ISTANBUL TECHNICAL UNIVERSITY ★ ENERGY INSTITUTE

MODELS FOR ENERGY EFFICIENCY OBLIGATION SYSTEMS THROUGH DIFFERENT VIEWS

M.Sc. THESIS

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Energy Science and Technology Division

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Thesis Advisor: Prof. Dr. Gülgün KAYAKUTLU

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İSTANBUL TEKNİK ÜNİVERSİTESİ ★ ENERJİ ENSTİTÜSÜ

FARKLI BAKIŞ AÇILARI İLE ENERJİ VERİMLİLİĞİ YÜKÜMLÜLÜK SİSTEMİ MODELLERİ

YÜKSEK LİSANS TEZİ

Enerji Bilim ve Teknoloji Anabilim Dalı

Enerji Bilim ve Teknoloji Programı

Tez Danışmanı: Prof. Dr. Gülgün KAYAKUTLU

NİSAN 2019

Neslihan YILMAZ ÖZGÖZEN, a M.Sc. student of ITU Institute of Energy Science and Technology student ID 301131021, successfully defended the thesis/dissertation entitled "MODELS FOR ENERGY EFFICIENCY OBLIGATION SYSTEMS THROUGH DIFFERENT VIEWS", which she prepared after fulfilling the requirements specified in the associated legislations, before the jury whose signatures are below.

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Date of Submission : 09.04.2019
Date of Defense : 16.04.2019

To my family,

PREFACE

I would like to express my sincere thanks to Prof. Dr. Gülgün Kayakutlu my esteemed thesis advisor, for her guiding and major contributions in this process.

I also would like to thank my friends and family who have believed in and never refrain to support me and my husband Hikmet Özgözen who is always with me in this challenging process...

Hope to be worthy of all this...

April 2019 — Neslihan Yılmaz Özgözen

Endüstri Mühendisi

TABLE OF CONTENTS

Page

ABBREVIATIONS

CERT : Carbon Emission Reduction Target
CHP : Combined Heat and Power
DSO : Distribution System Operator
ECO : Energy Company Obligation
EEC : Energy Efficiency Commitment
EED : Energy Efficiency Directive
EEOS : Energy Efficiency Obligation Scheme
ESCO : Energy Service Company
EU : European Union
GDP : Gross Domestic Product
GME : Electricity Market Operator
LNG : Liquefied Natural Gas
LPG : Liquefied Petroleum Gas
NEEAP : National Energy Efficiency Action Plan
OECD : The Organisation for Economic Co-operation and Development
TOE : Tonnes of Oil Equivalent
TWC : Tradable White Certificate
WCS : White Certificate System
YEGM : General Directorate of Renewable Energy

LIST OF TABLES

Page

FIGURE LIST

Page

MODELS FOR ENERGY EFFICIENCY OBLIGATION SYSTEMS THROUGH DIFFERENT VIEWS

SUMMARY

Energy efficiency and energy saving gain rising importance while foreign dependency is increasing and environmental problems such as global warming become prevalent.

Energy Efficiency Obligation Scheme (EEOS) is among the fundamental tools to increase energy efficiency in the EU (European Union). Many EU countries have successfully implemented EEOS and further white certificate markets as a central tool for increasing energy efficiency. The obtained results show that significant amount of energy savings can be achieved through EEOS. Italy has seen particularly positive achievements with a white certificate market by avoiding consumption of 6.7 million TOE [1].

With increasing population and fast economic development energy consumption in Turkey has increased significantly and current policies need to be updated and additional measures need to be implemented.

Energy Efficiency Strategy Document records that Turkey aims to decrease the energy intensity by 20% until 2023 and accordingly new policies and strategies are being carried out in every sector to achieve this result. The implementation of National Energy Efficiency Action Plan (NEEAP) in terms of energy saving was a great step in Turkey. In particular, horizontal actions (Number 2 and 11) constitute a direct basis for this system. Although a lot of work has been accomplished for increasing energy efficiency, other policies such as market based approaches need to be adopted in order to reach 2023 targets.

In this document EEOS has been analyzed in detail. The structure of the system, and its local mechanism in different countries have been scrutinized in detail. There are different alternative ways of implementing the EEOS in Turkey. This thesis proposes two different views of implementing the mechanisms through the regulator’s view and the electricity distributors’ view, to whom the obligation is applied. The first one tries to maximize the total energy savings by applying the obligations and giving incentives, whereas the latter, minimizes the total cost of implementing energy efficiency projects and paying penalties. Both view are modeled using the mixed integer programming and the case study is run for the 21 local power distributors in Turkey. The proposed models have scientifically demonstrated that implementing the obligation bottom limit is more successful than the penalty application. Hence, when implementing the EEOS in Turkey the total saving estimate through the regulator’s view are expected to be higher.

All these studies are expected to shed light on the energy efficiency liability system to be implemented in Turkey in the future. For this purpose, it is thought that the inclusion of energy service companies in these models will have a positive effect on the success of the system. Therefore, it is anticipated that simulation can be performed with different parameters.

The uninterrupted, cost-effective and globally sustainable energy supply is at the heart of national energy policies all over the world. In line with this objective, the strategies, policies and models developed are of great importance because they are large-scale and long-lasting. Within the scope of this study, it has been concluded that energy resources and technologies should have the flexibility to localize and to resist unexpected changes. This requires investment in options that provide flexibility and the implementation of policies and models to eliminate scenarios that might hinder policy change. When acting with this awareness, it is important to take the possible costs that may arise into account.

On the other hand, the use of imported energy resources significantly affects the national economy and deepens the current account deficit. In this context, policies should be directed towards increasing domestic production and energy efficiency.

FARKLI BAKIŞ AÇILARI İLE ENERJİ VERİMLİLİĞİ YÜKÜMLÜLÜK SİSTEMİ MODELLERİ

ÖZET

Enerji verimliliği ve enerji tasarrufu konuları enerjide dışa bağımlılığın artması, küresel ısınma ve çevre sorunlarının ön plana çıkmasıyla önem kazanmaktadır. Bu kapsamda, dışa bağımlılığın azaltılması, çevrenin korunması, enerji maliyetlerinin ekonomiye olan yükünün azaltılması ve enerjide arz güvenliğinin sağlanması gerekliliği tüm dünyayı enerji verimliliğine yöneltmiş ve bu konudaki çalışmaları hızlandırmıştır.

Enerji verimliliği önlemleri enerji talebinde azalma ile birlikte sera gazı emisyonlarını azaltmanın da önemli bir aracı olarak görülmektedir. Özellikle, fosil yakıtların tüketiminin azaltılması iklim değişikliğine yönelik stratejilerin desteklenmesinde önemli role sahiptir. Bu da enerji verimliliğinin, enerji ve iklim politikaları ile yakından ilişkili olduğunun göstergesidir. Bu amaçla, uluslararası anlamda çeşitli enerji verimliliği politikaları belirlenmiştir.

2012 yılında yürürlüğe giren Avrupa Birliği Enerji Verimliliği Direktifi (EED), enerjinin verimli şekilde kullanılmasına yönelik çalışmalara yasal dayanak olarak kabul edilmektedir. Avrupa Birliği ülkeleri, enerji veya CO2 vergileri, enerji verimli teknolojilerin kullanımının artırılması için teşvikler, düzenlemeler veya gönüllü anlaşmalar gibi enerji tüketimini azaltacak alternatif politikalar uygulayabilmektedir.

Avrupa Birliği'nde enerji verimliliğini sağlamak için mevcut politikalara ilaveten tasarlanan temel politika araçları arasında, Enerji Verimliliği Yükümlülük Sistemi (EEOS) özellikle dikkat çekicidir. Enerji verimliliği politikasının önemli bir aracı olan EEOS şu anda bazı Avrupa ülkelerinde uygulanmaktadır. Her ülkede öncelik verilen sektörler, verimlilik projeleri ve ülkenin ulusal enerji endüstrisi yapısına göre farklılık göstermekle birlikte elde edilen sonuçlar, önemli oranlarda enerji tasarrufunun EEOS sayesinde elde edilebileceği göstermektedir.

Bazı EEOS’lerde, yükümlü katılımcıların onaylanmış enerji verimliliği önlemleri sertifikalandırılmaktadır. Bu sertifikalar Beyaz Sertifikalar olarak adlandırılmaktadır. Bu sistemde onaylanmış enerji tasarrufu hedefleri sertifika cinsinden belgelenmektedir. Yükümlü katılımcılar enerji tasarrufu hedeflerine ulaşmak için yaptıkları çalışmalarla beyaz sertifika kazanabilmekte, sistemdeki başka yükümlü katılımcılardan sertifika satın alabilmekte veya fazla sertifikalarını diğer yükümlü katılımcılara satabilmektedir.

Artan nüfus ve sanayileşme ile birlikte Türkiye’de enerji tüketimi önemli ölçüde artış göstermiş olup enerji verimliliğinin artırılmasına yönelik mevcut politikalara ek önlemler alınması amaçlanmıştır. Bu kapsamda, kanun ve mevzuatlar hazırlanmış,

enerji verimililiğinin arttırılmasına yönelik planlar uygulamaya konulmuştur. Bu bağlamda, 2007 yılında yürürlüğe giren Enerji Verimliliği Kanunu ile yeni bir dönüşüm süreci başlatılmıştır.

2012 yılında yayımlanan Enerji Verimliliği Strateji Belgesi ile de 2023 yılı enerji verimliliği hedefleri oluşturulmuş ve Ulusal Enerji Verimliliği Eylem Planı (NEEAP) hazırlanarak etkin bir biçimde uygulamaya geçirilmesi öngörülmüştür. Ayrıca, NEEAP içerisindeki yatay eylemler başlığı altındaki 2 ve 11 numaralı aksiyonlar enerji verimliliği yükümlülük sistemi ile doğrudan ilgili olduğundan bu çalışmaya temel oluşturan politikalardan biridir. Diğer yandan, üye devletler ile enerji verimliliği konusunda ortak bir çerçeve oluşturmaktadır. Bu kapsamda, EED uyumu açısından önemli bir adım olarak görülmektedir.

Enerji Verimliliği Strateji Belgesi'ne göre Türkiye 2023 yılına kadar enerji yoğunluğunu %20 oranında azaltmayı hedeflemekle beraber, bu hedefe ulaşabilmek amacıyla bütün sektörlerde enerjinin daha verimli kullanılmasını sağlamak için politika ve stratejiler oluşturmaktadır. Şu ana kadar enerji verimliliğinde önemli adımlar atılarak birçok çalışma gerçekleştirilmiş olsa da, 2023 yılı hedefine ulaşabilmek için piyasa tabanlı politika araçları gibi ilave farklı politikalar göz önünde bulundurulması gerektiği sonucuna varılmıştır.

Avrupa Birliği'nin 2012/27/EU Enerji Verimliliği Direktifinin 7. maddesinde Enerji Verimliliği Yükümlülükleri Sistemi (EEOS) tanımlanmıştır. Bu kapsamda, sistemin uygulandığı ülkelerde EEOS'nin enerji verimliliği hedeflerinin gerçekleştirilmesi için kurulacak en etkili mekanizmalardan biri olduğu görülmektedir. Bu sistemde belirlenen piyasa katılımcılarının enerji verimliliği çalışmaları yapma ve belirlenen tasarruf hedeflerine ulaşma zorunluluğu bulunmaktadır. Yükümlü katılımcılar, enerji verimliliği hedeflerine ulaşamadıkları takdirde ceza alabilmektedir. Belirlenen hedefin üzerinde tasarruf yapan yükümlü katılımcılar ise fazla tasarruflarını bir sonraki döneme aktarabilmektedir. Bazı sistemlerde ise katılımcılar arasında enerji tasarrufları transfer edilebilmektedir.

EEOS ile katılımcılar, hedeflerine nasıl ulaşacaklarını kendileri belirleyebilmekte olup alacakları enerji verimliliği aksiyonları ile ilgili fayda/maliyet optimizasyonu yapabilmektedirler. Yükümlü katılımcılar, yıllık enerji satışı, müşteri sayısı gibi belirlelen kriterlere göre tüm enerji türlerinin üreticisi, tedarikçisi, dağıtıcısı veya perakendecisi olabilmektedir. Yükümlü katılımcılar sistem yöneticilerine, enerji verimliliği eylemlerini rapor etmektedirler. Yapılan eylemlerin izleme, raporlama ve doğrulaması genellikle sistem yöneticisi tarafından gerçekleştirilmektedir. Sistem yöneticisi doğrudan eylemlerin denetimini yapabileceği gibi bağımsız denetçiler ile de çalışabilmektedir [2].

Bu çalışma kapsamında EEOS detaylı bir şekilde incelenmiştir. Sistemin yapısı, uygulanmakta olduğu ülkelerdeki işleyişi ayrıntılarıyla anlatılmıştır. EEOS tasarımları ülkeler arasında önemli farklılıklar göstermektedir. Bunun temel nedeni, her ülkenin rekabetçi enerji piyasası, politika ve hedeflerinin farklı olmasından kaynaklanmaktadır. Bu doğrultuda, Türkiye'de uygulanacak olan EEOS'nin, Türkiye'nin özellikleri dikkate alınarak mekanizma tasarımının dikkatlice değerlendirilmesi öngörülmüştür.

Bu tez, düzenleyici ve elektrik dağıtıcıları bakış açıları olmak üzere mekanizmaların uygulanmasına yönelik iki farklı yaklaşım ortaya koymaktadır. Birinci model, yükümlülüklerin uygulanması ve düzenleyici tarafından teşvik sağlanması ile enerji tasarrufunu en üst düzeye çıkarmayı amaçlamaktadır. İkinci modelin amacı ise, enerji verimliliği projelerinin uygulanması ve hedeflenen tasarrufun elde edilememesi durumunda cezaların ödenmesi ile ortaya çıkan toplam maliyeti en aza indirmektir.

Her iki bakış açısı için de karışık tamsayılı programlama kullanılarak modelleme yapılmıştır. Örnek olarak, Türkiye'deki 21 lokal elektrik dağıtım firması için çalışma yürütülmüştür. Kurulan modellerde elektrik dağıtım firmaları en fazla 5 farklı enerji tasarrufu projesi uygulayabilmektedir. Elektrik dağıtıcılarının tercih ettikleri projeler amaç fonksiyonuna göre farklılık göstermiştir. Birinci model, enerji verimliliğini arttırarak enerji talebini azaltmayı hedeflemektedir. Bu noktada, tercih edilen projelere ilişkin maliyetler, dolayısıyla yatırım maliyetleri oldukça etkilidir. İkinci model, proje maliyetleri ve hedeflenen enerji tasarrufu oranının sağlanamaması durumunda düzenleyicinin uygulayacağı ceza maliyetleri toplamını minimize etmeyi hedeflemektedir. Elektrik dağıtım firmaları proje uygulama maliyetleri ile hedef enerji tasarrufu miktarının sağlanamaması durumunda ortaya çıkacak maliyetleri göz önünde bulundurmalıdır. Tüm bu çalışmalar sonucunda, enerji verimliliğini arttıracak en etkili mekanizmanın bulunması amacıyla model çıktıları değerlendirilmiştir. Önerilen modeller, yükümlülük alt sınırını uygulamanın ceza başvurusundan daha başarılı olduğunu bilimsel olarak göstermiştir. Dolayısıyla, EEOS'i Türkiye'de uygularken, düzenleyici bakış açısı ile kurulan modelin sağlayacağı toplam tasarrufun daha yüksek olması beklenmektedir.

Tüm bu çalışmaların, ileride ülkemizde uygulanacak enerji verimliliği yükümlülük sistemine ışık tutması beklenmektedir. Bu amaçla, geniş kapsamlı kurulmuş olan bu modellerde enerji hizmet şirketlerinin sisteme dahil edilmesinin sistem başarısının sağlanmasında olumlu etki yaratabileceği düşünülmektedir. Dolayısıyla, farklı parametreler ile simulasyon gerçekleştirilebileceği öngörülmektedir.

