

AN AGGREGATE ECONOMIC EQUILIBRIUM MODEL FOR SUSTAINABLE
ENERGY POLICY ANALYSIS AND IMPLICATIONS FOR TURKEY

by

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ABSTRACT

AN AGGREGATE ECONOMIC EQUILIBRIUM MODEL FOR SUSTAINABLE ENERGY POLICY ANALYSIS AND IMPLICATIONS FOR TURKEY

This study explores economic effects of various energy and environmental policies for Turkey using an energy-economy-environment aggregate equilibrium model. The model aggregates energy demands, capital requirements and labor inputs under an economy-wide nested constant elasticity of substitution production function. Growing energy demand is met by increased supply produced by various alternatives including a variety of renewable energy technologies. The associated environmental sub model includes feedback links both to the energy sector and economy. A willingness to pay function is used to establish those links. The willingness to pay equation is based on data gathered from a pilot survey, in which the Contingent Valuation Methodology was employed. An increased use of electricity from renewable sources is further encouraged by the endogenous technological learning functions integrated into the model. Results suggest various useful policy implications for an environmentally and economically sustainable development of the country and provide long-term energy policy plans.

ÖZET

SÜRDÜRÜLEBİLİR ENERJİ POLİTİKA ANALİZİ İÇİN BİR TÜMLEŞİK EKONOMİK DENGE MODELİ VE TÜRKİYE UYGULAMALARI

Bu çalışmada çeşitli enerji ve çevre politikalarının Türkiye üzerine getireceği ekonomik etkiler, bir enerji-ekonomi-çevre tümleşik modeli ile araştırılmaktadır. Model; enerji talepleri, sermaye getirileri ve işçi girdilerini tüm ekonomiyi kapsayan birbiri içerisine yerleştirilmiş sabit ikame esnekliği üretim fonksiyonu altında birleştirmektedir. Büyüyen enerji talebi yenilenebilir enerji teknolojilerini de içeren çeşitli alternatif enerji kaynaklarından gelen artan talep tarafından karşılanmaktadır. Çevresel alt model hem enerji sektörü hem de ekonomiyle geri bildirim bağlantılarına sahiptir. Bu bağlantıları oluşturmak için bir ödeme istekliliği fonksiyonu kullanılmaktadır. Ödeme istekliliği fonksiyonu Koşullu Değer Biçme yöntemi kullanılarak uygulanan bir anket çalışmasından alınan verilerden elde edilmiştir. Yenilenebilir enerji kaynaklarından elde edilen elektriğin artan oranda kullanımı model içerisine entegre edilen içsel öğrenme fonksiyonları tarafından desteklenmektedir. Sonuçlar ülkenin çevresel ve ekonomik olarak sürdürülebilir gelişimi için yararlı politika hareketleri önermekte ve uzun dönem enerji politika planları sağlamaktadır.

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LIST OF SYMBOLS/ABBREVIATIONS

<i>b</i>	Learning index
<i>C</i>	Consumption
<i>CO₂</i>	Carbon dioxide
<i>CUM</i>	Cumulative production
<i>E</i>	Electricity
<i>ECC</i>	Total costs for conventional energy
<i>ECR</i>	Total costs for renewable energy
<i>ef</i>	Emission factor
<i>ELEC</i>	Electricity generation
<i>ELEC0</i>	Initial capacity for electricity
<i>ELECINC</i>	Incremental capacity for electricity generation
<i>ELECPR</i>	Cost of electricity generation
<i>EN</i>	Increment in electricity
<i>ENE</i>	Conventional energy consumption
<i>F</i>	Factor incomes from abroad
<i>GDP</i>	Gross domestic product
<i>HN</i>	Total number of households
<i>I</i>	Investment
<i>income</i>	Percentage of households entering the definite category
<i>K</i>	Capital
<i>k</i>	Technology type for electricity generation
<i>KN</i>	Increment in capital
<i>L</i>	Labor force
<i>l</i>	Renewable energy carrier type
<i>LN</i>	Increment in labor force
<i>m</i>	Fuel type for non-electric energy generation
<i>M</i>	Import
<i>NE</i>	Non electric energy
<i>NELEC</i>	Non-electric energy generation

