing of wood
202	Manufacture of products of wood, cork, straw and plaiting materials
2021	Manufacture of veneer sheets; Manufacture of plywood, laminboard, particle board and other panels and boards
2022	Manufacture of builders carpentry and joinery
2023	Manufacture of wooden containers
2029	Manufacture of other products of wood; Manufacture of articles of cork, straw and plaiting materials
21	Manufacture of paper and paper products
210	Manufacture of paper and paper products
2101	Manufacture of pulp, paper and paperboard
2102	Manufacture of corrugated paper and paperboard and of containers of paper and paperboard
2109	Manufacture of other articles of paper and paperboard
22	Publishing, printing and reproduction of recorded media
221	Publishing
2211	Publishing of books, brochures, musical books and other publications
2212	Publishing of newspapers, journals and periodicals
2213	Publishing of recorded media
2219	Other publishing
222	Printing and service activities related to printing
2221	Printing
2222	Service activities related to printing
223	Reproduction of recorded media
2230	Reproduction of recorded media
23	Manufacture of coke, refined petroleum products
231	Manufacture of coke oven products
2310	Manufacture of coke oven products
232	Manufacture of refined petroleum products
2320	Manufacture of refined petroleum products
233	Processing of nuclear fuel

Table B.1: International Standards Industrial Classification (ISIC, 3.Rev)

Manufacturing Industry (Cont.)

Code	
2330	Processing of nuclear fuel
24	Manufacture of chemicals and chemical products
241	Manufacture of basic chemicals
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds
2412	Manufacture of fertilizers and nitrogen compounds
2413	Manufacture of plastics in primary forms and of synthetic rubber
2320	Manufacture of refined petroleum products
233	Processing of nuclear fuel
2330	Processing of nuclear fuel
24	Manufacture of chemicals and chemical products
241	Manufacture of basic chemicals
2411	Manufacture of basic chemicals, except fertilizers and nitrogen compounds
2412	Manufacture of fertilizers and nitrogen compounds
2413	Manufacture of plastics in primary forms and of synthetic rubber
2413	Manufacture of plastics in primary forms and of synthetic rubber
242	Manufacture of other chemical products
2421	Manufacture of pesticides and other agro-chemical products
2422	Manufacture of paints, varnishes and similar coatings, printing ink and mastics
2423	Manufacture of pharmaceuticals, medicinal chemicals and botanical products
2424	Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and toilet preparations
243	Manufacture of man-made fibers
2430	Manufacture of man-made fibers
25	Manufacture of rubber and plastics products
251	Manufacture of rubber products
2511	Manufacture of rubber tyres and tubes; retreading and rebuilding of rubber tyres
2519	Manufacture of other rubber products
252	Manufacture of plastics products
2520	Manufacture of plastics products
26	Manufacture of other non-metallic mineral products
261	Manufacture of glass and glass products
269	Manufacture of non-metallic mineral products nec.
2691	Manufacture of non-structural non-refractory ceramic ware
2692	Manufacture of refractory ceramic products
2693	Manufacture of structural non-refractory clay and ceramic products
2694	Manufacture of cement, lime and plaster
2695	Manufacture of articles of concrete, cement and plaster
2696	Cutting, shaping and finishing of stone
2699	Manufacture of other non-metallic mineral products nec.

Table B.1: International Standards Industrial Classification (ISIC, 3.Rev)

Manufacturing Industry (Cont.)

Code	
27	Manufacture of basic metals
271	Manufacture of basic iron and steel
2710	Manufacture of basic iron and steel
272	Manufacture of basic precious and non-ferrous metals
273	Casting of metals
2731	Casting of iron and steel
2732	Casting of non-ferrous metals
28	Manufacture of fabricated metal products, except machinery and equipment
281	Manufacture of structural metal products, tanks, reservoirs and steam generators
2811	Manufacture of structural metal products
2812	Manufacture of tanks, reservoirs and containers of metal
2813	Manufacture of steam generators, except central heating hot water boilers
289	Manufacture of other fabricated metal products; metal working service activities
2891	Forging, pressing, stamping and roll-forming of metal, powder metallurgy
2892	Treatment and coating of metals; general mechanical engineering
2893	Manufacture of cutlery, hand tools and general hardware
2899	Manufacture of other fabricated metal products nec.
29	Manufacture of machinery and equipment not elsewhere classified
291	Manufacture of general purpose machinery
2911	Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
2912	Manufacture of pumps, compressors, taps and valves
2913	Manufacture of bearings, gears, gearing and driving elements
2914	Manufacture of ovens, furnaces and furnace burners
2915	Manufacture of lifting and handling equipment
2919	Manufacture of other general purpose machinery
292	Manufacture of special purpose machinery
2921	Manufacture of agricultural and forestry machinery
2922	Manufacture of machine-tools
2923	Manufacture of machinery for metallurgy
2924	Manufacture of machinery for mining, quarrying and construction
2925	Manufacture of machinery for food, beverage and tobacco products
2926	Manufacture of machinery for textile, apparel and leather production
2927	Manufacture of weapons and ammunition
2929	Manufacture of other special purpose machinery
293	Manufacture of domestic appliances nec.
30	Manufacture of office, accounting and computing machinery

Table B.1.: International Standards Industrial Classification (ISIC, 3.Rev)

Manufacturing Industry (Cont.)

Code	
31	Manufacture of electrical machinery and apparatus nec.
311	Manufacture of electric motors, generators and transformers
312	Manufacture of electricity distribution and control apparatus
313	Manufacture of insulated wire and cable
314	Manufacture of accumulators, primary cells and primary batteries
315	Manufacture of electric lamps and lighting equipment
319	Manufacture of other electrical equipment not elsewhere classified
32	Manufacture of radio, television and communication equipment and apparatus
323	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
3230	Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods
33	Manufacture of medical, precision and optical instruments, watches and clocks
3311	Manufacture of medical and surgical equipment and orthopaedic appliances
3312	Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment
3313	Manufacture of industrial process control equipment
332	Manufacture of optical instruments and photographic equipment
33	Manufacture of watches and clocks
34	Manufacture of motor vehicles, trailers and semi-trailers
341	Manufacture of motor vehicles
342	Manufacture of bodies (coachwork) for motor vehicles, manufacture of trailers and semi-trailers
343	Manufacture of parts and accessories for motor vehicles and their engines
35	Manufacture of other transport equipment
351	Building and repairing of ships and boats
3511	Building and repairing of ships
3512	Building and repairing of pleasure and sporting boats
352	Manufacture of railway and tramway locomotives and rolling stock
353	Manufacture of aircraft and spacecraft
359	Manufacture of transport equipment nec.
3591	Manufacture of motorcycles
3592	Manufacture of bicycles and invalid carriages
3599	Manufacture of other transport equipment not elsewhere classified
36	Manufacture of furniture, Manufacturing not elsewhere classified