Kesintisiz, düşük maliyetli ve küresel olarak sürdürülebilir enerji arzının güvence altına alınması, tüm dünyada ulusal enerji politikalarının merkezinde yer almaktadır. Bu hedef doğrultusunda, geliştirilen stratejiler, politikalar ve modeller, büyük ölçekli ve uzun ömürlü olması nedeniyle büyük önem arz etmektedir. Bu çalışma kapsamında, enerji kaynakları ve teknolojilerin yerlileştirilmesi ve beklenmedik değişikliklere karşı koyabilecek esnekliğe sahip olması gerektiği sonucuna varılmıştır. Bu da esneklik sağlayacak seçeneklere yatırım yapılması ve politika değişimine engel olabilecek senaryoların bertaraf edilmesini sağlayan politika ve modellerin uygulanmasını gerektirmektedir. Bu bilinç ile hareket edildiğinde ortaya çıkabilecek muhtemel maliyetlerin de dikkate alınması önem arz etmektedir.

Diğer yandan, ithal enerji kaynaklarının kullanılması, ülke ekonomisini önemli ölçüde etkilemekte olup cari açık sorununu derinleştirmektedir. Bu kapsamda, oluşturulan politikalar, yerli üretimin ve enerji verimliliğinin arttırılmasına yönelik olmalıdır. Ancak, diğer zengin enerji kaynaklarına sahip ülkeler ile karşılıklı anlaşmalar sağlanması ülke ekonomisinin üstündeki yükü azaltmak açısından uzun dönemli stratejiler arasında değerlendirilebilir. Böylelikle, ülkerin yarar sağlayacak kalıcı temeller oluşturması ve maliyet avantajı doğrultusunda farklı enerji kaynaklarını ikame edebilmesi sistem esnekliği kazandıracaktır.

Özetle, hem enerji güvenliği ve maliyet öncelikleri hem de iklim değişikliği konusundaki sorumluluk, Türkiye’nin enerji verimliliği konusunda daha sistematik politikalar uygulamasını gerektirecektir.

1. INTRODUCTION

Energy efficiency policies and strategies are in the global agenda as a tool for energy security, sustainability and contributor to economic improvement. Many countries are prioritizing efficient use of energy due to reasons such as global warming and climate change as well as economic constraints.

EU has determined solid targets for 2020, 2030 and 2050 in order to keep its energy saving and efficiency at desired levels. In addition to traditional policies many European countries are implementing white certificate systems or energy efficiency obligations in order to meet these targets [3].

Although White Certificate Systems (WCS) can be exercised in all sectors, it certifies obligations of electricity and natural gas producers and/or distributors regarding energy efficiency [1]. The participants of WCS are obliged to meet the pre-determined energy efficiency targets. The ones who cannot meet their required levels of efficiency become subject to penalties or they are obliged to buy white certificates corresponding to their unmet targets.

The energy consumption in Turkey is increasing faster than in developed countries because of reasons like increasing population and fast growth of service sector. Besides, Turkey is among the foreign dependent countries in terms of energy. The efficiency is targeted to be increased in all stages of energy from production to ultimate consumption for the sustainability of natural resources and energy security.

In this framework a new transformation has started with the Energy Efficiency Legislation which took effect in 2007. 2023 energy efficiency targets have been determined through the Energy Efficiency Strategy Document published in 2012 and thus Turkey aims to decrease its energy intensity by 20% until 2023. Also preparation of National Energy Efficiency Action Plan and its effective implementation has been projected.

Despite a lot of effort has been put forward to increase energy efficiency, the target of decreasing energy intensity continues to be a difficult task to accomplish. For that reason, we propose that Turkey needs to establish market based policies. National Energy Efficiency Action Plan (NEEAP), which came into force in 2017, the establishment of EEOS in Turkey is clearly mentioned [4].

In this document the possible implementation of the EEOS in Turkey which has been successful in Europe and the energy saving via the proposed model has been analyzed.

1.1 Purpose of the Thesis

This thesis is intended to contribute to construction of the Energy Efficiency Obligation Scheme (EEOS) implementations in Turkey by analyzing European experiences. Thereby we will propose alternative models to calculate the total savings achieved to realize the objectives stated in the National Energy Efficiency Action Plan (NEEAP) in Turkey.

1.2 Stages of the Study

Introduction to the study contains general information on energy efficiency. In the second part Energy Efficiency Policies in Europe and in Turkey are discussed. Then, EEOS, which is the main subject of the study, has been examined in detail. In the same section, Turkey's energy consumption and energy efficiency potential are examined in depth on a sectoral basis, certain proposals have been made regarding the measures to be taken for assessing the potential. In the third part, the methodology to be used in the model has been explained. In order to establish the structure of the EEOS which will be examined in the same section, mixed integer models related to applicability of EEOS in Turkey have been proposed and its outputs have been discussed. In the fourt session, the models were simulated using real and random data. In the last chapter, information about the results of the study is given and suggestions for future studies are presented.

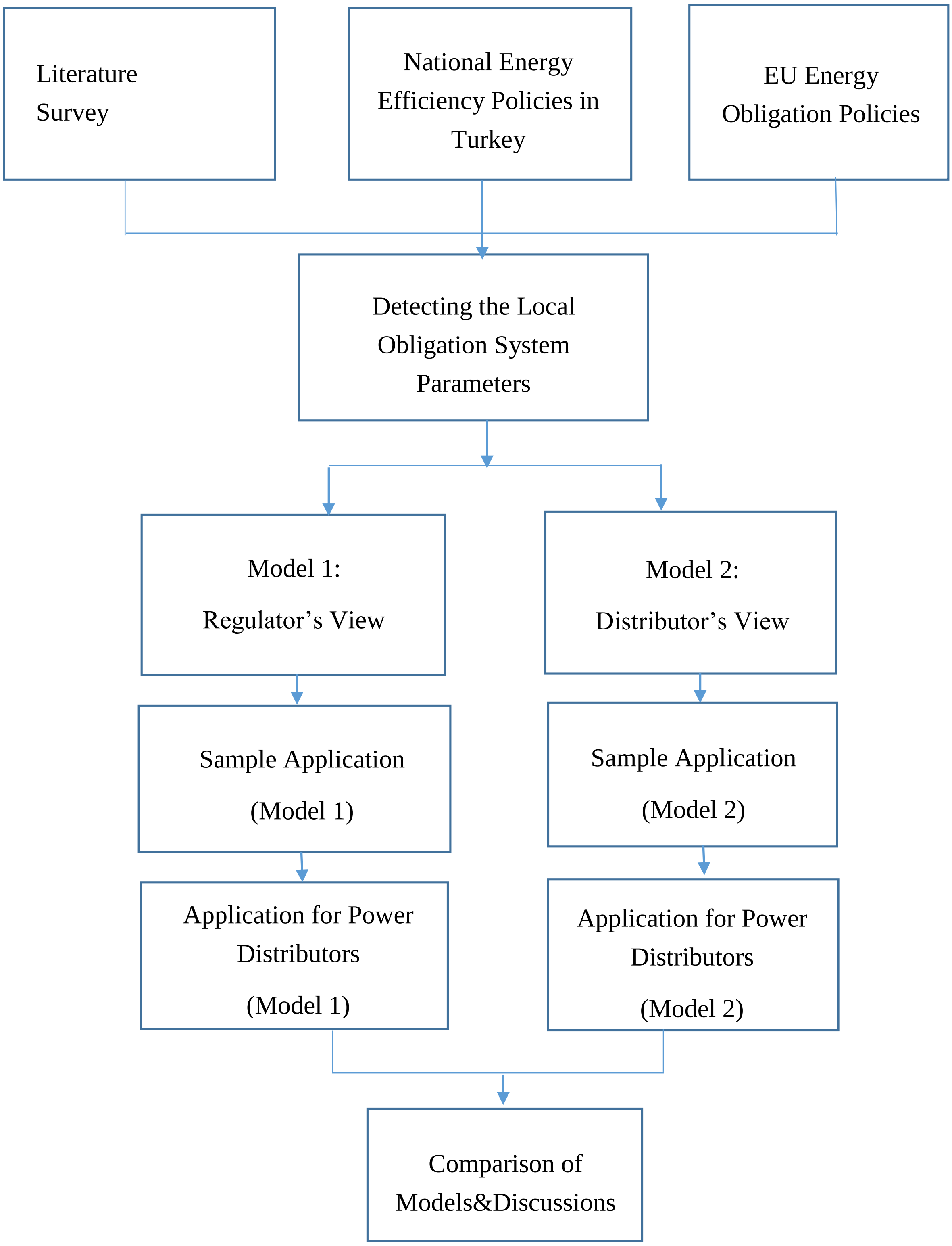

Figure 1.1 : Study Flow.

2. REVIEW OF ENERGY EFFICIENCY POLICIES

2.1 Energy Efficiency Concepts

Energy efficiency and its policies gain increasing importance globally. In this regard, energy efficiency, energy saving and energy intensity concepts need to be explained.

Increasing energy efficiency means producing the same output through a smaller input without decreasing living standards or production quality. Thus, it is possible to obtain the same amount of output with less consumption of resources in the production stage.

High efficiency means lower energy costs for enterprises. Energy efficiency which is considered as a new energy source increases economic competition resilience in sectors with high energy need [5].

Energy efficiency is a way of managing and decreasing energy consumption. Decreasing energy demand is considered to be the most economic and practical way of decreasing energy dependency and green-house gases according to McKinsey and Company [6]. Such a decrease in energy demand can be achieved through technological improvements in the infrastructure and changing consumption behaviours of consumers. Hence natural resources can be protected through such measures.

Energy efficiency is an important method of energy saving. On the other hand, there are cases where the total energy consumption has been increased due to rebound effect. Replacing old and inefficient equipments with more efficient and increasing number of heavily used equipments and therefore increasing the consumption is a good example. Hence, consumer behavour has a critical importance in energy saving. Consequently, in order to minimize energy consumption, policies need to implement the right combination of energy efficiency and energy saving methods [7].

Energy saving is the reduction in the consumption of the energy in every stage through the measures taken by producers, distributors and users for generating a certain amount of production or for providing a certain amount of service or for usage.

Sustainability and efficient use of energy resources necessitate grand endeavors at national and international level. Certain energy efficiency policies have been determined to satisfy this goal [8].

There are four main efficiency policy groups defined in economic theories, depending on the policy instruments, the country's own domestic market situation and the behavior of market participants. They are: *regulatory instruments*, *financial instruments*, *voluntary instruments* and *market-based instruments* [9].

Legislation and secondary legislation lay down legal grounds for energy efficiency studies and each of the standards that set the basis for energy efficiency studies by identifying the technical criteria are considered as *regulatory instruments.*

The basic logic of the use of *financial instruments* is leading the human behavior to increase energy efficiency by increasing the cost of financial reward or commodity. In this context, financial instruments are classified as financial incentives given directly or indirectly to the consumers and given to producers or retailers, tax and micro-credit models.

The financial incentives given directly to the consumers, are implemented to ensure that the energy consuming equipment is replaced with a more efficient one.

Financial incentives, which are indirectly given to the consumer, include a score based on the efficiency class of the product he / she receives instead of the direct financing support to the consumer in exchange for the purchase of energy efficient products.

Taxes on energy directly affect commodity prices. Hence, energy consumption amounts respond very quickly to tax changes. Therefore, taxes are used as an important tool in directing energy consumption and in promoting energy types with high energy efficiency [10].

Microcredits include subsidized (low or zero interest) loans that are determined on the basis of the savings from the cost of energy. These credits can be provided by the state or energy providers and energy management and consulting companies.

Another economic policy instrument is the financial incentives for producers to sell more productive products. Thanks to giving grant to companies that perform a certain amount of sales or by giving premium to the sales staff per product they sell, the process of transformation of productive products into the market can be accelerated.

Voluntary instruments are agreements signed with industrial enterprises to reduce their energy intensity. In Turkey, grant support is provided to industrial enterprises in order to encourage voluntary work.

Market-based energy policies can be summarized in four certificates. "Green Certificates" are to show how much of the generated electricity is from renewable energy sources. "Yellow Certificates" aim to promote the use of cogeneration. "Black Certificates" (Carbon Certificates) are designed to reduce greenhouse gas emissions. "White Certificates" have the direct objective to increase energy efficiency [11].

This study will detail the White certificate, its implementations and suggest alternative models based on the existing applications to measure the achievements.

2.2 European Union Energy Efficiency Policies

Establishing a competitive energy market, ensuring energy supply security and protecting the environment on the basis of sustainable development are the three main objectives of the EU's energy policies. The EU aims to strike a balance among these three objectives in policy-making. The EU legislation includes regulations on ensuring liberalization of the energy markets in order to create more competitive and energy-efficient markets, offer more options and cheaper prices to consumers. For a sustainable energy policy, fighting climate change is an important component of the EU energy policies [12].

In order to monitor energy-related objectives in a systematic way, the European Union has set goals for years 2020, 2030 and 2050. These objectives provide the EU with a consistent policy framework for greenhouse gas emissions, renewable energy sources and energy efficiency.

In March 2007, the EU leaders committed themselves to transform Europe in a highly energy-efficient, low carbon economy with 2020 Energy Strategy. They agreed on the priorities of the EU between 2010 and 2020 called “20-20-20” targets. This includes three basis targets for 2020:

- A 20% mitigation in EU greenhouse gas emissions from 1990 levels;
- Increasing the share of EU energy consumption produced from renewable resources to 20%;
- An enhancing in the EU’s energy efficiency to achieve a 20% savings on the EU primary energy consumption.

The targets were set and were activated through the Climate and Energy Package in 2009 [1].

The EU Member States agreed on the following objectives for 2030:

- Mitigate greenhouse gas emissions by 40% compared to 1990 levels;
- Guarantee that 27% of the energy consumed by the EU is derived from renewable sources;
- Increase energy efficiency by at least 27%;
- To achieve a 15% rate as an internal connection target among EU countries and to complete the internal energy market by promoting infrastructure projects.

By 2050, the EU aims to reduce greenhouse gases by 80% to 90% compared to 1990 [13].

2.2.1 European Union Energy Efficiency Directive (2012/27/EU)

The Energy Efficiency Directive (EED) of 2012/27/EU entered into force on December 4, 2012. The EED offers legally binding measures to increase efforts to use energy more efficiently at every stage of the energy chain. Legal obligations to establish energy saving schemes in Member States, public sector to lead by example, energy audits, energy services, efficient Combined Heat and Power (CHP), energy efficiency funds, metering, consumer behaviour and so on. EED is the main policy instrument at the EU level to reach the 20% energy saving goal in 2020.

One of the key articles of the EED is Article 7, introducing Energy Efficiency Obligation Scheme (EEOS). According to Article 7 of EED requires Member States to submit EEOS and to provide a certain quantity of final energy savings in end-use sectors. Under EEOS, energy companies should save 1.5% of energy sales annually through additional energy efficiency projects. This puts Member States under obligation to establish an EEOS or to adopt alternative policy measures in order to save a certain amount of energy among final consumers [14].

2.2.2 Energy Efficiency Obligation Scheme (EEOS)

EEOS is an energy efficiency policy tool. The system, which has a very flexible structure, and hence, shows great changes depending on the different national circumstances. It activates all participants, from the energy supplier to the distributor and energy service providers. It also provides standards and targets for energy efficiency operations.

EEOS is based on market-based mechanism by which the regulator sets targets and frees market actors to achieve the targets in the best possible way. A regulatory body is generally energy, economy, environment, climate, development etc. ministry. There is also a system administrator that is responsible for the operation of the system. System administrators are usually energy agencies of the countries or institutions and organizations connected to the ministries. Other institutions that provide technical support to the system may also be included.

The main actors of EEOS are the participants who are obliged to make energy efficiency improvement. The obliged participants may be the producer, supplier, distributor or retailer of all energy types (electricity, natural gas, petroleum products, heat) that exceed certain threshold values (annual energy sales, number of customers, etc.). In addition, some eligible participants who do not have any obligation can be included in the system at their request. Obligations are determined for certain periods. It usually covers 2, 3 or 5 years periods. All end-use sectors (housing, services, industry, transport) are suitable for implementing energy efficiency actions. Social needs and objectives can be included in EEOS.