<i>NELEC0</i>	Initial capacity for non-electric energy
<i>NELECINC</i>	Incremental capacity for non-electric energy generation
<i>NELECPR</i>	Cost of non-electric energy generation
<i>NEN</i>	Increment in non-electric energy
<i>p</i>	Period length
<i>REN</i>	Renewable energy consumption
<i>REN0</i>	Initial capacity for renewable energy
<i>RENINC</i>	Incremental capacity for renewable energy generation
<i>RENPR</i>	Cost of renewable energy generation
<i>RENPR0</i>	Initial price for renewable energy
<i>RET</i>	Renewable energy technologies
<i>sl</i>	Value share of labor within capital-labor pair
<i>sk</i>	Value share of capital within capital-labor pair
<i>se</i>	Value share of electricity within electricity-nonelectric energy pair
<i>sne</i>	Value share of non-electric energy within electricity-nonelectric energy pair
<i>t</i>	Time period
<i>TR</i>	Tourism revenue
<i>W</i>	Worker remittances
<i>WTP</i>	Willingness to pay
<i>X</i>	Export
<i>Y</i>	Gross output
<i>YN</i>	Increment in gross output
<i>z</i>	Income category
α	Scale parameter for capital-labor pair
β	Scale parameter for electricity-non electric energy pair
γ	Scale parameter
Δ	Annual discount rate
η_1	Fraction factor for export
η_2	Fraction factor for import
λ	Annual survival factor

ω	Annual growth rate of household
ψ	Annual growth rate of income
ρ	Substitution elasticity parameter
σ	Elasticity of substitution
<i>ANOVA</i>	Analysis of variance
<i>BAU</i>	Business as usual
<i>CVM</i>	Contingent valuation methodology
<i>EM1</i>	Scenario: Emission stabilization at 2000 levels
<i>EM2</i>	Scenario: Emission stabilization at 2005 levels
<i>EM3</i>	Scenario: Emission stabilization at 2010 levels
<i>EM4</i>	Scenario: 10% growth in CO ₂ emission
<i>GHG</i>	Greenhouse gas
<i>HPM</i>	Hedonic price method
<i>IG1</i>	Scenario: Annual average income growth of 6%
<i>IG2</i>	Scenario: Annual Average income growth of 9.5%
<i>IG3</i>	Scenario: Annual Average income growth of 12.5%
<i>IP1</i>	Scenario: Income _k : 0.15, 0.20, 0.20, 0.20, 0.25
<i>IP2</i>	Scenario: Income _k : 0.02, 0.03, 0.05, 0.40, 0.50
<i>IP3</i>	Scenario: Income _k : 0.00, 0.00, 0.00, 0.50, 0.50
<i>kWh</i>	kiloWatt-hour
<i>LIB</i>	Scenario: Doubling in bioenergy learning index
<i>LID</i>	Scenario: Doubling in all learning indexes
<i>LIG</i>	Scenario: Doubling in geothermal energy learning index
<i>LIS</i>	Scenario: Doubling in solar energy learning index
<i>LIW</i>	Scenario: Doubling in wind energy learning index
<i>MENR</i>	Ministry of energy and natural resources
<i>MINOS</i>	Modular in-core nonlinear optimization system
<i>MIX1</i>	Scenario: Combination of EM1 - LID - IG1 - IP1
<i>MIX2</i>	Scenario: Combination of EM2 - LID - IG1 - IP2
<i>MIX3</i>	Scenario: Combination of EM3 - LID - IG1 - IP3