APPENDIX C

C. DATA REGARDING PRIORITIZATION CRITERIA

Table C.1: Water Consumption of Manufacturing Industry in Turkey

	Main industry group	**Water consumption ('000 m^3/year)**
10	Manufacture of food products	117,022
11	Manufacture of beverages	13,927
12	Manufacture of tobacco products	1,203
13	Manufacture of textiles	167,290
14	Manufacture of wearing apparel	24,284
15	Manufacture of leather and related products	828
16	Manufacture of wood and of products of wood and cork, except furniture;	6,844
17	Manufacture of paper and paper products	18,869
18	Printing and reproduction of recorded media (	364
19	Manufacture of coke and refined petroleum products	8,181
20	Manufacture of chemicals and chemical products	67,519
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1,573
22	Manufacture of rubber and plastic products	6,393
23	Manufacture of other non-metallic mineral products	52,652
24	Manufacture of basic metals	787,878
25	Manufacture of fabricated metal products, except machinery and equipment	7,065
26	Manufacture of computer, electronic and optical products	4,237
27	Manufacture of electrical equipment	8,096
28	Manufacture of machinery and equipment n.e.c.	3,935
29	Manufacture of motor vehicles, trailers and semi-trailers	8,106
30	Manufacture of other transport equipment	2,373
31	Manufacture of furniture	1,591
32	Other manufacturing	603
33	Repair and installation of machinery and equipment	913

(TÜİK, 2008)

Table C.2: Energy Consumption of Manufacturing Industry Sub-sectors in Turkey

	Main Industry Group	**Energy consumption (TEP/year)**
15	Manufacture of food products and beverages	1,407,969
16	Manufacture of tobacco products	29,483
17	Manufacture of textiles	2,289,299
18	Manufacture of wearing apparel ;	327,896
19	Tanning and dressing of leather	82,828
20	Manufacture of wood and of products of wood and cork. except furniture	165,407
21	Manufacture of paper and paper products	388,843
22	Publishing. printing and reproduction of recorded media	29,154
23	Manufacture of coke. refined petroleum products and nuclear fuel	1,707,629
24	Manufacture of chemicals and chemical products	1,053,261
25	Manufacture of rubber and plastics products	265,672
26	Manufacture of other non-metallic mineral products	4,881,953
27	Manufacture of basic metals	4,807,901
28	Manufacture of fabricated metal products. except machinery and equipment	189,876
29	Manufacture of machinery and equipment nec.	152,155
30	Manufacture of office. accounting and computing machinery	510
31	Manufacture of electrical machinery and apparatus nec.	80,800
32	Manufacture of radio. television and communication equipment and apparatus	29,885
33	Manufacture of medical. precision and optical instruments. watches and clocks	6,748
34	Manufacture of motor vehicles. trailers and semi-trailers	259,382
35	Manufacture of other transport equipment	29,273
36	Manufacture of furniture. Manufacturing nec.	78,126

(TÜİK, 2005)

Table C.3: Wastewater Discharge Amounts of Manufacturing Industry in Turkey

	Main industry group	Wastewater amount ('000 m^3/year)
10,	Manufacture of food products	69,605
11	Manufacture of beverages	6,747
12	Manufacture of tobacco products	608
13	Manufacture of textiles	131,315
14	Manufacture of wearing apparel	21,208
15	Manufacture of leather and related products	759
16	Manufacture of wood and of products of wood and cork, except furniture	1,203
17	Manufacture of paper and paper products	16,157
18	Printing and reproduction of recorded media (	314
19	Manufacture of coke and refined petroleum products	5,701
20	Manufacture of chemicals and chemical products	34,273
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	1,124
22	Manufacture of rubber and plastic products	3,705
23	Manufacture of other non-metallic mineral products	20,703
24	Manufacture of basic metals	687,158
25	Manufacture of fabricated metal products, except machinery and equipment	5,289
26	Manufacture of computer, electronic and optical products	4,164
27	Manufacture of electrical equipment	6,692
28	Manufacture of machinery and equipment n.e.c.	2,011
29	Manufacture of motor vehicles, trailers and semi-trailers	5,492
30	Manufacture of other transport equipment	1,219
31	Manufacture of furniture	979
32	Other manufacturing	508
33	Repair and installation of machinery and equipment	903

(TÜİK, 2008)

Table C.4: Solid Waste Generated by Manufacturing Industry in Turkey

	Main industry group	Solid waste generated (ton/year)
10,	Manufacture of food products	665,554
11	Manufacture of beverages	39,431
12	Manufacture of tobacco products	4,235
13	Manufacture of textiles	314,020
14	Manufacture of wearing apparel	82,441
15	Manufacture of leather and related products	1,757
16	Manufacture of wood and of products of wood and cork, except furniture;	33,866
17	Manufacture of paper and paper products	119,263
18	Printing and reproduction of recorded media (	3,327
19	Manufacture of coke and refined petroleum products	16,492
20	Manufacture of chemicals and chemical products	410,320
21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	106,377
22	Manufacture of rubber and plastic products	20,062
23	Manufacture of other non-metallic mineral products	557,384
24	Manufacture of basic metals	4,729,602
25	Manufacture of fabricated metal products, except machinery and equipment	33,330
26	Manufacture of computer, electronic and optical products	3,528
27	Manufacture of electrical equipment	66,516
28	Manufacture of machinery and equipment nec,	17,026
29	Manufacture of motor vehicles, trailers and semi-trailers	49,865
30	Manufacture of other transport equipment	17,050
31	Manufacture of furniture	6,907
32	Other manufacturing	2,128
33	Repair and installation of machinery and equipment	8,403

(TÜİK, 2008)