Obliged participants can implement energy efficiency actions directly or establish partnerships with the third parties, such as energy service companies, local authorities or installation practitioners.

The cost of the actions of energy efficiency to be carried out mostly belongs to the obliged participants, but sometimes incentives are given by the government. Moreover, the obliged participants can put a share of the cost of energy efficiency analysis to the end-users’ energy bills.

The obliged participants report to the system administrators the energy efficiency actions they have made in accordance with the rules of the system. Reporting, monitoring and verification of actions are mostly performed by the system administrator. For monitoring, a registration system is usually used where each obliged participant has a separate account. This registration system also includes reports of the actions of obliged participants. The system administrator can control direct actions as well as third party verifiers such as independent auditors.

The obliged participants can be penalized if they do not achieve their energy efficiency targets. Participants who exceed their targets can transfer their excess savings to the next period. In some EEOS, energy savings can be transferred among the obliged participants.

In some EEOSs, validated energy efficiency actions of the obliged participants are certified. In other words, the issuance of certificate of project based savings and the probability to trade certificates, namely White Certificates are considered as an additional policy alternative that arises from the implementation of energy saving obligations. Participants can earn a White Certificate through the tasks to achieve their energy saving objectives; buy certificates from other obliged participants in the system; or sell the excess certificates they have obtained to the other obliged participants. Depending on the volume of trade, a virtual market platform can be established to ensure the bilateral or multilateral trade of certificates between the obliged participants. The installation of this platform can be provided by the system administrator externally. If the process volume is very low, the system administrator can do this in a less dynamic way. The responsible institution can register documents and accept periodic change requests.

As it is seen in the Figure 2.1.,14 of the 28 EU member states have established and are still implementing the EEOS according to the directive [15].

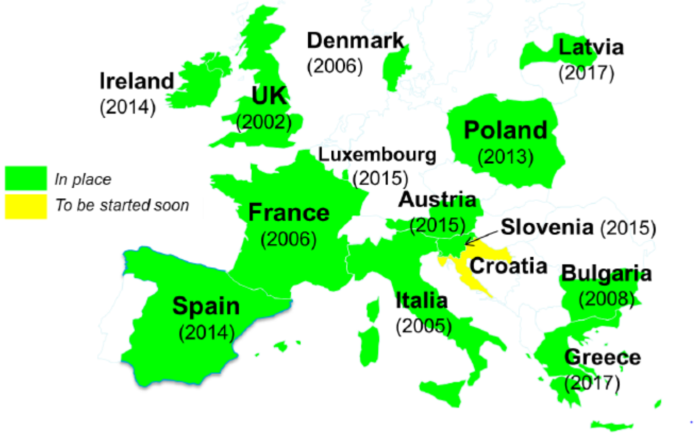

Figure 2.1 : Map of the 14 Countries Covered by the 2017 Snapshot.

2.3 Basic Principles of the White Certificate System

White certificate system has a set of design variables which have an important effect on the efficiency of the system. It is reviewed under six categories as stated below [16].

a. Sources of demand for white certificates,
b. Describing and assigning targets,
c. Describing and certifying energy efficiency activities,
d. Monitoring and verifying energy saving activities,
e. Compatibility procedures and enforcement; and
f. Market features and operation.

a. Sources of demand for white certificates

The selection of obliged party is primarily done between electricity/natural gas distributor or supplier. It should be specified that enforcing the obligation to certain actors does not mean that other energy carriers would be excluded from Tradable White Certificate (TWC) system. The obliged parties are permitted to execute energy efficiency actions in all possible end-user sectors. Distributors act as monopolies and are herewith under regulation. Within this context, it may be comparatively easy to impose extra obligations in distribution companies.

In other respects, the gathered costs related to the TWC liability from clients by distributors should be consistent with the instructions of distribution tariffs. Supply companies mostly have entrenched and direct connection with the clients. That ensures supply companies incentives to stimulate services related to energy efficiency. Moreover, electricity supply being a competitive field promises cost efficiency of energy efficiency actions. Competition is need to be considered when enforcing obligation on supply companies. TWC should not hinder competition by preferring small or large companies or preventing development of international retail markets.

b. Describing and assigning targets

The authorities should decide the scope of the white certificate targets. Furthermore, it should be determined what type of target to use suc as relative or absolute. In addition, it should be determined on whether the target will increase during ceritification period or the target is prevalent for the period. Without taking into account, the mechanism preferred to rise energy efficiency, queries which are not related to the TWC mechanism, need to be resolved.

The objective of the certificates is to record the energy savings realized in a clear way and then to establish an instrument to efficiently evaluate the energy efficiency potential where suitable. The scope of the efficiency improvements should be in comparison to the transaction costs related to growing the scope and quality of the TWC program. Building a market for TWCs can attract notice as a new energy service business and act as a source of revenue from activities initiated by such exterior support.

c. Describing and certifying energy efficiency activities

A crucial subject in TWC structures is the suitability of projects that create certificates. It also requires to be determined if validated measures should be rights-based system or application-based system or a combination of those. Application-based system is a straight-forward way to guarantee technology objectivity, which result in lower costs and efficient output of the TWC-mechanism. When affecting patricularly small clients, the trade-off between “mechanism accuracy” and transaction costs related to implementation processes become more essential. Minor savings per unit of measure is a sound claim on the side of rights-based system. Lessening management exertion might dominate efficiency achievements from technology objectivity. Application-based system appeals more simply innovative solutions, while rights-based system can be used as a instrument to support certain energy efficiency measures or industries according to selection. Firm obligations require to usual revise on baseline definitions in savings estimates regarding to standard measures as well as application based calculations.

d. Monitoring and verifying energy saving activities

The monitoring and verification of energy-saving activities within the context of White Certificate System is less simple than for example the monitoring of renewable energy production within the scope of a green certificate system. Due to the amount of energy 'saved' it is cannot be directly calculated, but must be projected by comparing measured energy consumption with a counterfactual baseline. Execution of standard lists enable monitoring and verifying load increase. Ex-ante definition of energy savings realized from a "standard action" needs calculating an action or technology specific baseline. Therefore, calculation based energy savings can deviate from actual energy savings accomplished.

e.Compatibility procedures and enforcement

Sufficient compatibility and execution mechanisms are required to guarantee the reliability of the TWC program and the efficient functioning of the certification industry. In addition to fulfilling their individual energy saving objectives, market actors must conform with the monitoring, verification and reporting procedures for measures and the regulations for the issuance of certificates. Compliance with the targets can be implemented with a fine which can be detailed as a financial penalty for each kWh energy that is not achieved.

f. Market features and operation

Permitting trade with the certificates makes more areas for market activity. The less dynamic ESCO business is, the more it is significant to encourage trading chances. If the TWC market is working well affairs decent, the problem of even liability is getting less important. Trading may also be allowed between liable participants or allowed to step in the market. The application of trading option is more useful and cost effective if the size of suitable industries in the system is large.

Further regularions can be necessary for the greatest potential performance of the white certificate market. The certification and the enrolment and follow-up of certificates are main significant market scheme characteristics. A practitioner is a market player who takes actions on a client's premises. The measures can be identified and funded by the responsible participant who accepts the certificates relative to the calculated or pre-defined savings. The lower the right to practice, the more space for different businesses to be merged and innovations to discover. In a system where TWCs are provided in regular lists, specific monitoring or permission ratings are required for quality control objectives. In the application-based system, it is less significant to check the practitioners in advance, whereas the verification process is more demanding and more costly [1].

Certification of energy savings and trading of white certificates are separate issues. Trading is not a prerequisite for certification: a certificate is a tool that guarantees that a particular project saves money. The certificate can be used as an book-keeping instrument to confirm in accordance with energy saving objectives or other liabilities. The threshold value of the certificate and the validity period of a certificate are crucial for the parties who can issue certificates.

Trading can be done in different ways:

- *Horizontal trading* is realized between liable participants. In addition to that, trading can take place on a spot market or on a bilateral basis (For example, certificate trade in Italy and France and obligation/project trade in the UK and Denmark);
- *Vertical trading* via liable participants buy certified savings/projects from third parties (For instance, in Italy, France, the UK and Denmark);
- *Temporary trading,* in particular banking/financial transactions, the transfer of some of the savings above the targets to the subsequent period (For example, in Italy, UK, France and Denmark) [17].

Although the basic principles are the same, the different roles of energy efficiency targets, sub-sectors prioritized in energy efficiency projects and competition in the national energy industry structure of the country are different, causing some changes in the design of national WCSs. It is shown that the participants of WCS in general in the Figure 2.2.

Regulatory body, is the key participant in determining energy efficiency targets and distributing the obligations to accomplish these targets. Also, it determines whether energy suppliers can achieve their energy efficiency targets and the penalty to be given in case they cannot reach. The regulatory body may also implement additional measures to ensure that energy efficiency objectives are met.

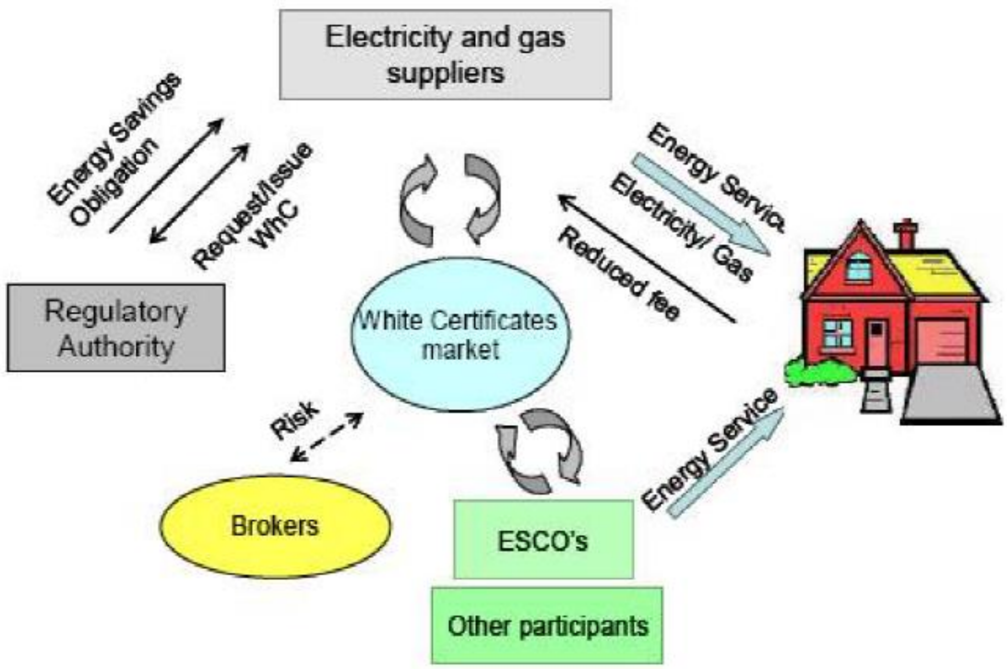

Figure 2.2 : Participants of a Generic White Certificate Market [18].

Electricity and natural gas supply and / or distribution companies may request and trade the white certificates from the regulatory body. Participants of this system must provide the amount of savings determined by the regulatory body within the specified period. By carrying out energy efficiency studies on their own customers, they provide the documentation of their work with white certificates. In case they cannot achieve their energy efficiency objectives, they will choose to participate in the market and obtain a white certificate, or they will pay the penalty amount set by the regulatory authority.

Energy service companies (ESCOs) are companies that are able to propose lowering the energy cost of the customer, usually taking the share of lower costs such as reimbursement of energy efficiency and financing for upgrades. There is no obligation determined by the regulatory authority.

The end users are system participants who decide on what measures to take in terms of energy efficiency and implement the saving measures themselves. End users typically reimburse for the actions to practitioners such as liable participants or

ESCOs. The cost of the saving measures will play a role in determining the market value of white certificates.

The other participants are those who do not have any energy efficiency liability for energy efficiency but can buy and sell these certificates. Participants, such as financial institutions and brokers, will contribute to the money flow of the system and facilitate the transactions and reduce the investment risk. The role of these participants and their adaptation to the system vary by country [18].

2.4. White Certificate System Implementations in the European Countries

White Certificate Schemes have been tried in many European countries and have been effective in achieving measurable energy savings. Italy, France, Denmark and the UK are the countries that have made the most progressive for white certificates in Europe and exceeded their energy-saving targets [1].

Italy and France are the only countries where the energy efficiency policies include energy savings obligations in combination with fully tradable white certificates. Trading can be realized in various types and official certification of savings is not essentially a prerequisite for trading. Hence, exclusive of trading of certified energy savings, trading of suitable measures is possible except formal certification, or trading of liabilities. For instance, in the UK certified energy savings can be traded between liable participants without formal certificates and obliged participants may buy certified savings.

Energy savings can include various commodities, such as primary energy, final energy, or CO2 substance of energy saved. Some countries have realized the liabilities in primary energy like Italy and, some have realized them in final energy such as Denmark and France. The target in the UK is stated in CO2 while beforehand it was stated in final energy.

It can be said that the benefits of a certification program are positively correlated with the count of industries and the extent of appropriate energy carriers. The wider the range of energy saving potential, the more white certificates can help in finding the most cost-effective methods for achieving energy savings. Voluntary energy efficiency deals play a critical role in the implementation of the EU energy efficiency targets.

So as to provide policy stability and the effective planning of the organization, annual targets are set within the multi-year period. For multi-year targets, a liability period takes 3 years on average. Whereas providing a constancy, this is a rather short term for adjusting the design.

14 out of 28 EU member states have established and are still implementing the Energy Efficiency Obligation System. However, some European countries such as Italy, France, Denmark and the UK have proceeded uttermost with progressing a market for white certificates [18].

An important instrument of energy policies is the WCS, which is currently being implemented in some European countries. WCS can be applied to all sectors, mainly certifying the energy efficiency efforts that electricity, natural gas producers and distributors are obliged to perform. These certifications can be obtained either by investment in new technologies or by means of reducing energy requirements.

Next section will be spared for the details of WCS.

2.4.1 Denmark

In Denmark, electricity, gas and heat distribution companies are expose to annual energy saving objectives in the period 2006-2013. The objectives are decided by the Minister of Energy & Climate Change. The system administrator is the Danish Energy Agency. Targets are arranged at industrial basis for electricity and gas and are successively allocated on the base of average market share of electricity or gas distribution in the 3 previous years. Article 7 in great measure fostered on Danish practise with an energy efficiency liability system, which implies that Article 7 is already applied in Denmark.

Denmark has had a well-established and successful WCS scheme aimed at climate, economic, and energy saving goals. The objectives are expressed in the final energy.

The total annual obligation was 2.95 PJ/year for 2006–2009 (0.7 % of total final consumption); 6.1 PJ/year for 2010–2012 (1.2 % of total final consumption); 10.7 PJ/year for 2013–2014 and 12.2 PJ/year for 2015–2020. Energy savings can be analysed as a detailed engineering calculation or based on standard amounts. On the contrary, other national programs, most savings in Denmark obtain from projects using specific engineering calculations [19].

2.4.2 France

France initiated a white certificate scheme in 2006, with a target of 54 TWh valid for the period 2006-2009. The first list of standardized actions was updated several times as of 2009. The third period of the energy saving certificates scheme, started on 1 January 2015 for a period of 3 years, with a requirement to 700 TWh cumac. This goal, which represents an increase of the saving obligation compared with the previous period, should enable France to fulfil its commitments to energy savings. Specifically, it will contribute to significantly fulfil Article 7 objective until 2020.

The establishment of the French White Certificates System, and its rules and objectives are determined by Ministry of Ecology, Sustainable Development and Ministry of the Economy, Finances and Industry.