Table C.5: Hazardous Waste Generated by Manufacturing Industry in Turkey

	Main Industry Group	Hazardous Waste ('000 m^3/year)
15	Manufacture of food products and beverages	6,782
16	Manufacture of tobacco products	8,974
17	Manufacture of textiles	160
18	Manufacture of wearing apparel ;	28,303
19	Tanning and dressing of leather	12,765
20	Manufacture of wood and of products of wood and cork. except furniture	58
21	Manufacture of paper and paper products	16,243
22	Publishing. printing and reproduction of recorded media	3,053
23	Manufacture of coke. refined petroleum products and nuclear fuel	1,096
24	Manufacture of chemicals and chemical products	14,287
25	Manufacture of rubber and plastics products	369,927
26	Manufacture of other non-metallic mineral products	34,119
27	Manufacture of basic metals	5,732
28	Manufacture of fabricated metal products. except machinery and equipment	71,087
29	Manufacture of machinery and equipment nec.	229,417
30	Manufacture of office. accounting and computing machinery	10,351
31	Manufacture of electrical machinery and apparatus nec.	1,291
32	Manufacture of radio. television and communication equipment and apparatus	38,291
33	Manufacture of medical. precision and optical instruments. watches and clocks	8,153
34	Manufacture of motor vehicles. trailers and semi-trailers	20,796
35	Manufacture of other transport equipment	11,083
36	Manufacture of furniture. Manufacturing nec.	3,440

(TÜİK, 2008)

Table C.6: Greenhouse Gases Emissions from Manufacturing Industry

Main Industry Group	Energy consumption (TJ/year)	Emissions originated from energy consumption* (tC/year)			Emissions originated from industrial processes** (tC/year)	Total emission (tC/year)
		CO_2	CH_4	N_2O		CO_2
Manufacture of food products and beverages	52,863	1,057,259	2,220	26,220	-***	1,085,699
Manufacture of tobacco products	764	15,288	32	379	-	15,700
Manufacture of textiles	41,183	823,653	1,730	20,427	-	845,809
Manufacture of wearing apparel ;	3,195	63,892	134	1,585	-	65,610
Tanning and dressing of leather	176	3,527	7	87	-	3,622
Manufacture of wood and of products of wood and cork, except furniture	4,541	90,815	191	2,252	-	93,258
Manufacture of paper and paper products	17,917	358,340	753	8,887	-	367,980
Publishing, printing and reproduction of recorded media	4,787	95,735	201	2,374	-	98,310
Manufacture of coke, refined petroleum products and nuclear fuel	57,016	1,140,315	2,395	28,280	-	1,170,989
Manufacture of chemicals and chemical products	66,339	1,326,774	2,786	32,904	2,368,000	1,362,464
Manufacture of rubber and plastics products	6,981	139,624	293	3,463	-	143,380
Manufacture of other non-metallic mineral products	125,505	2,510,090	5,271	62,250	19,328,000	2,577,612
Manufacture of basic metals	151,943	3,038,868	6,382	75,364	460,000	3,120,614
Manufacture of fabricated metal products, except machinery and equipment	4,645	92,907	195	2,304	-	95,406
Manufacture of machinery and equipment not elsewhere classified	5,432	108,638	228	2,694	-	111,561

(TÜİK 2005)

Table C.6: Greenhouse Gases Emissions from Manufacturing Industry (Cont'd)

Main Industry Group	Energy consumption (TJ/year)	Emissions originated from energy consumption* (tC/year)			Emissions originated from industrial processes** (tC/year)	Total emission (tC/year)
		CO_2	CH_4	N_2O		CO_2
Manufacture of office, accounting and computing machinery	-	-	-	-	-	0
Manufacture of electrical machinery and apparatus not elsewhere classified	1,110	22,208	47	551	-	22,805
Manufacture of radio, television and communication equipment and apparatus	835	16,708	35	414	-	17,157
Manufacture of medical, precision and optical instruments, watches and clocks	484	9,675	20	240	-	9,935
Manufacture of motor vehicles, trailers and semi-trailers	6,077	121,532	255	3,014	-	124,801
Manufacture of other transport equipment	1,161	23,229	49	576	-	23,854
Manufacture of furniture, Manufacturing not elsewhere classified	328	6,564	14	163	-	6,740

(TÜİK 2005)

* Emission factors are used for the calculation of emission values. Emission factors are as follow;

CO_2:20 tC/TJ (1 TJ fuel for energy causes 20 tC emission)

CH_4: 2 KG CH_4 /TJ = 0,042 tC/TJ

N_2O: 0,6 KG N_2O/TJ = 0,496 tC/ TJ

** Greenhouse gases originated from industrial processes are taken from Turkey Greenhouse Gas Inventory – National Inventory Report.

*** Zero or negligible

Table C.7: Employment of Manufacturing Industries in Turkey

	Main Industry Group	Employment (person)
15	Manufacture of food products and beverages	149,734
16	Manufacture of tobacco products	16,097
17	Manufacture of textiles	219,719
18	Manufacture of wearing apparel	153,011
19	Tanning and dressing of leather	16,430
20	Manufacture of wood and of products of wood and cork. except furniture	10,706
21	Manufacture of paper and paper products	21,063
22	Publishing. printing and reproduction of recorded media	12,094
23	Manufacture of coke. refined petroleum products and nuclear fuel	7,331
24	Manufacture of chemicals and chemical products	58,592
25	Manufacture of rubber and plastics products	40,692
26	Manufacture of other non-metallic mineral products	68,087
27	Manufacture of basic metals	56,795
28	Manufacture of fabricated metal products. except machinery and equipment	50.197
29	Manufacture of machinery and equipment nec.	67,637
30	Manufacture of office. accounting and computing machinery	1,212
31	Manufacture of electrical machinery and apparatus nec.	31,643
32	Manufacture of radio. television and communication equipment and apparatus	15,919
33	Manufacture of medical. precision and optical instruments. watches and clocks	5,541
34	Manufacture of motor vehicles. trailers and semi-trailers	47,493
35	Manufacture of other transport equipment	12,920
36	Manufacture of furniture. Manufacturing nec.	30,280

(TÜİK, 2001)

Table C.8: Export Values of Manufacturing Industry in Turkey

	Main Industry Group	Export ('000$ /year)
15	Manufacture of food products and beverages	6,475,836
16	Manufacture of tobacco products	276,802
17	Manufacture of textiles	11,323,038
18	Manufacture of wearing apparel ;	11,503,751
19	Tanning and dressing of leather	606,793
20	Manufacture of wood and of products of wood and cork. except furniture	534,955
21	Manufacture of paper and paper products	1,051,948
22	Publishing. printing and reproduction of recorded media	145,155
23	Manufacture of coke. refined petroleum products and nuclear fuel	7,325,096
24	Manufacture of chemicals and chemical products	4,994,803
25	Manufacture of rubber and plastics products	4,749,916
26	Manufacture of other non-metallic mineral products	4,321,013
27	Manufacture of basic metals	22,569,898
28	Manufacture of fabricated metal products. except machinery and equipment	5,531,449
29	Manufacture of machinery and equipment nec.	9,763,363
30	Manufacture of office. accounting and computing machinery	135,240
31	Manufacture of electrical machinery and apparatus nec.	4,975,080
32	Manufacture of radio. television and communication equipment and apparatus	2,276,648
33	Manufacture of medical precision and optical instruments. watches and clocks	404,334
34	Manufacture of motor vehicles. trailers and semi-trailers	19,361,877
35	Manufacture of other transport equipment	3,360,386
36	Manufacture of furniture. Manufacturing nec.	3,500,277

(TÜİK, 2008)

Table C.9: Suitability of Sectors to Cleaner (Sustainable) Production

	Main Industry Group	Ranking	Score
15	Manufacture of food products and beverages	2	21
16	Manufacture of tobacco products	17-18-19-20-21-22*	3.5
17	Manufacture of textiles	5	18
18	Manufacture of wearing apparel ;	9	14
19	Tanning and dressing of leather	10	13
20	Manufacture of wood and of products of wood and cork, except furniture	16	7
21	Manufacture of paper and paper products	14	9
22	Publishing, printing and reproduction of recorded media	15	8
23	Manufacture of coke, refined petroleum products and nuclear fuel	17-18-19-20-21-22	3.5
24	Manufacture of chemicals and chemical products	6	17
25	Manufacture of rubber and plastics products	12	11
26	Manufacture of other non-metallic mineral products	13	10
27	Manufacture of basic metals	3-4	19.5
28	Manufacture of fabricated metal products, except machinery and equipment	3-4	19.5
29	Manufacture of machinery and equipment nec.	17-18-19-20-21-22	3.5
30	Manufacture of office, accounting and computing machinery	17-18-19-20-21-22	3.5
31	Manufacture of electrical machinery and apparatus nec.	1	22
32	Manufacture of radio, television and communication equipment and apparatus	17-18-19-20-21-22	3.5
33	Manufacture of medical, precision and optical instruments, watches and clocks	17-18-19-20-21-22	3.5
34	Manufacture of motor vehicles, trailers and semi-trailers	7-8	15.5
35	Manufacture of other transport equipment	7-8	15.5
36	Manufacture of furniture, Manufacturing nec.	11	12

* 6 sectors have the same importance.

(CP/RAC, 2007)

Table C.10: Employment of Manufacturing Industries in İzmir

	Main Industry Group	Employment (person)
15	Manufacture of food products and beverages	28,999
16	Manufacture of tobacco products	6,258
17	Manufacture of textiles	6,839
18	Manufacture of wearing apparel	41,058
19	Tanning and dressing of leather	2,552
20	Manufacture of wood and of products of wood and cork. except furniture	3,581
21	Manufacture of paper and paper products	5,793
22	Publishing. printing and reproduction of recorded media	5,464
23	Manufacture of coke. refined petroleum products and nuclear fuel	2,966
24	Manufacture of chemicals and chemical products	7,530
25	Manufacture of rubber and plastics products	781
26	Manufacture of other non-metallic mineral products	9,104
27	Manufacture of basic metals	29,325
28	Manufacture of fabricated metal products. except machinery and equipment	6,629
29	Manufacture of machinery and equipment nec.	27,294
30+32+33	Manufacture of office. accounting and computing machinery	3,423
31	Manufacture of electrical machinery and apparatus nec.	5,476
34	Manufacture of motor vehicles. trailers and semi-trailers	24,821
35	Manufacture of other transport equipment	1,949
36	Manufacture of furniture. Manufacturing nec.	19,536

(SGK, 2008)

Table C.11: Number of Companies in Manufacturing Industry in İzmir

	Main Industry Group	**Number of Companies**
15	Manufacture of food products and beverages	563
16	Manufacture of tobacco products	15
17	Manufacture of textiles	167
18	Manufacture of wearing apparel ;	283
19	Tanning and dressing of leather	129
20	Manufacture of wood and of products of wood and cork. except furniture	58
21	Manufacture of paper and paper products	82
22	Publishing. printing and reproduction of recorded media	35
23	Manufacture of coke. refined petroleum products and nuclear fuel	34
24	Manufacture of chemicals and chemical products	189
25	Manufacture of rubber and plastics products	196
26	Manufacture of other non-metallic mineral products	157
27	Manufacture of basic metals	123
28	Manufacture of fabricated metal products. except machinery and equipment	195
29	Manufacture of machinery and equipment nec.	608
30	Manufacture of office. accounting and computing machinery	4
31	Manufacture of electrical machinery and apparatus nec.	91
32	Manufacture of radio. television and communication equipment and apparatus	22
33	Manufacture of medical precision and optical instruments. watches and clocks	93
34	Manufacture of motor vehicles. trailers and semi-trailers	114
35	Manufacture of other transport equipment	48
36	Manufacture of furniture. Manufacturing nec.	166

(BTSB, 2011)