The participants in the system are all supply companies of energy (electricity, natural gas, petroleum products and heat (district heating)). Participants gain white certificate for their energy savings. They also have the right to purchase certificate from the market. In France, certificates are expressed in terms of final energy and kWh accumulated over the lifespan and discounted (kWh cumac). Almost half of the certificates have been issued in response to savings in the residential sector [17].

2.4.3 Italy

In Italy, White Certificate System was launched in 2005. The obliged participants can fulfill their obligations by applying energy efficiency projects or by obtaining white certificates from voluntary participants on a dedicated platform managed by the GME (Italian Energy Market Manager) [20].

The Italian White Certificate system uses four evaluation approaches:

- In the deemed savings approach actual savings do not have to be calculated, as the method relies completely on ex-ante estimates. This methodology is appropriate for uniform projects in the household or public sector. Deemed savings projects have a least threshold of 20 TOE per year.
- Engineering approach is based upon estimate formulations with some parameters to be calculated.

- Third approach is based upon monitoring strategies where energy savings are calculated by comparison consumption before and after the project, taking into consideration altering circumstances. The minimum size is 40 TOE of annual savings. Monitoring plans are particularly appropriate for sector due to their large minimum project threshold of 60 TOE and the restricted accessibility of technical information sheets for deemed savings and simplistic monitoring projects in that industry.
- The so-called Major Projects are a comparatively latest method. These projects are aimed at extensive infrastructure actions, industrial developments or the transportation area. The minimum necessity is a project threshold of 35,000 TOE of savings per year and a lifespan of at least 20 years [21].

The Italian White Certificates System is obliged to save primary energy consumption for electricity and natural gas distribution operators with more than 50.000 clients who can realize energy efficiency projects. The threshold limit was originally 100.000 clients. The cause of applying the size/threshold is to restrain the managerial costs of the system.

In the Italian White Certificates System, participants who cannot collect a sufficient amount of white certificates until the stated date are offered two options.

- If the obliged participants do not provide at least 60% of their targets, they are penalized requested to compensate the energy efficiency target which is missing next year.
- If the obliged participants have reached 60% of their targets, they are not charged any penalty. They are required to compensate for the missing energy efficiency target.

Stede says that Italian white certificate system has certain issues at the beginning but it achieved to become a success story. The main instrument in Italy’s 2014 NEEAP is white certificate mechanism. The white certificate scheme mainly focuses on industrial sector. 94% of all energy savings are expected be achieved through industrial sector until 2020 [21].

Table 2.1 : Summary of White Certificate Schemes in Selected Countries.

Countries	Intoduction Date	Obliged Organizations	Obliged Party	Targets	Sector	Savings Distribution on Sectoral Basis
Denmark	2006	Electricity, natural gas, heat and oil distributors	Grid companies	Lifetime delivered energy, Pj	All sectors	%45 industry, %30 households, %20 service and %1 transportation
France	2006	Electricity, natural gas, heat and oil suppliers	Suppliers	Lifetime delivered energy, kWh	Households, service and transportation sectors	2006-2014: %70 households %14 commercial buildings, %8 industry, %3 transportaion %2 network, %2 agriculture 2015-2017: %49 households %18 commercial buidings, %20 industry, %5 network, %5 agriculture %2 transportation
UK	1994	Electricity and natural gas suppliers	Suppliers with ≥ 50.000 customers	Savings in CO2	Households	%100 Households
Italy	2005	Electiricity and natural gas distributors	Grid companies with ≥ 50.000 customers	Cumulative primary energy,toe	All sectors	%80 industry

Table 2.2 : Overall Objective of the European Systems for White Certificates.

Country	Policy Objectives
Denmark	Reducing energy consumption
France	More efficiency in consumption Mitigating carbon emissions Energy security
Italy	Mitigating carbon emissions Reducing dependence on energy imports Developing a market for energy efficient products and services
UK	Mitigating of carbon emissions Reducing energy costs for low incomes and retirees

2.4.4 UK

In 1994, the UK established supplier obligations (SO-supplier Obligations) and was the first country to grant liability to energy suppliers.

The obliged participants, the number of customers in the residential sector and energy sales are composed of 15 electricity and natural gas suppliers that exceed certain thresholds.

In the UK, Energy Efficiency Commitment (EEC) took place in two stages from 2002 to 2008 in 3-year periods. The EEC-1 program (2002-2005) required all gas and electricity supply companies with 15,000 or more residential customers to provide a certain amount of fuel standardized energy utilities. While the total savings target was 62 fuel standardized TWh, savings above the target were achieved and the total delivery savings reached 86.8 fuel standardized TWh. In EEC-2 (2005-2008), the threshold for energy saving obligation was raised to 50,000 customers and the target was fixed at 130 fuel standardized TWh. In 2005, more than a quarter of the target for the second period has already been reached, due to the acquisition of savings from EEC-1. In addition, although it seems to have roughly doubled the target between EEC-1 and EEC-2, it is difficult to establish a definite number due to changes in the way the savings are calculated. The realized energy savings in EEC-2 were 192 TWh. Carbon Emission Reduction Target (CERT), which is the third stage (2008-2012), has a target of 185 Mt CO_2 lifetime saving [22].

In addition to this policy on energy efficiency, the UK Government created a lawful mechanism permitting the liability to reimburse the costs of energy efficiency actions called Green Deal. The cost of energy efficiency studies carried out by households is reflected on electricity bills with the Green Deal policy in the UK. Thus, payments are collected through energy bills [23].

2.5 Energy Strategies in Turkey

2.5.1 Findings on energy issues

Energy policy is a complex structure consisting of different and intertwined policy processes. The challenge of thinking about energy policies lies in separating and prioritizing these many policy elements and key links between them. Therefore, it is important to establish a coherent framework that will enable the evaluation and prioritization of the strategic options arising primarily from political, economic, technical, security, environmental trends and structural breaks. In this respect, access to fossil fuels, utilization of new technologies in energy supply and demand, and nuclear energy management should be considered in detail. Supply security, cost and sustainability, which are the general objectives for all energy policies, can be addressed in the context of these three areas.

Therefore, four themes of global importance should be emphasized. The first is the diversification of energy resources, suppliers and infrastructures. Since the diversification in structural changes may be insufficient, it is important to plan the energy policies in the system dimension and also to plan the options that can be used when necessary. In order to be prepared for the sudden changes in the demand or supply structure, the need for redundant production and distribution capacity planned to provide flexibility and the consideration of structures for rapid scaling of new technologies are the indispensable elements of strategic planning. Thus, when sudden changes in the field of energy are encountered, it aims to strengthen the ability of a country to maneuver quickly in the energy supply/demand profile.

The second important factor is that the market structure in global oil and gas trade should be considered as the main variable that will affect the strategic plans. From the perspective of national supply security of energy-importing countries, integrated fuel markets on a global scale provide high security of supply, provided that access roads are secured. As a result, trade in energy-importing countries creates interdependencies that will compel national economic and security accounts. On the other hand, it provides disproportionate bargaining power to supplier countries.

Emphasizing the importance of oil and gas market structures in national energy security strategies reveals the link between the structure of world fossil fuel markets and the national security reflexes of fossil fuel importing countries. In the whole world, divided markets create a dynamic that can hamper or at least limit the wider global cooperation, which can trigger defensive national security reflexes and the emergence of bilateral / regional interdependencies.

In this context, the growing volume of shale gas reserves and the increased Liquefied Natural Gas (LNG) trade offer a transformative opportunity to integrate global gas markets and promise to alleviate a major energy security concern all over the world. Therefore, for countries that care about global energy security, it should be a general strategic priority to support this trend and avoid policy barriers to global natural gas trade.

Looking at the global security perspective, new oil reserves in the US and other geographies should not initiate a new debate on the regionalization of oil trade. US discourse on energy independence or regional self-sufficiency has already led to regional security debates elsewhere in the world, leading to defensive reflexes. As the global view of oil trade is a very important assurance of the global security system, the debate on regionalization of the oil market has the potential to cause negative consequences beyond the energy trade.

The third basic proposal is the rapid recovery of the world from its high carbon emission route. While evaluating low or zero carbon energy technologies, national policy interests are divided into two. One of the two different perspectives that shape this dilemma is that the country is mainly consumer in the new energy technologies, while the other is hoping to become one of the suppliers of these technologies in the world in the future. These two different perspectives lead to very different policy choices in promoting the use of new technologies across the country. The consumer country view is more timid about the use of these technologies. The high installation costs of new technologies and the expectation that these costs will decrease continuously in the future cause the postponement of these investments. The global supplier country perspective considers the widespread use of these technologies in the local market as an opportunity to develop national technology and brand, and to create a global market share. Therefore, it prefers to provide policy support to new energy technologies.

This policy dilemma emerged at the national level on a global scale the widespread use of new technologies undermines its efforts. Countries that do not expect to be a global supplier delay the use of these technologies. In order to prevent this and increase investments in and use of new technologies worldwide, more countries should become an economic stakeholder in the growth of the global market for these new technologies. In order to move away from the current global high carbon route, it is necessary to mobilize wider resources on new energy technologies in the world, to create higher demand and to awaken national interest and hope on policies. In order to achieve this, it is imperative to ensure that more technologies are expected to be the share of new countries in the globally expected income.

Finally, it is the evaluation of the issue of nuclear energy. Nuclear power plants have high installation costs and are therefore very long lasting for economic feasibility. The discontinuation or premature termination of nuclear power generation is a significant risk because of a global breakdown of safety or security in the production or use of nuclear power. Therefore, it is inconvenient to consider the national nuclear power accounts independent from the long-term global nuclear safety and security risks. Therefore, while assessing nuclear energy policies, the global risk environment must be considered and the importance of creating intellectual and institutional capacity as part of efforts to minimize global risk should be emphasized.

Thus, it is concluded that a knowledgeable, committed and responsible management approach should be the main element of any nuclear energy initiative in order to reduce the risks of safety and armament in the global nuclear power industry. In the coming decades, nuclear energy is likely to become more widespread all over the world. In a complex and dense area such as energy, maintaining long-term validity is a demanding process [24].

2.5.2 National energy policies

The biggest portion of the trade deficit arises because energy industry. This makes energy industry a strategic field. Increasing domestic production and decreasing imports is a critical element for solving this problem.

Turkey’s energy potential can be divided into two categories as fossil and renewable. Turkey is dependent to imports by 98% in natural gas and 93% in oil. In terms of fossil fuels, the country can meet its needs only in lignite reserves.

Every country determines its strategic energy policies based on its own conditions. Accordingly, Turkey’s policies are as follows:

- Streamlining the establishment of renewable energy production,
- Increasing the volume of coal mines and thermal power plants,
- Supporting and incentivizing coal investments
- Ensuring sustainability of natural gas through procurement from Middle East, Central Asia, Eastern Mediterranean and Africa,
- Reaching 100.000 MWs of installed capacity in line with 2023 energy vision,
- In the long run developing an energy portfolio composed of 30% from hydro electricity, 30% thermal, 30% renewable and 10% nuclear.

The renewable energy volume has been growing by 8.6% in the world in the last 5 years whereas in Turkey it has been 12.6%. This share is targeted to be increased through supporting the investments in renewable energy. Here the critical point is supporting renewable energy resources other than hydro electricity power plants.

Turkey’s solar electricity generation potential is about 500.000 MW. Nevertheless, by the end of 2017 the established capacity reached 642 MW and clearly this potential cannot be utilized sufficiently due to insufficient equipment, technology and legislative hurdles. On the other hand, the recent investments which increased the share of solar power generation are remarkable. Especially, the anti-damping tax against Chinese solar panels have facilitated domestic production.

8% of Turkey’s established power production capacity which is around 88.000 MW is constituted from wind power. In 2017, the amount of wind power capacity reached 6.516 MW. In 2023 the capacity is expected to reach 100.000 MW and in this total wind power is expected to constitute 20.000 MW whereas solar power will reach 5.000 MW.

The investments towards diversifying and expanding resources which also take geopolitic location into consideration are ongoing. In this regards, foundation of a wind turbine production facility with 65% domestic input as well as the transfer of idle public coal facilities to private industry in line with increasing domestic coal usage are on the agenda.

In global markets 10.8% of electricity production comes from nuclear energy. There are 454 nuclear power plants half of which being located in USA, France, China and Japan. Turkey entered in this sector with a big delay and 3 projects. One of these projects is Akkuyu Nuclear Power Plant and the other is Sinop Nuclear Power Plant. The location search for the third one is ongoing. 3 units of the Akkuyu Nuclear Power Plant which is made up of 4 in total will be effective as of 2023. And the following one is aimed to be running in the following year. Turkey, aiming to set up eight reactors in Akkuyu and Sinop aims to produce 5% of its electricity need from nuclear plants. Akkuyu Power Plant is the biggest investment in Turkey as a lump sum. Once the project is in effect with a 4.800 MW of total capacity it will produce around 35 billion kWh electricity.

As a result, the aim is to decrease Turkey's international dependence and weakness in energy production through domestication of resources and production technologies through mainly renewable and nuclear energy production investments [25].

2.5.3. Energy efficiency policies of Turkey

The primary and essential components of Turkey's national energy policy are increasing energy efficiency throughout each stage - from production to transfer to final consumption; prevention of redundant usage and energy losses; and decreasing energy intensity both at a sectoral level as well as at macro level.

The first step towards energy efficiency has been taken by the Energy Efficiency Legislation taking effect in 2007.

The main regulatios for energy efficiency in Turkey are:

- Energy Efficiency Law (2007)
- Energy Efficiency Strategy Document (2010-2023)
- National Climate Change Action Plan (2011-2023)
- 10th Development Plan (2014-2018)
- National Energy Efficiency Action Plan (2017-2023)

2.5.3.1 Energy Efficiency Legislation (2007)

The purpose of this Law is to increase the efficiency of energy resources and energy consumption for the efficient use of energy, to prevent waste, to lessen the burden of energy costs on the economy and to protect the environment. Energy Efficiency Legislation includes the procedures and rules to be implemented in the generation, transmission, distribution and consumption steps of energy, industrial enterprises, buildings, electric power generation facilities, transmission and distribution networks and energy efficiency in transportation, development of energy awareness throughout the society, utilization of renewable energy sources [26].

2.5.3.2 Energy Efficiency Strategy Document (2010-2023)

The Energy Efficiency Strategy Document has been prepared for the following purposes:

- to ensure the participation of public sector, private sector and non-governmental organizations and their cooperation,
- to identify a set of result-oriented policies and concrete targets,
- to determine the necessary actions to achieve these targets,
- to define the responsibilities of the organizations in the process.

The Energy Efficiency Strategy Paper consists of seven strategic purposes covering 2010-2023 and strategic targets and strategic actions related to these purposes. The first, second and fourth strategic purposes are related to EEOS.

SP1: To reduce energy intensity and energy losses in industry and services sector. The strategic objective of this purpose is to reduce the reduced energy intensities of each industry sub-sector by at least 15% until 2020. There are five strategic actions towards this goal. One of the most important of them is the necessity of energy studies to be carried out in industry, service and building sectors with sufficient size. In this way, energy saving potentials are determined and a basis for energy efficiency studies is established. The energy saving potentials determined by the studies conducted so far will be a guide for the obliged participants in the EEOS. It is also important to activate financial supports to be implemented in voluntary agreements and efficiency-enhancing projects.

SP2: Reducing energy demands and carbon emissions of buildings through high energy efficiency, and disseminating sustainable eco-friendly buildings that use renewable energy resources. For this purpose, in 2023, the objective of establishing thermal insulation and energy efficient heating systems that meet the current standards in the buildings (in the metropolitan areas, buildings with class group 2 or more and total area of use in all commercial and service buildings over 10.000 m2) has been determined within the scope of the Urban Transformation Law and Earthquake Code. In addition, the introduction of maximum emission and energy requirements in buildings, the promotion of thermal insulation, efficient heating and cooling systems are also among planned actions related to this purpose.

SP4: To increase efficiency in electricity generation, transmission and distribution; reduce energy losses and environmentally harmful emissions. One of the strategic objectives of this SP is to develop measures on demand side in order to reduce the energy intensity by at least 20% by 2023. In line with this objective, the action of performing step-by-step tariff, multi-term meter and smart grid applications according to the energy and power amount has been defined. This action is closely related to the potential obliged participants in the EEOS, which is an energy distributor.

Energy and power management systems have become mandatory in 2013 as variable speed drives in variable load motor systems with over 50 kW and variable speed drives in energy consuming plants over 10,000 TOE per year [27]. This action will be an example of the energy efficiency studies that can be done in the industrial sector by obliged participants in EEOS.

2.5.3.3 National Climate Change Action Plan (2011-2023)

Reducing energy intensity, reducing loss and leakage rates in electricity distribution is one of the objectives of the Climate Change Action Plan. In addition, increasing the energy efficiency in the industrial and building sectors is among the objectives of this action plan [12]. The energy efficiency studies that will be carried out by the obliged participants in the EEOS will be supportive to achieve these objectives.

2.5.3.4 Tenth Development Plan (2014-2018)

The Tenth Development Plan also supports the reduction of energy intensity and savings.

Furthermore, following measures are included within the scope of the Energy Efficiency Improvement Program in the Tenth Development Plan; reducing the primary energy intensity, replacing the AC electric motors used in the industry with the higher efficiency ones, converting the external building envelope and heating systems surrounding the building in the old buildings with low or insufficient insulation to a thermally insulationed quality to meet the current standards; there are plans to take encouraging measures to spread micro cogeneration practices [28]. Hence establishment of EEOS in Turkey will support to the realization of these goals.

2.5.3.5 National Energy Efficiency Action Plan (2017-2023)

The National Energy Efficiency Action Plan (NEEAP) is a guide in introducing new policies and programs to achieve the energy saving targets of a Member State's. The National Energy Efficiency Action Plan (NEEAP) have been introduced as a way to show how a Member State has introduced new policies and programs to achieve energy saving target. NEEAP is based on the Energy Efficiency Law, the National Climate Change Strategy Document, the Energy Efficiency Strategy Paper, the Tenth Development Plan and the 2015-2019 Strategic Plan. Furthermore, within the scope of the EU Directive 2012/27/EU, member states are obliged to prepare national energy efficiency action plans, which provide a common structural framework for energy efficiency and methods for implementation. To put the NEEAP into practice is an important step for Turkey in terms of compliance with the Directive. During 2017-2023 period, Turkey has targeted the cumulative reduction of primary energy consumption to 23.9 MTOE with NEEAP [4]. 55 actions are defined under 6 headings in NEEAP.

Horizontal actions numbered 2 and 11 under the heading of horizontal topics in NEEAP are directly relevant to the submission of Energy Efficiency Obligation Schemes (EEOS) system.

H2- Development of National Energy Efficiency Financing Mechanism; The aim of the action will be to require energy distribution (electricity, natural gas) and/or supply companies under energy efficiency obligation, and the parties to perform energy efficiency practices. If they lack the capacity to meet their obligations, they will contribute to the national energy efficiency financing mechanism by providing resources to their targets.

H11- Energy Efficiency for Energy Distribution or Retail Companies Obligation Program; The aim of the action is to give the national energy efficiency target as an obligation to the relevant energy companies in accordance with their market shares and to try to achieve this target by developing various projects for the end users or increasing the energy efficiency of their own activities.

In Turkey the establishment of EEOS will also be supported to achieve the objectives of the actions described under the headings in the building & services and industry & technology NEEAP.

B5- Rehabilitation of existing buildings and improvement of energy efficiency; the aim of the action is to raise awareness among end users to support directly or indirectly and to impose obligations in order to increase energy efficiency in areas such as high efficiency windows, lighting, white goods, heat pump, boiler and elevator motor usage in the building sector with thermal insulation.

I1 - Dissemination of Cogeneration Systems in Large Industrial Plants Using Heat;

The aim of the measure is to encourage the implementation of cogeneration systems by introducing the obligation of feasibility / study for the application of cogeneration systems to the industrial enterprises which will be newly established or will be undergoing a major rehabilitation with a thermal power requirement of more than 20 MW and thus to minimize the transmission and distribution losses by the use of on-site production technologies.

I3-Increasing Efficiency in Industrial Sector; The aim of the action is to reduce energy intensities in each industry sub-sector by at least 10% with sectoral cooperation.

2.6. Energy Consumption of Turkey

In recent years, along with population growth and economic development trends in Turkey, the total energy consumption has increased step by step. The implementation of policies and strategies to use our natural resources limited to meet the rapidly increasing energy demand of our country, to expand energy generation with new technologies, to increase the efficiency of current technologies and to evaluate alternative energy sources is becoming very important. Thus, it is necessary to clarify some concepts related to energy consumption.

Energy intensity mentioned earlier, is the ratio of energy consumption (TOE) to a financial indicator Gross Domestic Product (GDP). The intensity calculated as a result of the ratio of primary energy consumption to GDP is the primary energy intensity, and the intensity calculated as a result of the final energy consumption to GDP ratio is called the final energy intensity. Low energy intensity is an indication of efficient use of energy. A reduction in energy intensity means that the desired economic output can be accessed with less energy input [29].

The consumption of energy sources that can be consumed directly without any energy conversion such as coal, oil and natural gas is the primary energy consumption. Energy types such as electric, fuel oil and diesel which are converted into usable forms from primary sources, is secondary energy. Final energy is the utilizable secondary energy which is used by the end-user. For example heat (hot water) for a radiator or electricity from the plug at home is the secondary energy. Consequently, final energy consumption includes all energy supplied to the end-user [30].

Primary energy consumption of Turkey had an increase almost 71.5% between the years 2000 to 2016. In the primary energy consumption of Turkey, coal, oil and natural gas resources has come to the fore. The total share of these three resources in total primary energy consumption is 87.3% for 2016. The share of coal and oil in total consumption decreased in 2016 compared to 2000, and this decrease was replaced by natural gas. While the share of natural gas in total primary energy consumption was 15.7% in 2000, this ratio increased to 28.1% in 2016. Although renewable energy sources (solar, wind, geothermal heat, biofuel) do not have a large share in total supply, they increased by 14.4% on average in the period of 2000-2016 and realized the fastest increase in source basis.

When Turkey's total final energy consumption is analyzed in terms of resources, petroleum, coal, natural gas and electricity resources are prominent. The share of these four sources in total final energy consumption was 85% in 2000, which is increased to 94% in 2016. The share of natural gas, which was 7% in 2000, increased to 21% in 2016 and the share of electricity consumption increased from 14% to 19%. Although oil and coal consumption increased, their share in total final energy consumption decreased.

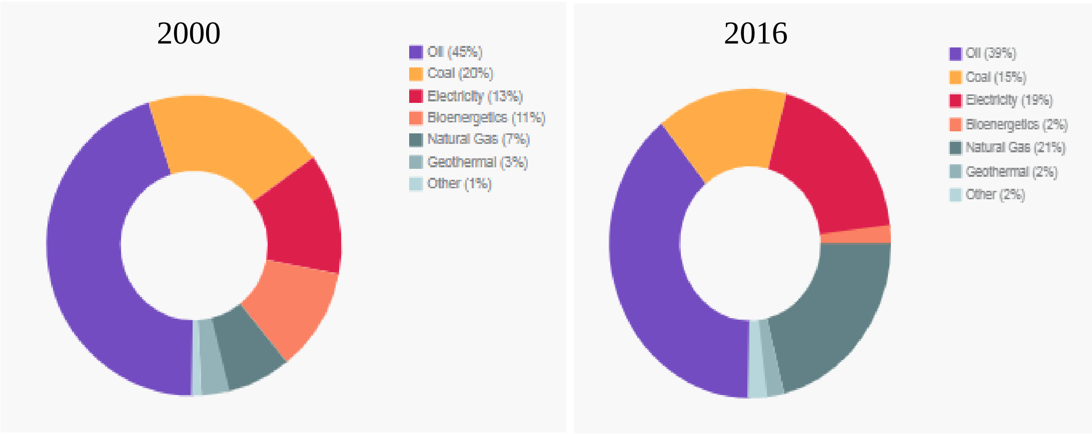

Figure 2.3 : Distribution of Total Final Energy Consumption by Source.

In 2016, the energy consumed in the residential sector increased by 36.8% compared to 2000 and reached 19.7 MTOE. In the period of 2000-2016, the highest increase in consumption was natural gas. The share of natural gas in total energy consumption in residential buildings increased from 13.2% in 2000 to 48.8% in 2016. In 2016, electricity was the second most consumed fuel in houses after natural gas with a share of 22.4% in total consumption. In this respect, natural gas and electricity resources are extremely important and 71.2% of the total energy consumed in the houses is composed of these two resources.

When the energy consumed by the household is examined according to the usage areas, it becomes prevalent that the energy consumed for heating has a significant share. In 2000, the energy used for space heating corresponded to 68.7% of the total energy consumed in the houses and in 2016 it decreased to 59.9%. The main reasons for this are the transition from low-efficiency coal-fired stoves to more efficient gas heating systems and electrical appliances and the introduction of thermal insulation regulations and the widespread use of insulation in buildings. Although the share of the total energy consumed in houses has decreased, space heating still has the largest share in energy consumption. In 2000, the energy consumption was the highest in share after the space heating, electrical appliances and lighting, cooking and water heating, while the share of water heating increased with the increase in natural gas consumption. In 2016, the usage areas were respectively space heating, electrical appliances & lighting, water heating and cooking.

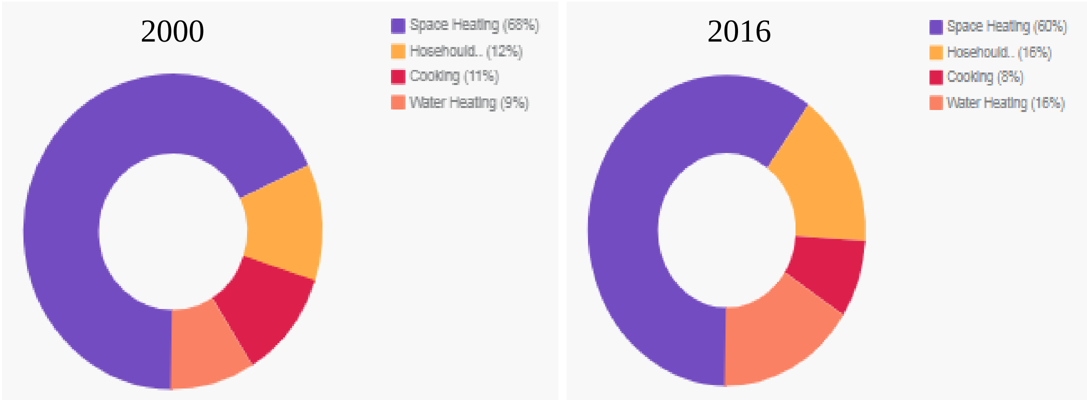

Figure 2.4 : The Share of Final Energy Consumption in Residential Areas.

While the energy consumed in the transportation sector in 2000 was 12 MTOE, this value increased by 120.5% in 2016 and reached 26.5 MTOE. Highway transportation is the type of transportation where energy consumption is the most intensive. In 2016, 93.9% of the total energy consumed in the transportation sector was realized by highway transport. In 2000, this rate was 87.5%. The other transportations were respectively air, railway and maritime.

In 2016, the energy consumed in the industrial sector increased by 47.9% compared to 2000 and reached 32.8 MTOE. The average annual rate of increase in this period was 2.5%. In the period 2000-2007, although the energy consumed in industry has increased by an average of 4.7% annually, the energy consumption of the industrial sector has decreased with the impact of the global economic crisis in 2008 and 2009. In the following years, the amount of energy consumed in industry exceeded the consumption value of the pre-crisis period with the sector surviving the effects of the crisis.

When the energy consumed in the industrial sector is examined on fuel basis, the coal resource was in the first place with 9.88 MTOE consumption in 2000, and in 2016, electricity source was placed first with 9,17 MTOE consumption. Electricity consumption is followed by coal, natural gas, petroleum products and heat sources.

When the energy consumed in the manufacturing industry in the period of 2000-2016 is taken into consideration in terms of sub-sectors, it is seen that there is an increasing trend in the energy consumption of all sub-sectors. The sub-sectors where energy consumption is the highest are manufacturing of basic metals and non-metallic minerals. In terms of energy consumption, these two sub-sectors are followed by the chemical, textile and food sectors.

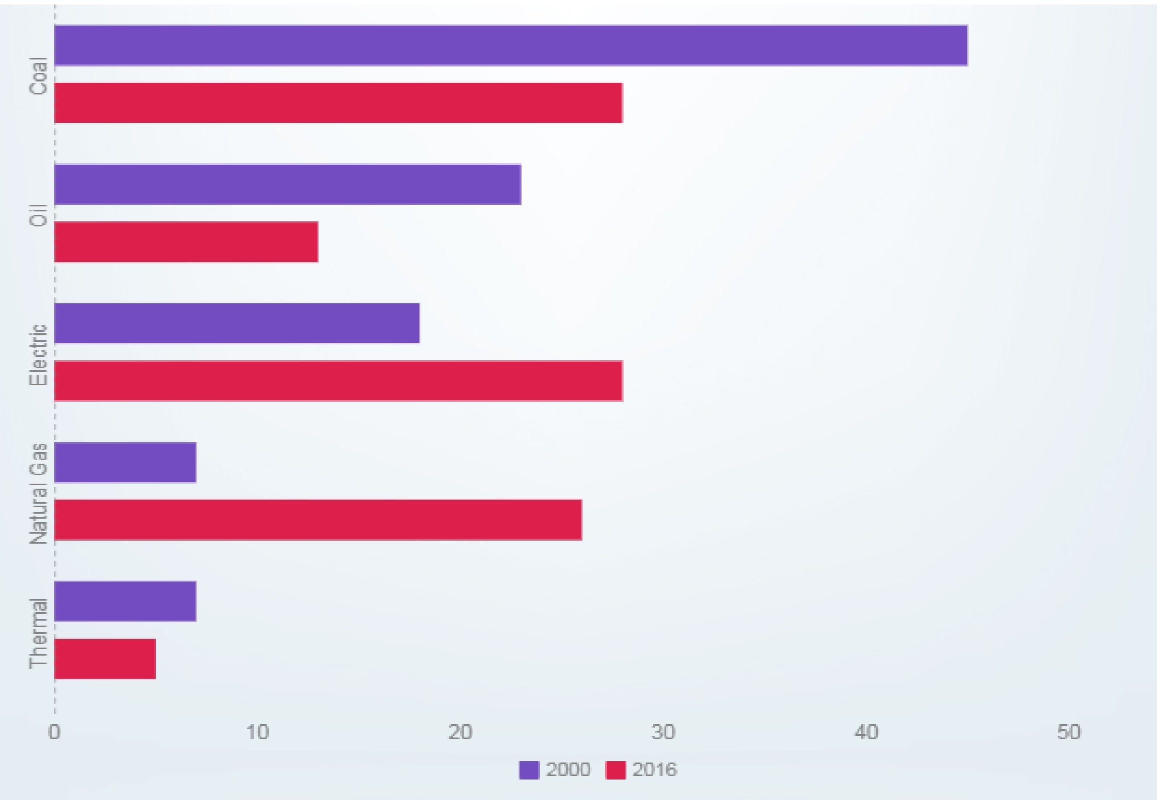

Figure 2.5 : Distribution of Energy Consumption in Industry (%).