Table C.12: Export Values of in Manufacturing Industry in İzmir

	Main Industry Group	Export ($ /year)
15	Manufacture of food products and beverages	755,115,316
16	Manufacture of tobacco products	150,520,816
17	Manufacture of textiles	232,730,838
18	Manufacture of wearing apparel ;	903,731,911
19	Tanning and dressing of leather	42,743,415
20	Manufacture of wood and of products of wood and cork. except furniture	11,810,793
21	Manufacture of paper and paper products	141,635,519
22	Publishing. printing and reproduction of recorded media	8,340,583
23	Manufacture of coke. refined petroleum products and nuclear fuel	185,761,612
24	Manufacture of chemicals and chemical products	662,999,299
25	Manufacture of rubber and plastics products	276,095,535
26	Manufacture of other non-metallic mineral products	258,358,157
27	Manufacture of basic metals	512,331,263
28	Manufacture of fabricated metal products. except machinery and equipment	184,170,516
29	Manufacture of machinery and equipment nec.	540,651,563
30	Manufacture of office. accounting and computing machinery	2,844,530
31	Manufacture of electrical machinery and apparatus nec.	167,473,524
32	Manufacture of radio. television and communication equipment and apparatus	4,270,559
33	Manufacture of medical. precision and optical instruments. watches and clocks	60,749,332
34	Manufacture of motor vehicles. trailers and semi-trailers	480,861,762
35	Manufacture of other transport equipment	23,160,303
36	Manufacture of furniture. Manufacturing nec.	110,301,196

(TÜİK, 2011)

Table C.13: Added Value of in Manufacturing Industry in İzmir

	Main Industry Group	Added Value ($ /year)
15	Manufacture of food products and beverages	477,352,131
16	Manufacture of tobacco products	1,437,034,728
17	Manufacture of textiles	105,962,631
18	Manufacture of wearing apparel ;	168,080,503
19	Tanning and dressing of leather	14,488,035
20	Manufacture of wood and of products of wood and cork. except furniture	4,195,078
21	Manufacture of paper and paper products	134,366,398
22	Publishing. printing and reproduction of recorded media	21,154,098
23	Manufacture of coke. refined petroleum products and nuclear fuel	2,469,911,249
24	Manufacture of chemicals and chemical products	1,671,530,983
25	Manufacture of rubber and plastics products	288,059,532
26	Manufacture of other non-metallic mineral products	276,846,652
27	Manufacture of basic metals	473,279,828
28	Manufacture of fabricated metal products. except machinery and equipment	355,051,459
29	Manufacture of machinery and equipment nec.	530,980,639
30	Manufacture of office. accounting and computing machinery	19,199,488
31	Manufacture of electrical machinery and apparatus nec.	308,198,240
32	Manufacture of radio television and communication equipment and apparatus	774,202,018
33	Manufacture of medical precision and optical instruments. watches and clocks	36,089,666
34	Manufacture of motor vehicles. trailers and semi-trailers	260,080,816
35	Manufacture of other transport equipment	85,606,703
36	Manufacture of furniture. Manufacturing nec.	350,480,322

(TÜİK, 2011)

APPENDIX D

D. QUESTIONNAIRES & MATRICES

Table D.1: Criteria Ranking for Cleaner (Sustainable) Production (Turkey)

Criteria	Rank
Number of people employed	
Export share	
Water consumption	
Energy consumption	
Wastewater discharged	
Solid waste generated	
Hazardous waste generated	
GHG Emissions	
Suitability of sectors to cleaner production	

Table D.2: Criteria Weighting Matrix with Eigenvalue Method (Turkey)

	Employment	Export share	Water Consumption	Energy Consumption	Wastewater	Solid waste	Hazardous waste	GHG emissions	Suitability to Cleaner Production
Employment	1								
Export share		1							
Water Consumption			1						
Energy Consumption				1					
Wastewater					1				
Solid waste						1			
Hazardous waste							1		
GHG emissions								1	
Suitability to Cleaner Production									1

Table D.3: Criteria Ranking for Cleaner (Sustainable) Production (İzmir)

Criteria	**Rank**
Number of people employed	
Number of companies	
Export share	
Added Value	
Herfindahl–Hirschman Index	
Water consumption	
Energy consumption	
Wastewater discharged	
Solid waste generated	
Hazardous waste generated	
GHG Emissions	
Suitability of sectors to cleaner production	

Table D.4: Criteria Weighting Matrix with Eigenvalue Method (İzmir)

	Empl.	Number of Comp.	Added Value	Export share	HHI	Water Cons.	Energy Cons.	Waste water	Solid waste	Hazardous waste	GHG emissions	Suitability to CP
Employment	1											
Number of Companies		1										
Added Value			1									
Export share				1								
Herfindahl-Hirschman Index (HHI)					1							
Water Consumption						1						
Energy Consumption							1					
Wastewater								1				
Solid waste									1			
Hazardous waste										1		
GHG emissions											1	
Suitability to CP												1

Table D.5: MCDM Matrix for Sectoral Prioritization for Turkey with WSM (Entropy) Method

	Employment	Export	Water Cons.	Energy Cons.	Wastewater	Solid waste	Hazardous waste	GHG emissions	Suitability to CP	WSM Score
	Criteria Weights (Entropy)									
ISIC Code	0.055	0.056	0.182	0.111	0.153	0.143	0.141	0.140	0.018	
15	0.137	0.052	0.109	0.080	0.126	0.201	0.219	0.202	0.083	**0.148**
16	0.015	0.002	0.002	0.002	0.003	0.001	0.007	0.001	0.014	**0.004**
17	0.201	0.090	0.076	0.118	0.120	0.021	0.004	0.020	0.071	**0.069**
18	0.140	0.092	0.016	0.005	0.028	0.007	0.001	0.007	0.055	**0.024**
19	0.015	0.005	0.001	0.001	0.002	0.001	0.000	0.001	0.051	**0.003**
20	0.010	0.004	0.002	0.010	0.002	0.006	0.000	0.006	0.028	**0.005**
21	0.019	0.008	0.015	0.032	0.021	0.010	0.003	0.010	0.036	**0.015**
22	0.011	0.001	0.001	0.009	0.002	0.002	0.000	0.002	0.032	**0.003**
23	0.007	0.059	0.019	0.063	0.019	0.007	0.095	0.013	0.014	**0.033**
24	0.054	0.040	0.072	0.097	0.089	0.086	0.242	0.096	0.067	**0.103**
25	0.037	0.038	0.005	0.019	0.007	0.005	0.002	0.005	0.043	**0.011**
26	0.062	0.035	0.028	0.225	0.016	0.097	0.028	0.092	0.040	**0.069**
27	0.052	0.180	0.617	0.288	0.507	0.444	0.274	0.433	0.077	**0.399**
28	0.046	0.044	0.003	0.013	0.005	0.041	0.005	0.039	0.077	**0.021**
29	0.062	0.078	0.019	0.007	0.034	0.034	0.001	0.031	0.014	**0.027**
30	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.014	**0.000**
31	0.029	0.040	0.002	0.006	0.004	0.008	0.054	0.011	0.087	**0.017**
32	0.015	0.018	0.002	0.003	0.003	0.001	0.004	0.001	0.014	**0.004**
33	0.005	0.003	0.000	0.000	0.000	0.001	0.000	0.000	0.014	**0.001**
34	0.043	0.155	0.004	0.017	0.006	0.018	0.060	0.020	0.061	**0.030**
35	0.012	0.027	0.001	0.002	0.001	0.002	0.000	0.002	0.061	**0.005**
36	0.028	0.028	0.003	0.001	0.006	0.009	0.000	0.008	0.047	**0.008**