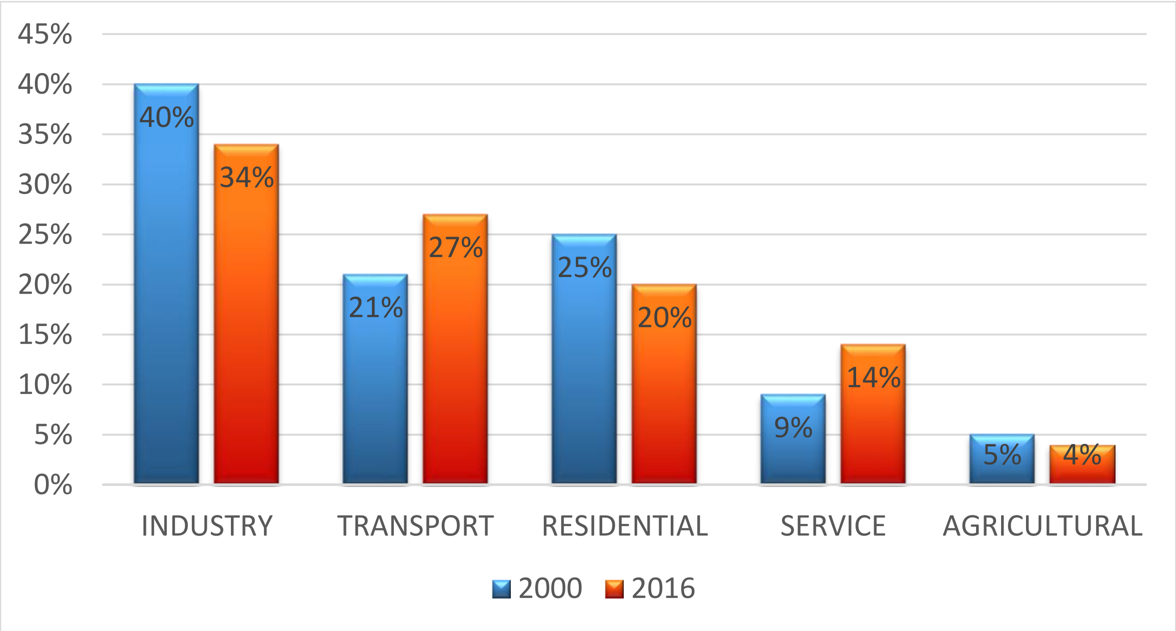

Figure 2.6 : Final Energy Consumption Rates by Sectors in Turkey.

2.7. Evaluation of Energy Efficiency Potential of Turkey

On the other hand, primary energy intensity of Turkey, which is an indicator of energy efficiency, was 0.12 TOE/1.000 2010 $ in 2016. In the primary energy intensity, the world average is 0.18 TOE/1.000 2010 $ and the average of OECD and EU-28 countries is 0.11 and 0.09 TOE/1.000 2010 $, respectively. Being very close to the average of OECD countries the energy intensity of Turkey remains high even if compared with the average of the EU countries [31].

In this framework, with the development of energy efficiency at all stages from energy production to final consumption the reduction in energy consumption is one of the priorities and important components of our national energy policy.

Energy consumption data given in the previous section will provide the basis for further studies by shedding light on the selection of appropriate policies.

In particular, the industrial sector has become the focus of energy efficiency enhancements due to high energy consumption. According to the General Directorate of Renewable Energy (YEGM), energy efficiency studies in the industrial sector show that is possible to realize half of the potential projects without any investment need. Energy efficiency studies that can be done with some simple measures can pay for their own costs in a short time with small investments. Examples of such studies are repair of leaks (water, gas, fuel, pressurized water, steam, condensate leaks, etc.), ensuring optimum combustion efficiency in furnaces, insulation in pipelines and equipment, repair and maintenance of steam traps, periodical cleaning of fittings. On the other hand, examples of projects with a repayment period of the investment cost is between 2 and 5 years are: installation of lighting automation, installation of compensation system, replacement of inefficient electric motors with efficient electric motors and use of variable speed drives in pump, compressor and fan systems etc. As examples for projects with a repayment period of more than five years, such as the establishment of cogeneration or trigeneration systems, which is also considered within the scope of energy efficiency studies [32].

As mentioned in the previous section, energy consumption of the households is mainly responding to the heating needs.

In Turkey, after 2000, the properties of materials used in the construction of buildings (e.g. TS 825 Thermal Insulation of Buildings Rules) has been redefined and has contributed largely to the decline in energy consumption in buildings. Also, The Regulation of Energy Performance of Buildings issued in 2008 contributed significantly to this improvement.

Apart from the insulation of buildings, the use of energy-saving window systems such as double-glazed windows, the expansion of the natural gas network and the central heating system will result in a considerable energy saving potential.

Another important measure to increase energy efficiency in buildings is the replacement of inefficient lamps in the public and service sectors, and the use of motion and photo sensors to save energy. In addition, by introducing different incentive systems, significant energy savings can be achieved by replacing the inefficient household appliances used in households with efficient ones [33].

Freight and passenger transportation is mainly carried out by road. Shifting of freight transport to maritime and railway, passenger transport to rail systems will provide significant energy savings. Referring to Turkey's transport statistics, the great importance of changing transport modes is apparent. A wide range of energy saving potentials can be assessed through the deployment of a smart traffic management system, public transport, car sharing and motorized transport, such as bicycle integrated transport planning.

3. METHODOLOGY AND MODELLING

3.1 Methodology

In many real life optimization problems the decision variables are expected to have integer values. In the optimization terminology, in case this is the only deviation from linear programming, apart from being discrete decisions, the problem is defined as an *integer programming* problem. In order for an integer programming problem to be defined correctly all or some of its decision variables need to be constrained to assume nonnegative integer values. This type of problem is of particular importance in business and industry, where, the fractional solutions are unrealistic because the units are not divisible. For example, it is absurd to speak of 2.3 men working on a project or 8.7 machines in a workshop. However in a linear programming problem, decision variables are not constrained to integer values, they can assume any real value.

Mixed integer programming deals with optimization techniques in which an objective function is optimized subject to both equality and inequality constraints, and where two types of variables can be specified: continuous variables which can take any real value within given bounds, and binary variables which can take only 0-1values. The unique feature is the capability of handling the latter type of variables which can be associated to discrete decisions in application problems.

In this study, *mixed integer programming* has been used. In binary decisions, each variable can only take a value of 0 or 1. That can be used to model yes/no decisions, such as whether to select or reject of an option or in this case whether to implement a specific project [32]. The decision to select the projects to be invested are to be binary (invest or not) but the monetary values of costs, incentives etc. can be continuous and the savings are the improvements in percentages which can also be continuous. That is why the Mixed Integer Models were required.

This study focuses on achieving maximum energy saving amount during the distribution stage of energy. It is possible to set up different models to maximize the amount of energy saving under different circumstances. Hence, two models with different objective functions using mixed integer optimization were formulated and they will be explained. We have developed a mixed integer optimization model where different types of projects are considered. The use of integer variables greatly expands the scope of useful optimization problems that one can define and solve.

3.2 Problem Statement

The Energy Efficiency Obligation System (EEOS) is accepted to be important to increase the energy efficiency in Turkey. This system is thought to have a wide range of applications particularly in electricity distribution in Turkey. To demonstrate this, a theoretical model based on real and random data was created. The amounts of energy distributed by each of 21 distributors in Turkey is based on the real data of the last three years, namely 2016, 2017 and 2018. On the otherhand, the model assumes five different types of energy efficiency projects with different cost and yields can be implemented. These values have been generated randomly within a certain range to simulate real life scenarios. In this study, a mixed integer model based on two separate alternative views. The first is focused on maximizing energy savings by conducting certain projects with some incentives and an obligation; and the second minimizes the total cost of selected projects to achieve the obligated level of saving and the penalties when obligation is not fullfilled. Thus, the first one represents the Regulator's objectives, whereas the second one simulates the obligator's objectives.

It is well known that there is still a very large room for a variety of efficiency projects in Turkey. If only 21 power distributors have implemented some of these projects with differing costs and different rate of savings, there will be a considerable amount of saving. These projects may consist of various initiatives to improve the distributor's energy saving rate. For example, a project may be designed to reduce loss and leakage rates in electricity generation, transmission and distribution, or to renew machinery and equipment to avoid operational flows. The decision variables in each model indicate the necessity of implementing a certain project for a specific distributor. Therefore, the projects may or may not be implemented by one distributor, hence represented by binary decision variables. The output “1” means the project will be carried out and “0” means it will be suspended.

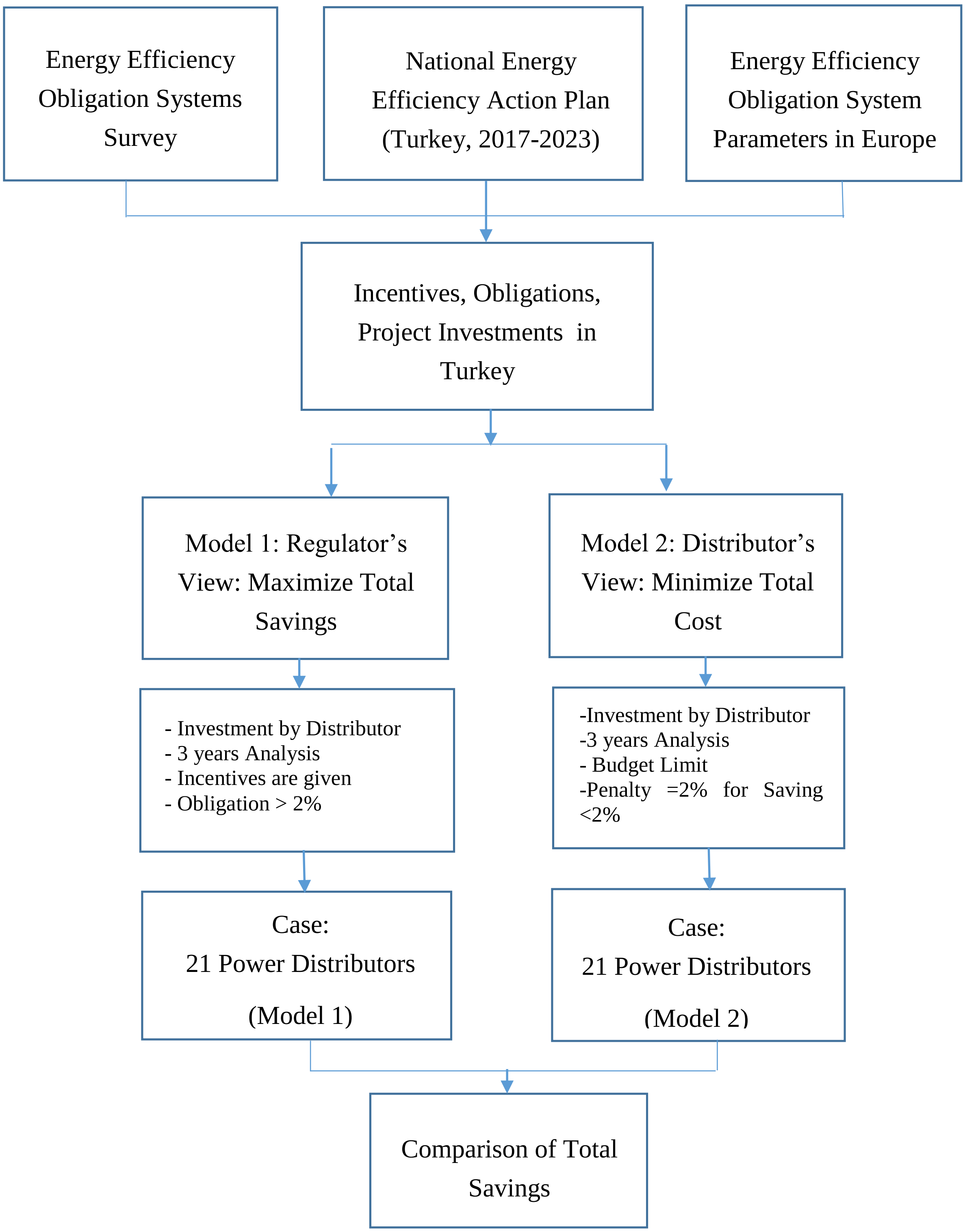

Figure 3.1 : Study Flow.

It is assumed that each distributor is obliged to allocate a certain budget in order to carry out a certain set of projects. That means, we are trying to select the projects which will maximize the total energy savings in the first model.

Whereas, we are trying to implement the projects that in total satisfy the obligations with minimum total cost in the second model.

Our results, can be used as a reference to develop a white certificate system designed for electricity distributors and is expected to inspire future initiatives.

3.3 Model 1 Maximize Total Amount of Energy Saved

Energy efficiency can be realized by the distribution companies implementing a variety of projects. Distributors aim to maximize energy savings through decreasing the demand.

3.3.1 Assumptions

- Distributors have to allocate certain amount of funds (budgets) for energy saving projects annually.
- Efficiency projects can have costs in the range of €100,000-€1,000,000.
- Government provides certain amount of incentives to each distributor as a contribution for funds. The amount is similar for all the distributors.
- Power unit price is determined by the market and taken as an annual average standard for the whole year applied similarly for all distributors.
- Each distributor invests in maximum of 5 projects in 3 years, the saving of which is calculated as the decrease in demand for the distributor in one year.

3.3.2 Variables and parameters

$X_{i,j}$ is the decision variable that will determine if distributor i invests in saving project j. If project j is not invested by distributor i then the value of $X_{i,j}$ will be found as 0 and as 1 otherwise. $D_{i,t-1}$ refers to energy demand of distributor i before applying energy saving projects. Expected energy demand of distributor i after the energy saving projects is shown with $D_{i,t}$.

$Y_{i,j}$,K_i , p , $c_{i,j}$, σ and η can be defined as parameters of Model 1.

Table 3.1 : Variables and Parameters of Model 1.

Variables and Parameters	
i	: Identifying number for each electricity distributor (1, 2, ..., 21)
j	: Identifying number for each project (1,2, ...,n)
t	: Time period (1, 2,...,T). "t-1" denotes before implementation of saving projects and "t" denotes after their implementation.
$X_{i,j}$	: Binary variable that shows whether project j was executed by distributor i
$Y_{i,j}$	: Estimated energy saving amount provided by project j executed by distributor i
S_i	: Energy saving percentage of distributor i
$D_{i,t}$	: Annual energy demand of distributor i in period t
K_i	: Energy capacity of distributor i
p	: Selling price of energy
I_i	: Investment amount by distributor i
F_i	: Total funds allocated to saving projects by distributor i
N_i	: Total incentives given to a distributor for projects by government
$c_{i,j}$	: Cost of project j executed by distributor i
σ	: Rate of income to be invested to energy saving projects
η	: Rate of incentive given to a distributor for projects by government

3.3.3 Objective Function

The model aims to decrease energy demand by increasing energy efficiency. The objective function's goal is to reach the maximum energy saving. In this model, the difference between energy demand before and after energy conservation projects is defined as the total energy saving.

If the result of this formula is a positive value, energy saving is successful. In this context, first model's objective functions becomes a maximizing problem because S_i gives the amount of saving per distributor after implementing the projects.

$$MaxZ = \sum_{i} S_i \tag{3.1}$$

3.3.4 Constraints

The main decision variable of the model is $X_{i,j}$ and all variables affecting its value will be reviewed here. Some of them are included in the model as constraints and some are defined with their mathematical formula. First definition, S_i , is the main component of the objective function and is defined as the rate of decrease on energy demand after energy conservation projects. In this model, the difference between energy demand before and after implementation of the energy conservation projects shows the total annual energy saving ratio.

$$S_i = \frac{(D_{i,t-1}) - (D_{i,t})}{(D_{i,t-1})} \quad \forall i \tag{3.2}$$

The government obliges a portion of the company's revenue to be funded into savings projects. This amount is defined as a parameter, namely σ. The following equation was established to ensure this requirement.

$$F_i = \sigma \sum_{t} (p_t . D_{i,t}) \quad \forall i \tag{3.3}$$

When the investment capacity is determined for each distributor, funds allocated to the energy efficiency projects and incentives received from the government for these projects should be taken into consideration. The amount of investment in projects for each distribution company should not exceed the sum of funds and incentives.

$$I_i \leq F_i + N_i \quad \forall i \tag{3.4}$$

The decision to carry out a project depends on the chosen projects, costs of which do not exceeding the investment capacity. The cost of each project and investment capacity are different for each distribution company and the following equation is key for the investment decision.

$$I_i = \sum_j c_{i,j} . X_{i,j} \quad \forall i \tag{3.5}$$

The government assigns incentives at a certain rate through the fund allocated by the distributor.

$$N_i = \eta . F_i \quad \forall i \tag{3.6}$$

Another parameter is the reduction in energy demand after implementation of selected projects. The energy savings that each project can provide are different and fixed for each distributor. Energy demand of distributor *i* can be defined as the difference between current energy demand and energy saving from all projects selected to be carried.

$$D_{i,t} = D_{i,t-1} - \sum_j . Y_{i,j} .. X_{i,j} \quad \forall i \tag{3.7}$$

Additionally, it is important to note that the energy demand of a distributor cannot exceed the energy capacity. This constraint applies both to the demand before saving projects ($D_{i,t-1}$) and to the demand after the projects ($D_{i,t}$). However, since $D_{i,t}$ is expected to be less than Di,t-1, this constraint can only be written by considering the first demand.

$$D_{i,t-1} \le K_i \quad \forall i \tag{3.8}$$

Finally, statistical data from global examples indicate that the minimum annual saving rate cannot be less than 2% based on all EEOS models applied worldwide. This result can be incorporated as a constraint in the model.

$$S_i \ge 0.02 \text{ for } \forall i \tag{3.9}$$

3.3.5 The Complete Model 1

The final model consists of combining the selected objective function and all the constraints described in the previous section. Mixed Integer programming will be used when real data is incorporated to analyze the model. Objective function is defined as the summation of savings of 21 distributors which covers the total energy saving in Turkey.

$$MaxZ = \sum_i S_i \tag{3.1}$$

Subject to:

$$S_i = \frac{(D_{i,t-1}) - (D_{i,t})}{(D_{i,t-1})} \quad \forall i \tag{3.2}$$

$$F_i = \sigma \sum_t (p_t . D_{i,t}) \quad \forall i \tag{3.3}$$

$$I_i \le F_i + N_i \quad \forall i \tag{3.4}$$

$$I_i = \sum_j c_{i,j} . X_{i,j} \quad \forall i \tag{3.5}$$

$$N_i = \eta . F_i \quad \forall i \tag{3.6}$$

$$D_{i,t} = D_{i,t-1} - \sum_j . Y_{i,j} .. X_{i,j} \quad \forall i \tag{3.7}$$

$$D_{i,t-1} \le K_i \quad \forall i \tag{3.8}$$

$$S_i \ge 0.02 \text{ for } \forall i \tag{3.9}$$

$$X_{i,j} \in \{0,1\} \tag{3.10}$$

$$S_i, D_{i,t}, I_i, F_i \ge 0 \tag{3.11}$$

3.4. Model 2 Minimize Total Cost of Obligation

Energy saving is an obligation declared by the regulator with certain terms defined in advance. Penalties and incentives oblige distribution companies to define a budget for the energy conservation projects. This model is based on the assumption that a certain amount of penalty is paid if total saving is under the limits.

3.4.1 Assumptions

- The number of energy saving projects in Turkey have a huge variation.
- Distributors have to pay a certain penalty if they cannot meet the target energy

saving.

- Penalty terms and conditions are the same for all distributors.
- Each distributor has a limited budget of investment.

3.4.2 Variables and parameters

All variables and parameters are explained in Table 3.10. and most of them are similar with variables of model 1.

$X_{i,j}$ is still decision variable of this model and it is defined as a binary variable. If project j is conducted by distributor i, $X_{i,j}$ takes the value 1; otherwise it takes the value 0. S_i and $D_{i,t-1}$ are other variables used in the model. $Y_{i,j}$,K_i , δ_i , $c_{i,j}$ and φ can be defined as parameters of the model. $D_{i,t-1}$ refers to energy demand of distributor i before applying energy saving projects. Estimated energy demand of distributor i after the energy saving projects is shown with $D_{i,t}$.

In this model, obligated saving percentage represented by δ_i is taken as 2%. However, the Regulator may increase or decrease this value according to its policies. As a result of δ_i increase, the savings will increase, otherwise, it will decrease.

Table 3.2 : Variables and parameters of Model 2.

Variables and Parameters	
i	: Identifying number for each electricity distributor (1, 2, ..., 21)
j	: Identifying number for each project (1,2, ...,n)
t	: Time period (1, 2,...,T). "t-1" denotes before implementation of saving projects and "t" denotes after their implementation.
$X_{i,j}$	: Binary variable that shows whether project j was executed by distributor i
$Y_{i,j}$	: Estimated energy saving amount provided by project j executed by distributor i
S_i	: Energy saving percentage of distributor i
$D_{i,t}$	: Annual energy demand of distributor i in period t
K_i	: Energy capacity of distributor i

Table 3.2 (continued): Variables and parameters of Model 2.

Variables and Parameters	
δ_i	: Energy saving percentage set by Regulator for distributor i
φ	: Percentage of the penalty to be paid in the absence of energy saving
$c_{i,j}$	: Cost of project j executed by distributor i
γ	: Binary variable if ($\delta_i - S_i$) is greater than 0 than takes the value 1, otherwise 0.
B_i	: Budget amount by distributor i

3.4.3 Objective Function

In the second model, minimizing total cost of energy saving is the goal for each distributor. Hence, the objective function contains project costs and Regulator enforcement. To reach the optimum result, the cost of each project applied by distributors and paying the penalty φ for not achieving the expected energy saving are evaluated together. The purpose of this objective function is to minimize the sum of these two different costs.

$$MinZ = \left(\sum_j c_{i,j} . X_{i,j} \right) + \gamma \left[\varphi (\delta_i - S_i) . D_{i,t-1} \right] \quad \forall i \tag{3.12}$$

The first part of the formula before the plus sign is related to the costs arising from implementation of the projects whereas the second part is related to the Regulator enforcement. If the savings achieved by the distributor is below the treshold limit (δ_i), γ takes the value 1 then the distributor pays a penalty proportional with the gap and its electricity demand. If the distributor achieves savings exceeding the treshold limit than the second part of the formula becomes unnecessary so γ takes the value 0.

This objective function gives a different solution for each distributor compared to first model; therefore a second model is established.

3.4.4 Constraints

The main decision variable of model 2 is $X_{i,j}$ like model 1. Most of the constraints are similar. For a better understanding of the model, mathematical definitions of constraints and parameters are added to this section again.

First parameter, S_i , is determined in the previous model as the rate of energy saving after energy conservation projects' implementation. The constraint function used in this model is as given in (3.2).

Another parameter is the reduction in energy demand after implementation of selected projects. The energy savings that each project can provide are different and fixed for each distributor. Energy demand of distributor *i* can be defined as the difference between current energy demand and energy saving from all projects selected to be carried. The constraint function used in this model is as given in (3.7).

Additionally, it is expected that energy demand of a distributor cannot exceed the energy capacity. This constraint applies both to the first demand before the saving projects $D_{i,t-1}$ and to the demand after the projects $D_{i,t}$. However, since $D_{i,t}$ is expected to be less than $D_{i,t-1}$, this constraint can only be written by considering the first demand. The constraint function used in this model is as given in (3.8).

As can be seen, the equations 3.2, 3.7 and 3.8 are the same as in the first model.

The budget for each distributor cannot exceed 3,000,000 EUR.

$$B_i \leq 3{,}000{,}000 \tag{3.13}$$

3.4.5 The Complete Model 2

The final model consists of combining the selected objective function and all the constraints described in the previous section. Mixed Integer programming is used to analyze the model. Objective function gives minimum energy saving cost per distributor.

$$Min Z = \left(\sum_j c_{i,j} . X_{i,j} \right) + \gamma \left[\varphi \left(\delta_i - S_i \right) . D_{i,t-1} \right] \quad \forall i \tag{3.12}$$

Subject to:

$$B_i \leq 3{,}000{,}000 \quad \forall i \tag{3.13}$$

In this model, (3.2), (3.7), (3.8), (3.10) and (3.11) constraints are used.

4. APPLICATIONS IN TURKEY

4.1 Model 1 Sample Application for Uludağ Elektrik Dağıtım A.Ş. (UEDAS)

- The above model was run on Excel Solver for years 2016, 2017 and 2018.
- It is assumed that UEDAS implemented up to 5 projects.
- The costs of these projects are generated randomly in the range of €100,000 to €1,000,000 randomly.

The program output is as follows.

Table 4.1 : Projects to be implemented for UEDAS in three years.

Projects/Years	Project 1	Project 2	Project 3	Project 4	Project 5
2016	1	0	1	0	1
2017	1	0	1	1	1
2018	1	0	1	1	1

The savings achieved in each project vary according to the distributor. The energy savings obtained as a result of these projects for UEDAS for all these three years are given in the table below.

Table 4.2 : Maximum energy saving calculated for UEDAS by years.

Years	Si
2016	2.17%
2017	2.33%
2018	2.77%

The table shows the energy savings obtained from the implementation of the selected projects for years 2016, 2017 and 2018.

4.2 Model 1 Application for All Distributors

- The above model was run on Excel Solver for years 2016, 2017 and 2018.
- In this example, each of 21 distributors have the chance to invest in the same 5 projects.
- The costs of these projects are generated randomly in the range of €100,000 to €1,000,000 but in line with the demand.

Table 4.3 : Cost of projects in 2018 (All values in EUR).

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
ADM	342,462	281,568	361,660	356,770	374,699
Akdeniz	368,073	302,208	372,628	380,019	345,342
Akedaş	276,411	126,599	106,775	137,213	121,460
Aras	712,359	706,069	724,291	708,069	751,385
Başkent	602,627	473,820	776,567	643,184	473,884
Boğaziçi	720,754	798,366	780,533	718,791	997,720
Çamlıbel	105,227	423,260	423,861	103,072	416,568
Çoruh	131,374	140,589	426,140	120,462	132,309
Dicle	579,116	577,951	614,161	668,006	642,503
Fırat	439,729	439,420	438,782	105,025	107,425
GDZ	485,204	390,655	999,887	568,554	869,096
İstanbul Anadolu	414,509	483,313	414,926	380,761	499,332
Kayseri	108,523	100,544	430,757	427,040	428,578
Meram	432,898	424,573	383,628	333,943	367,071
Osmangazi	433,428	501,149	472,703	483,525	497,838
Sakarya	325,788	375,979	375,063	405,885	371,430
Toroslar	774,813	721,345	753,904	749,962	738,422
Trakya	629,978	219,497	638,307	647,365	657,825
UEDAS	493,661	439,211	501,411	490,407	563,445
Vangölü	506,263	521,174	484,872	499,869	510,856
Yeşilırmak	468,931	178,090	447,540	462,537	473,524

It is seen in this table that the costs for implementing the same Project can differ, due to locations, labor costs, architecture of the Project.

As defined earlier the projects have differing savings for different distributors.

Table 4.4 : Savings for each Project for 2018 (GWh).

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
ADM	51.11	47.46	57.50	58.41	53.85
Akdeniz	39.34	49.18	35.76	30.40	46.49
Akedaş	41.76	29.34	44.77	27.09	45.52
Aras	51.04	47.66	37.18	48.33	40.90
Başkent	57.38	67.95	81.54	61.91	72.48
Boğaziçi	185.48	147.85	196.23	129.03	86.02

Table 4.4 (continued): Savings for each Project for 2018 (GWh).

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
Çoruh	31.77	43.93	31.38	47.85	54.52
Dicle	69.85	72.88	63.77	78.96	50.11
Fırat	52.92	24.80	56.22	23.43	47.68
GDZ	99.54	86.27	73.00	87.93	102.86
İstanbul Anadolu	77.48	50.36	76.19	80.07	54.24
Kayseri	24.60	58.48	34.64	49.20	37.90
Meram	42.64	17.24	48.99	53.52	35.38
Osmangazi	31.84	43.30	36.29	46.48	42.02
Sakarya	61.55	36.73	65.52	68.50	56.58
Toroslar	90.72	61.06	80.26	87.24	71.53
Trakya	45.07	48.20	51.96	48.83	51.33
UEDAS	89.34	74.89	88.02	99.85	86.71
Vangölü	39.65	25.64	28.03	33.15	42.04
Yeşilırmak	51.17	45.61	63.41	64.52	52.84

Data input for the model are obtained from TEIAS and EPDK websites as follows [38], [39].

Table 4.5 : Energy Demands for 2016, 2017 and 2018 on Distributor Basis GWh.

Distributor	2016	2017	2018
ADM	8,309	8,512	9,127
Akdeniz	8,392	8,521	8,941
Akedaş	3,862	3,982	3,762
Aras	2,807	2,935	3,380
Başkent	15,108	15,333	15,100
Boğaziçi	25,204	25,711	26,881
Çamlıbel	2,211	2,380	2,361
Çoruh	3,589	3,728	3,922
Dicle	20,879	21,279	15,184
Fırat	2,454	2,602	2,756
GDZ	14,667	15,008	16,590
İstanbul Anadolu	11,681	11,896	12,914
Kayseri	2,198	2,333	2,510
Meram	8,988	9,134	9,072
Osmangazi	6,210	6,341	6,367
Sakarya	9,127	9,310	9,927
Toroslar	16,086	16,319	17,447
Trakya	6,418	6,630	6,260
UEDAS	11,435	11,708	13,138
Vangölü	3,724	3,853	3,418
Yeşilırmak	4,895	5,108	5,562

Table 4.6 : Unit Electric Price for 2016, 2017 and 2018.

Year	Electric Price EUR/kWh
2016	0.059
2017	0.065
2018	0.071

After running the linear programming model (defined in section 3.3.5) with the above parameters for all distributors, the projects to implement are selected for 2018 as in Table 4.7.

Table 4.7 : The decision whether to implement projects for Model 1 for 2018.

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
ADM	0	1	1	1	1
Akdeniz	1	1	0	0	1
Akedaş	1	0	1	1	0
Aras	1	1	0	1	0
Başkent	0	1	1	0	1
Boğaziçi	1	1	1	0	0
Çamlıbel	0	1	0	1	1
Çoruh	0	1	0	1	1
Dicle	1	1	1	1	0
Fırat	1	0	1	0	1
GDZ	1	1	0	1	1
İstanbul Anadolu	1	0	1	1	0
Kayseri	0	1	0	1	1
Meram	1	0	1	1	0
Osmangazi	0	1	0	1	1
Sakarya	1	0	1	1	0
Toroslar	1	0	0	1	1
Trakya	0	1	1	1	1
UEDAS	1	0	1	1	1
Vangölü	1	0	0	1	1
Yeşilırmak	1	0	1	1	1

Table 4.8 shows the current energy demand, the amount of investment required for each distributor to implement selected projects, and the energy savings and energy demand resulting from these measures.

As a result, it is seen that a total of 5.308 GWh energy saving is achieved. This amount of energy savings almost corresponds to the amount of electricity that the Yeşilırmak distributes for 2018. However, it is equal to 2.65% of total electricity demand after energy saving projects are implemented.

Table 4.8 : Maximum energy saving calculated for all distributors for 2018.