Table D.6: MCDM Matrix for Sectoral Prioritization for Turkey with WSM (Simple Ranking) Method

	Employment	Export	Water Cons.	Energy Cons.	Wastewater	Solid waste	Hazardous waste	GHG emissions	Suitability to CP	WSM Score
	Criteria Weights (Simple Ranking)									
ISIC Code	0.051	0.061	0.132	0.138	0.120	0.114	0.156	0.117	0.111	
15	0.137	0.052	0.109	0.080	0.126	0.201	0.219	0.202	0.083	**0.141**
16	0.015	0.002	0.002	0.002	0.003	0.001	0.007	0.001	0.014	**0.005**
17	0.201	0.090	0.076	0.118	0.120	0.021	0.004	0.020	0.071	**0.070**
18	0.140	0.092	0.016	0.005	0.028	0.007	0.001	0.007	0.055	**0.027**
19	0.015	0.005	0.001	0.001	0.002	0.001	0.000	0.001	0.051	**0.007**
20	0.010	0.004	0.002	0.010	0.002	0.006	0.000	0.006	0.028	**0.007**
21	0.019	0.008	0.015	0.032	0.021	0.010	0.003	0.010	0.036	**0.017**
22	0.011	0.001	0.001	0.009	0.002	0.002	0.000	0.002	0.032	**0.006**
23	0.007	0.059	0.019	0.063	0.019	0.007	0.095	0.013	0.014	**0.036**
24	0.054	0.040	0.072	0.097	0.089	0.086	0.242	0.096	0.067	**0.105**
25	0.037	0.038	0.005	0.019	0.007	0.005	0.002	0.005	0.043	**0.015**
26	0.062	0.035	0.028	0.225	0.016	0.097	0.028	0.092	0.040	**0.073**
27	0.052	0.180	0.617	0.288	0.507	0.444	0.274	0.433	0.077	**0.348**
28	0.046	0.044	0.003	0.013	0.005	0.041	0.005	0.039	0.077	**0.026**
29	0.062	0.078	0.019	0.007	0.034	0.034	0.001	0.031	0.014	**0.025**
30	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.014	**0.002**
31	0.029	0.040	0.002	0.006	0.004	0.008	0.054	0.011	0.087	**0.026**
32	0.015	0.018	0.002	0.003	0.003	0.001	0.004	0.001	0.014	**0.005**
33	0.005	0.003	0.000	0.000	0.000	0.001	0.000	0.000	0.014	**0.002**
34	0.043	0.155	0.004	0.017	0.006	0.018	0.060	0.020	0.061	**0.036**
35	0.012	0.027	0.001	0.002	0.001	0.002	0.000	0.002	0.061	**0.010**
36	0.028	0.028	0.003	0.001	0.006	0.009	0.000	0.008	0.047	**0.012**

Table D.7: MCDM Matrix for Sectoral Prioritization for Turkey with AHP Method

	Employment	Export	Water Cons.	Energy Cons.	Wastewater	Solid waste	Hazardous waste	GHG emissions	Suitability to CP	AHP Score
	Criteria Weights (Eigen Value)									
ISIC Code	0.053	0.065	0.165	0.190	0.104	0.106	0.182	0.171	0.151	
15	0.137	0.052	0.109	0.080	0.126	0.201	0.219	0.202	0.083	**0.165**
16	0.015	0.002	0.002	0.002	0.003	0.001	0.007	0.001	0.014	**0.006**
17	0.201	0.090	0.076	0.118	0.120	0.021	0.004	0.020	0.071	**0.081**
18	0.140	0.092	0.016	0.005	0.028	0.007	0.001	0.007	0.055	**0.031**
19	0.015	0.005	0.001	0.001	0.002	0.001	0.000	0.001	0.051	**0.010**
20	0.010	0.004	0.002	0.010	0.002	0.006	0.000	0.006	0.028	**0.009**
21	0.019	0.008	0.015	0.032	0.021	0.010	0.003	0.010	0.036	**0.021**
22	0.011	0.001	0.001	0.009	0.002	0.002	0.000	0.002	0.032	**0.008**
23	0.007	0.059	0.019	0.063	0.019	0.007	0.095	0.013	0.014	**0.044**
24	0.054	0.040	0.072	0.097	0.089	0.086	0.242	0.096	0.067	**0.124**
25	0.037	0.038	0.005	0.019	0.007	0.005	0.002	0.005	0.043	**0.018**
26	0.062	0.035	0.028	0.225	0.016	0.097	0.028	0.092	0.040	**0.092**
27	0.052	0.180	0.617	0.288	0.507	0.444	0.274	0.433	0.077	**0.406**
28	0.046	0.044	0.003	0.013	0.005	0.041	0.005	0.039	0.077	**0.032**
29	0.062	0.078	0.019	0.007	0.034	0.034	0.001	0.031	0.014	**0.028**
30	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.014	**0.002**
31	0.029	0.040	0.002	0.006	0.004	0.008	0.054	0.011	0.087	**0.032**
32	0.015	0.018	0.002	0.003	0.003	0.001	0.004	0.001	0.014	**0.006**
33	0.005	0.003	0.000	0.000	0.000	0.001	0.000	0.000	0.014	**0.003**
34	0.043	0.155	0.004	0.017	0.006	0.018	0.060	0.020	0.061	**0.043**
35	0.012	0.027	0.001	0.002	0.001	0.002	0.000	0.002	0.061	**0.013**
36	0.028	0.028	0.003	0.001	0.006	0.009	0.000	0.008	0.047	**0.014**