Distributor	Investments (EUR)	D(t-1) (GWh)	D(t) (GWh)	S(i) (%)
ADM	1,374,697	9,127	8,897	2.52%
Akdeniz	1,015,622	8,941	8,707	2.62%
Akedaş	520,399	3,762	3,648	3.02%
Aras	2,124,206	3,380	3,233	4.35%
Başkent	1,724,271	15,100	14,750	2.32%
Boğaziçi	2,299,653	26,881	26,136	2.77%
Çamlıbel	942,900	2,361	2,264	4.09%
Çoruh	393,360	3,922	3,776	3.73%
Dicle	2,439,234	15,184	14,848	2.21%
Fırat	985,936	2,756	2,627	4.69%
GDZ	2,313,509	16,590	16,213	2.27%
İstanbul Anadolu	1,210,196	12,914	12,576	2.62%
Kayseri	956,162	2,510	2,364	5.80%
Meram	1,150,469	9,072	8,874	2.18%
Osmangazi	1,482,512	6,367	6,235	2.07%
Sakarya	1,106,736	9,927	9,638	2.91%
Toroslar	2,263,196	17,447	17,056	2.24%
Trakya	2,162,994	6,260	6,060	3.20%
UEDAS	2,048,924	13,138	12,774	2.77%
Vangölü	1,516,987	3,418	3,303	3.36%
Yeşilırmak	1,852,532	5,562	5,330	4.17%
TOTAL	31,884,495	194,619	189,311	65.91%

4.3 Model 2 Sample Application for Uludağ Elektrik Dağıtım A.Ş. (UEDAS)

- The above model was run on Excel Solver for years 2016, 2017 and 2018.
- It is assumed that UEDAS implements 5 projects.
- The costs of these projects are generated randomly in the range of €100,000 to €1,000,000.
- The treshold limit (δ_i) is set to 0.02.

For Uludağ Elektrik Dağıtım A.Ş. (UEDAS), the program output is as follows.

Table 4.9 : Projects to be implemented for UEDAS in three years.

Projects/Years	Project 1	Project 2	Project 3	Project 4	Project 5
2016	1	0	1	0	1
2017	1	0	1	0	1
2018	1	0	1	0	1

As a result, it is seen that the same projects are chosen all three years.

The minimum cost and saved energy obtained as a result of these projects are given in the table below.

Table 4.10 : Minimum cost and energy saving for UEDAS for three years.

Years	Min Z (€)	Years	Si
2016	2,308,227	2016	1.88%
2017	2,352,085	2017	1.79%
2018	2,434,880	2018	1.71%

For 2016, the same projects are seen in both models for UEDAS. This means that both energy savings are maximized and cost minimization is achieved with the same project. The situation is different for 2017 and 2018. The reason for this is that if the target is not reached, the cost of the penalty is higher than the cost of the project.

4.4 Model 2 Application for All Distributors

- The above model was run on Excel Solver for years 2016, 2017 and 2018.
- In this example, each of 21 distributors have the chance to invest in the same 5 projects.
- The costs of these projects are generated randomly in the range of €100,000 to €1,000,000 but in line with the demand.
- The treshold limit (δ_i) is set to 0.02.

Table 4.11 : Cost of projects in 2018 (All values in €).

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
ADM	342,462	281,568	361,660	356,770	374,699
Akdeniz	368,073	302,208	372,628	380,019	345,342
Akedaş	276,411	126,599	106,775	137,213	121,460
Aras	712,359	706,069	724,291	708,069	751,385
Başkent	602,627	473,820	776,567	643,184	473,884
Boğaziçi	720,754	798,366	780,533	718,791	997,720
Çamlıbel	105,227	423,260	423,861	103,072	416,568
Çoruh	131,374	140,589	426,140	120,462	132,309
Dicle	579,116	577,951	614,161	668,006	642,503
Fırat	439,729	439,420	438,782	105,025	107,425
GDZ	485,204	390,655	999,887	568,554	869,096
İstanbul Anadolu	414,509	483,313	414,926	380,761	499,332
Kayseri	108,523	100,544	430,757	427,040	428,578
Meram	432,898	424,573	383,628	333,943	367,071
Osmangazi	433,428	501,149	472,703	483,525	497,838

Table 4.11 (continued): Cost of projects in 2018 (All values in €).

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
Sakarya	325,788	375,979	375,063	405,885	371,430
Toroslar	774,813	721,345	753,904	749,962	738,422
Trakya	629,978	219,497	638,307	647,365	657,825
UEDAS	493,661	439,211	501,411	490,407	563,445
Vangölü	506,263	521,174	484,872	499,869	510,856
Yeşilırmak	468,931	178,090	447,540	462,537	473,524

It is seen in this table that the cost for implementing the same Project can differ, due to locations, labor costs, architecture of the Project.

Table 4.12 : Savings for each Project 2018 (GWh).

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
ADM	41.98	10.95	106.79	104.05	110.44
Akdeniz	48.28	76.00	81.36	71.53	76.89
Akedaş	31.22	29.34	25.96	27.09	24.08
Aras	33.46	40.90	27.04	24.67	37.18
Başkent	63.42	67.95	81.54	70.97	66.44
Boğaziçi	64.51	53.76	75.27	110.21	59.14
Çamlıbel	13.93	14.64	15.58	13.46	15.82
Çoruh	29.42	28.24	31.38	28.24	27.06
Dicle	39.48	42.52	51.63	44.03	66.81
Fırat	25.36	24.80	28.66	22.60	20.12
GDZ	66.36	69.68	94.56	71.34	82.95
İstanbul Anadolu	85.23	55.53	76.19	87.82	67.15
Kayseri	24.60	20.83	34.64	31.38	32.88
Meram	78.02	80.74	67.13	82.56	62.60
Osmangazi	61.76	49.03	56.67	59.21	48.39
Sakarya	81.40	70.48	81.40	78.42	69.49
Toroslar	83.75	61.06	68.04	87.24	88.98
Trakya	50.71	45.70	51.33	53.21	53.21
UEDAS	76.20	42.04	74.89	35.47	73.57
Vangölü	30.08	22.22	22.56	30.42	29.39
Yeşilırmak	50.06	33.93	37.27	50.06	47.28

The table shows the energy savings in case of application of the selected project by each distributor. These values have been generated randomly within a certain range in line with demand.

As defined earlier the projects have differing savings for different distributors.

Data input for the model are obtained from TEIAS and EPDK websites as follows [38], [39].

Table 4.13 : Energy Demands for 2016, 2017 and 2018 on Distributor Basis GWh.

Distributor	2016	2017	2018
ADM	8,309	8,512	9,127
Akdeniz	8,392	8,521	8,941
Akedaş	3,862	3,982	3,762
Aras	2,807	2,935	3,380
Başkent	15,108	15,333	15,100
Boğaziçi	25,204	25,711	26,881
Çamlıbel	2,211	2,380	2,361
Çoruh	3,589	3,728	3,922
Dicle	20,879	21,279	15,184
Fırat	2,454	2,602	2,756
GDZ	14,667	15,008	16,590
İstanbul Anadolu	11,681	11,896	12,914
Kayseri	2,198	2,333	2,510
Meram	8,988	9,134	9,072
Osmangazi	6,210	6,341	6,367
Sakarya	9,127	9,310	9,927
Toroslar	16,086	16,319	17,447
Trakya	6,418	6,630	6,260
UEDAS	11,435	11,708	13,138
Vangölü	3,724	3,853	3,418
Yeşilırmak	4,895	5,108	5,562

Table 4.14 : Unit Electric Price for 2016, 2017 and 2018.

Year	Electric Price €/kWh
2016	0.059
2017	0.065
2018	0.071

After running the linear programming model (defined in section 3.4.5) with the above parameters for all distributors, the projects to implement are selected for 2018 as in Table 4.15.

Table 4.15 : The decision whether to carry out projects for Model 2 for 2018.

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
ADM	0	0	1	1	1
Akdeniz	0	1	1	0	1
Akedaş	1	0	0	0	0
Aras	1	1	0	0	1
Başkent	0	0	1	0	0
Boğaziçi	0	0	0	1	0
Çamlıbel	0	1	1	0	1
Çoruh	0	0	1	0	0
Dicle	0	0	0	0	1
Fırat	1	1	1	0	0

Table 4.15 (continued): The decision whether to carry out projects for Model 2 for 2018.

Distributor	Project 1	Project 2	Project 3	Project 4	Project 5
GDZ	0	0	1	0	1
İstanbul Anadolu	1	0	1	1	0
Kayseri	0	0	1	1	1
Meram	1	1	0	1	0
Osmangazi	0	1	1	0	1
Sakarya	1	0	1	1	0
Toroslar	1	0	0	1	1
Trakya	1	0	1	1	1
UEDAS	1	0	1	0	1
Vangölü	1	0	0	1	1
Yeşilırmak	1	0	1	1	1

This table shows the preferred projects by distributors for 2018.

Table 4.16 : Minimum cost and energy saving calculated for all distributors for 2018.

Distributor	Investments (€)	D(t-1) (GWh)	D(t) (GWh)	S(i) (%)	Total Cost (€)
ADM	1,093,129	9,127	8,910	2.38%	1,093,129
Akdeniz	845,743	8,941	8,740	2.25%	845,743
Akedaş	277,537	3,762	3,731	0.83%	277,581
Aras	2,124,206	3,380	3,268	3.30%	2,124,206
Başkent	777,807	15,100	15,018	0.54%	778,027
Boğaziçi	719,954	26,881	26,771	0.41%	720,381
Çamlıbel	1,263,738	2,361	2,315	1.95%	1,263,739
Çoruh	427,293	3,922	3,891	0.80%	427,340
Dicle	643,826	15,184	15,117	0.44%	644,063
Fırat	1,317,931	2,756	2,677	2.86%	1,317,931
GDZ	1,666,759	16,590	16,412	1.07%	1,666,913
İstanbul Anadolu	1,210,257	12,914	12,665	1.93%	1,210,266
Kayseri	1,286,375	2,510	2,411	3.94%	1,286,375
Meram	1,191,723	9,072	8,921	1.66%	1,191,754
Osmangazi	752,037	6,367	6,277	1.42%	752,074
Sakarya	1,106,736	9,927	9,686	2.43%	1,106,736
Toroslar	1,899,492	17,447	17,187	1.49%	1,899,581
Trakya	2,573,475	6,260	6,114	2.33%	2,573,475
UEDAS	2,434,880	13,138	12,913	1.71%	2,434,918
Vangölü	1,449,621	3,418	3,328	2.63%	1,449,621
Yeşilırmak	1,852,532	5,562	5,377	3.32%	1,852,532
TOTAL	26,915,050	194,619	191,730	39.69%	26,916,385

The table shows the current energy demand, the amount of investment required for each distributor to implement selected projects, and the energy savings and energy demand results. As a result, it is seen that a total of 2,889 GWh energy saving is achieved.

4.5 Comparison of Models

Comparing the two model outputs, the first difference is in the prefered projects to be carried out. The main reason is the difference between objective functions. In the first model, the energy saving is desired to be maximized while the second model focuses on minimizing the cost. Purpose of the two alternatives are evaluated with a varience.

Another important difference between these two models is that Model 1 yields higher savings compared to Model 2. This is because of the fact that the former objective function focuses on increasing savings, whereas the latter on minimizing the cost. But if the Regulator treshold limit is increased, the results would be different as well. As seen in the table, Model 1 yields higher energy savings than Model 2 since its objective function aims to maximize the saving. On the other hand, Model 2 aims to minimize the costs yet there are instances where costs of some distributors are higher compared to Model 1. The reason for that is the obligation of paying penalties unless saving targets are met. In such scenarios distributors pay penalties in addition to their project costs and therefore total expenditures become higher than Model 1.

Consequently, Model 1 appears to be more effective for yielding higher energy savings as well as not obligating extra penalties.

In practice, if the regulator feels the necessity it is always possible for both of the models to set minimum threshold saving limits. Wise fine-tuning of such thresholds are expected to increase effectiveness of the model hence yield higher savings. Such thresholds can be used by regulators as a tool for communicating annual goals with distributors and ensure that everyone is putting their best effort to reach these goals.

Table 4.17 : Comparison of Models for all distributors for 2018.

Distributor	Model 1 Total Cost (€)	Model 1 S(i) (%)	Model 2 Total Cost (€)	Model 2 S(i) (%)	Ratio of Costs (C1/C2)	Ratio of Savings (S1/S2)
ADM	1,374,697	2.52%	1,093,129	2.38%	1.00	1.06
Akdeniz	1,015,622	2.62%	1,015,622	2.25%	1.00	1.16
Akedaş	520,399	3.02%	637,399	0.83%	0.82	3.64
Aras	2,124,206	4.35%	2,124,206	3.30%	1.00	1.32

Table 4.17 (continued): Comparison of Models for all distributors for 2018.

Distributor	**Model 1 Total Cost (€)**	**Model 1 S(i) (%)**	**Model 2 Total Cost (€)**	**Model 2 S(i) (%)**	**Ratio of Costs (C1/C2)**	**Ratio of Savings (S1/S2)**
Başkent	1,724,271	2.32%	1,870,271	0.54%	0.92	4.30
Boğaziçi	2,299,653	2.77%	2,458,653	0.41%	0.94	6.76
Çamlıbel	942,900	4.09%	947,900	1.95%	0.99	2.10
Çoruh	393,360	3.73%	513,360	0.80%	0.92	4.66
Dicle	2,439,234	2.21%	2,595,234	0.44%	0.94	5.02
Fırat	985,936	4.69%	985,936	2.86%	1.00	1.64
GDZ	1,813,509	2.27%	1,906,509	1.07%	0.95	2.12
İstanbul Anadolu	1,210,196	2.62%	1,217,196	1.93%	1.00	1.00
Kayseri	1,495,442	5.80%	1,495,442	3.94%	1.00	1.47
Meram	1,150,469	2.18%	1,184,469	1.66%	0.97	1.31
Osmangazi	1,482,512	2.07%	1,540,512	1.42%	0.96	1.46
Sakarya	1,106,736	2.91%	1,106,736	2.43%	1.00	1.20
Toroslar	2,263,196	2.24%	2,314,196	1.49%	0.98	1.50
Trakya	2,162,994	3.20%	2,162,994	2.33%	1.00	1.37
UEDAS	2,048,924	2.77%	2,434,918	1.71%	0.84	1.62
Vangölü	1,516,987	3.36%	1,516,987	2.63%	1.00	1.28
Yeşilırmak	1,852,532	4.17%	1,852,532	3.32%	1.00	1.26

5. CONCLUSION AND RECOMMENDATIONS

Energy supply security, lowering costs, sustainability and environmental problems are in the agenda of all countries. Countries develop energy efficiency strategies and policies to find solutions for the energy resource issues.

Sustaining energy efficiency is the most effective method to overcome global issues such as international dependence and decreasing greenhouse gases. In this respect, countries have prepared incentive packages and brought certain obligations into effect. EEOS is among the energy efficiency policies which has been successfully implemented in Europe.

Our review demonstrates country specific designs based on governmental policies. Most crucial part of a EEOS is the design and management of a system, as well as monitoring, verification and control of that system. These are essential elements for the design and successful implementation of the EEOS.

Developing a penalty and incentive mechanism is one of the recommended methods in ensuring the successful implementation of the system. These incentives and deterring penalties need to be carefully balanced. In addition, enabling the trading of the certificates as an incentive is one of the primary contributors for success.

It is recommended to start with short and mid-term projects for the success and governing of the system. Based on government's efficiency policies enforcing a minimum limit for different sectors would contribute to reach targeted saving levels. Apart from that including energy service companies to the system would have a positive effect on the successful integration of the system to the market as well as creating new job opportunities. It is also recommended cooperation with public institutions and non-governmental organizations for the purpose of increasing awareness and establishment of necessary infrastructure.

Within the scope of this thesis energy efficiency policies in Europe and Turkey have been examined and EEOS in Europe has been scrutinized. Based on these reviews, we believe implementing this system would be the most effective medium to reach 2023 energy efficiency goals. In order to demonstrate a sample case and benefits of a possible EEOS, two alternative theoretical models with real and random data have been developed. Both of these models use mixed integer optimization approach.

The first of these models aims to maximize energy saving with obligations and incentives and the second aims to minimize the total costs of energy efficiency projects and penalties in order to reach the required energy saving levels. By comparing these two models, for the 21 local power distributors in Turkey we conclude that the first one is more effective in terms of higher saving.

This study is the first EEOS consideration in Turkey comparing the Regulator's view and the Distributors' view. We recommend to be extended the study with new parameters and new simulations. Including Natural Gas Distributors and Energy Service Companies in the set of obligators will expand the issues and hence new models are to be defined. We also believe adding stochastical and forecasting features to this model in order to represent uncertainties of demand in the power sector.

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