Table D.8: MCDM Matrix for Sectoral Prioritization for İzmir with WSM (Entropy) Method

ISIC Code	Employ ment	Number of comp.	Export	Added value	HHI	Water Cons.	Energy Cons.	WW	Solid waste	Hazard. waste	GHG	Suitabili ty to CP	WSM Score
	0.052	0.030	0.035	0.051	0.001	0.158	0.092	0.176	0.164	0.158	0.107	0.015	
15	0.121	0.167	0.132	0.047	0.037	0.068	0.061	0.055	0.068	0.012	0.075	0.090	0.066
16	0.021	0.004	0.026	0.140	0.219	0.004	0.008	0.003	0.002	0.001	0.000	0.012	0.012
17	0.029	0.050	0.041	0.010	0.009	0.025	0.025	0.024	0.008	0.005	0.015	0.076	0.020
18	0.140	0.084	0.158	0.016	0.034	0.013	0.013	0.014	0.007	0.009	0.000	0.057	0.025
19	0.011	0.038	0.007	0.001	0.037	0.000	0.004	0.001	0.000	0.000	0.000	0.052	0.003
20	0.012	0.017	0.002	0.000	0.011	0.001	0.002	0.000	0.001	0.004	0.002	0.024	0.003
21	0.024	0.024	0.025	0.013	0.056	0.017	0.026	0.018	0.018	0.004	0.004	0.033	0.016
22	0.019	0.010	0.001	0.002	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0.002
23	0.012	0.010	0.032	0.241	0.085	0.011	0.173	0.010	0.004	0.025	0.187	0.012	0.058
24	0.026	0.056	0.116	0.163	0.055	0.061	0.069	0.039	0.076	0.465	0.142	0.071	0.123
25	0.003	0.058	0.048	0.028	0.031	0.003	0.010	0.002	0.002	0.004	0.001	0.043	0.008
26	0.031	0.047	0.045	0.027	0.040	0.033	0.230	0.016	0.058	0.058	0.192	0.038	0.073
27	0.123	0.036	0.090	0.046	0.058	0.723	0.329	0.786	0.719	0.274	0.338	0.083	0.484
28	0.023	0.058	0.032	0.035	0.023	0.003	0.005	0.002	0.002	0.005	0.004	0.083	0.010
29	0.114	0.180	0.095	0.052	0.068	0.004	0.012	0.009	0.005	0.017	0.014	0.012	0.025
30	0.012	0.035	0.012	0.081	0.140	0.010	0.002	0.001	0.000	0.000	0.006	0.012	0.009
31	0.023	0.027	0.029	0.030	0.087	0.011	0.008	0.012	0.015	0.069	0.004	0.095	0.022
34	0.067	0.049	0.019	0.034	0.027	0.001	0.002	0.001	0.001	0.006	0.000	0.048	0.009
35	0.121	0.167	0.132	0.047	0.037	0.068	0.061	0.055	0.068	0.012	0.075	0.090	0.066
36	0.021	0.004	0.026	0.140	0.219	0.004	0.008	0.003	0.002	0.001	0.000	0.012	0.012

Table D.9: MCDM Matrix for Sectoral Prioritization for İzmir with WSM (Simple Ranking) Method

	Employ ment	**Number of comp.**	**Export**	**Added value**	**HHI**	**Water Cons.**	**Energy Cons.**	**WW**	**Solid waste**	**Hazard. waste**	**GHG**	**Suitabili ty to CP**	**WSM Score**
ISIC Code	0.051	0.065	0.065	0.063	0.062	0.114	0.112	0.093	0.086	0.123	0.091	0.076	
15	0.121	0.167	0.132	0.047	0.037	0.068	0.061	0.055	0.068	0.012	0.075	0.090	**0.078**
16	0.021	0.004	0.026	0.140	0.219	0.004	0.008	0.003	0.002	0.001	0.000	0.012	**0.028**
17	0.029	0.050	0.041	0.010	0.009	0.025	0.025	0.024	0.008	0.005	0.015	0.076	**0.029**
18	0.140	0.084	0.158	0.016	0.034	0.013	0.013	0.014	0.007	0.009	0.000	0.057	**0.042**
19	0.011	0.038	0.007	0.001	0.037	0.000	0.004	0.001	0.000	0.000	0.000	0.052	**0.014**
20	0.012	0.017	0.002	0.000	0.011	0.001	0.002	0.000	0.001	0.004	0.002	0.024	**0.007**
21	0.024	0.024	0.025	0.013	0.056	0.017	0.026	0.018	0.018	0.004	0.004	0.033	**0.022**
22	0.019	0.010	0.001	0.002	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.029	**0.007**
23	0.012	0.010	0.032	0.241	0.085	0.011	0.173	0.010	0.004	0.025	0.187	0.012	**0.055**
24	0.026	0.056	0.116	0.163	0.055	0.061	0.069	0.039	0.076	0.465	0.142	0.071	**0.108**
25	0.003	0.058	0.048	0.028	0.031	0.003	0.010	0.002	0.002	0.004	0.001	0.043	**0.019**
26	0.031	0.047	0.045	0.027	0.040	0.033	0.230	0.016	0.058	0.058	0.192	0.038	**0.067**
27	0.123	0.036	0.090	0.046	0.058	0.723	0.329	0.786	0.719	0.274	0.338	0.083	**0.332**
28	0.023	0.058	0.032	0.035	0.023	0.003	0.005	0.002	0.002	0.005	0.004	0.083	**0.024**
29	0.114	0.180	0.095	0.052	0.068	0.004	0.012	0.009	0.005	0.017	0.014	0.012	**0.044**
30	0.012	0.035	0.012	0.081	0.140	0.010	0.002	0.001	0.000	0.000	0.006	0.012	**0.021**
31	0.023	0.027	0.029	0.030	0.087	0.011	0.008	0.012	0.015	0.069	0.004	0.095	**0.036**
34	0.085	0.034	0.084	0.025	0.055	0.007	0.017	0.006	0.007	0.024	0.013	0.064	**0.033**
35	0.008	0.014	0.004	0.008	0.077	0.003	0.003	0.002	0.003	0.018	0.003	0.064	**0.018**
36	0.067	0.049	0.019	0.034	0.027	0.001	0.002	0.001	0.001	0.006	0.000	0.048	**0.020**

Table D.10: MCDM Matrix for Sectoral Prioritization for İzmir with AHP Method

	Employ ment	Number of comp.	Export	Added value	HHI	Water Cons.	Energy Cons.	WW	Solid waste	Hazard. waste	GHG	Suitabili ty to CP	AHP Score
ISIC Code	0.022	0.037	0.036	0.054	0.041	0.130	0.167	0.106	0.083	0.143	0.092	0.090	
15	0.121	0.167	0.132	0.047	0.037	0.068	0.061	0.055	0.068	0.012	0.075	0.090	0,078
16	0.021	0.004	0.026	0.140	0.219	0.004	0.008	0.003	0.002	0.001	0.000	0.012	0,017
17	0.029	0.050	0.041	0.010	0.009	0.025	0.025	0.024	0.008	0.005	0.015	0.076	0,030
18	0.140	0.084	0.158	0.016	0.034	0.013	0.013	0.014	0.007	0.009	0.000	0.057	0,037
19	0.011	0.038	0.007	0.001	0.037	0.000	0.004	0.001	0.000	0.000	0.000	0.052	0,014
20	0.012	0.017	0.002	0.000	0.011	0.001	0.002	0.000	0.001	0.004	0.002	0.024	0,007
21	0.024	0.024	0.025	0.013	0.056	0.017	0.026	0.018	0.018	0.004	0.004	0.033	0,021
22	0.019	0.010	0.001	0.002	0.014	0.000	0.000	0.000	0.000	0.000	0.000	0.029	0,007
23	0.012	0.010	0.032	0.241	0.085	0.011	0.173	0.010	0.004	0.025	0.187	0.012	0,044
24	0.026	0.056	0.116	0.163	0.055	0.061	0.069	0.039	0.076	0.465	0.142	0.071	0.102
25	0.003	0.058	0.048	0.028	0.031	0.003	0.010	0.002	0.002	0.004	0.001	0.043	0,018
26	0.031	0.047	0.045	0.027	0.040	0.033	0.230	0.016	0.058	0.058	0.192	0.038	0,065
27	0.123	0.036	0.090	0.046	0.058	0.723	0.329	0.786	0.719	0.274	0.338	0.083	0,388
28	0.023	0.058	0.032	0.035	0.023	0.003	0.005	0.002	0.002	0.005	0.004	0.083	0,024
29	0.114	0.180	0.095	0.052	0.068	0.004	0.012	0.009	0.005	0.017	0.014	0.012	0,038
30	0.012	0.035	0.012	0.081	0.140	0.010	0.002	0.001	0.000	0.000	0.006	0.012	0,015
31	0.023	0.027	0.029	0.030	0.087	0.011	0.008	0.012	0.015	0.069	0.004	0.095	0,034
34	0.085	0.034	0.084	0.025	0.055	0.007	0.017	0.006	0.007	0.024	0.013	0.064	0,029
35	0.008	0.014	0.004	0.008	0.077	0.003	0.003	0.002	0.003	0.018	0.003	0.064	0,017
36	0.067	0.049	0.019	0.034	0.027	0.001	0.002	0.001	0.001	0.006	0.000	0.048	0,018

APPENDIX E

SAMPLE CALCULATIONS

E.1. Sample Calculation for Entropy Method

Sample calculations were done for water consumption criterion.

The steps followed for the determination of criteria weights via Entropy Method are as follows:

v. Normalization: Water consumption data listed in Appendix C, Table C.1 were normalized by using Formula (2.1). Sample calculation was done for "Manufacture of textiles".

$$\text{Normalized value } = \frac{\mathrm{a_{ij}}}{\sum \mathrm{a_{ij}}} \quad (2.1)$$

$$Normalized\ value\ for\ \ textile\ = \frac{167{,}290\ \times 10^{3} m^{3}\ /y}{117{,}022 + 13{,}927 + \cdots + 913}$$

$$Normalized\ value\ for\ "Manufacture\ of\ textiles" = 0.0765$$

vi. Entropy Calculation:

$$\mathrm{E_j} = -\mathrm{k} \sum \mathrm{a_{ij}} \log\ (\mathrm{a_{ij}}) \quad (2.2)$$

$$E_{\text{water cons.mption}} = 22 \times [(0.1086 \times \log(0.1086)) + (0.0024 \times \log(0.0024)) + \ldots + 0.0034 \times \log(0.0034)]$$

$$E_{\text{water cons.mption}} = 0.476$$

vii. Dispersion Calculation:

$$D_{\mathrm{j}} = 1 - \mathrm{E_j} \quad (2.3)$$

$$D_{\text{water consumption}} = 1 - 0.0476$$

$$D_{\text{water consumption}} = 0.524$$

viii. Weight Calculation:

$$w_j = {D_j}/{\sum D_j} \tag{2.4}$$

$$w_{\text{water consumption}} = {0.524_j}/{\sum(0.524 + 0.440 + \cdots + 0.157)}$$

$$w_{\text{water consumption}} = 0.182$$

E.2. Sample Calculation for Weighted Sum Method

Sample calculations were done for Manufacture of textile industry sector (based on WSM-Entropy Method).

$$P_i = \sum_i^j a_{ij} w_j \qquad i=1,2,3,\ldots m \text{ and } j = 1,2,3,\ldots n \tag{2.5}$$

$$P_{\text{textile}} = (0.2010 \times 0.182) + (0.0904 \times 0.153) + \cdots + (0.0711 \times 0.055)$$

E.3. Sample Calculation for Sensitivity Analysis

Sample calculations were done for Manufacture of food products and beverages for export share criterion industry sector (based on WSM-Entropy Method).

iv. The threshold value for each measure of performance of Manufacture of food products and beverages regarding export share criterion was determined by using Formula (3.2).

$$T_{i,j,k} = \frac{(P_i - P_k)}{\left|P_i - P_k + w_j\,(a_{kj} - a_{ij} + 1)\right|} \times \frac{100}{a_{ij}} \tag{3.2}$$

$$T_{2,2,3} = \frac{(0,0780-0,0666)}{|0,0780-0,0666+0.035\,(0.0345-0.0517+1)|} \times \frac{100}{0.0517}$$

$$T_{2,2,3} = 482$$