<i>MIX4</i>	Scenario: Combination of EM4 - LID - IG1 - IP1
<i>EM1 – NUC</i>	Scenario: Combination of EM1-NUC
<i>EM2 – NUC</i>	Scenario: Combination of EM2-NUC
<i>EM3 – NUC</i>	Scenario: Combination of EM3-NUC
<i>EM4 – NUC</i>	Scenario: Combination of EM4-NUC
<i>Mtoe</i>	Million tonnes of oil equivalent
<i>MW</i>	Megawatt
<i>NGO</i>	Non governmental organization
<i>NUC</i>	Scenario: Nuclear energy included
<i>PV</i>	Photovoltaic
<i>SPO</i>	State Planing Organization
<i>TCM</i>	Travel cost method
<i>TSI</i>	Turkish Statistical Institute
<i>TUBITAK</i>	The Scientific and Technological Research Council of Turkey
<i>TWh</i>	Terawatthour
<i>UNFCCC</i>	United Nations Framework Convention on Climate Change
<i>YTL</i>	New Turkish Lira

1. INTRODUCTION

Intimate relationships between energy use, environmental degradation, and economic welfare necessitate an integrated analysis for sustainable policy development. Such analysis for policy and planning concerns of energy, economy and environment have been addressed many times in literature. There are various modeling techniques in literature approaching the problem in different ways.

Economic equilibrium modeling is a popular approach offering powerful analytical tools to conduct economic analysis of energy and environmental policies. These models are based on economic optimization and equilibrium assumptions. They can be classified under two categories: Disaggregate Economic Equilibrium and Aggregate Economic Equilibrium models. Disaggregate models are of the general equilibrium type differentiating between various sectors of the economy and simulating a market equilibrium for all goods and services. They typically inherit multi sector production functions as opposed to aggregate models which compute Gross Domestic Product (GDP) from an economy-wide aggregate production function. Aggregate models represent energy-economy interactions via energy demand and cost relations thereby featuring a detailed technological representation of the energy sector.

In this thesis, an aggregate modeling approach is employed to model the energy consumption of Turkey and assess the economic costs of various energy-environment scenarios including Kyoto Protocol emission limitations. The model incorporates detailed depreciation equations for energy technologies, endogenous technology learning functions for renewable energies, and also a Willingness to Pay (WTP) function into an aggregate economic equilibrium model. Most of the energy models rarely consider the consumer's WTP for CO₂ emission reduction. There are a few of them relating WTP with temperature and also GDP [1]. However, in this way, the great deal of uncertainty involved and lack of empirical evidence may induce misleading policy implications. Therefore, we derive a WTP function from the multiple regression analysis of a Contingent Valuation survey. The Contingent Valuation Methodology (CVM) is

employed as a generally favored survey technique for assigning monetary values on CO₂ emission reduction. The nonlinear optimization model is calibrated using survey results to simulate aggregate economic equilibrium for Turkey.

The thesis is embodied from six chapters. Chapter 2 is arranged so as to include two different subsections. In the first one, an extensive literature review for CVM is given and the methodology is compared with other alternatives while the second subsection reviews various energy and environmental policy modeling approaches.

Chapter 3 provides details of the CVM survey application including preparation and implementation of the questionnaire and statistical analysis of results.

Chapter 4 describes the model. Explanations of energy, economy, and environmental sub models and their interactions are presented. In addition, basic assumptions and model parameters that are used in the model calibration phase are introduced in this chapter.

Chapter 5 is formed by empirical analysis results. The scenarios used in the thesis are defined, results are presented and discussed. In addition, sensitivity analysis results are outlined and parameters mostly affect the results are briefly discussed.

Finally, Chapter 7 gives some concluding remarks and provides some suggestions for further research.

2. LITERATURE REVIEW

2.1. CONTINGENT VALUATION METHODOLOGY

Economic analysis is done to compare benefits and costs of a future action. However; such an analysis is governed by various difficulties when the good is a non-marketed one. The goods that are not bought or sold in the market (such as environmental goods and resources) are called non-marketed goods. A central problem for an economic analysis with the non-marketed goods and services is the difficulty of placing a monetary value on them. Because there is no market for these goods, it is not possible to obtain their actual cost and sales information.

Since the late 1960s, a wide environmental economics literature that investigates the ways of assigning monetary values on environmental goods and services has grown up. The concept of non-use value was introduced in 1967 by John V. Krutilla in his book “Resources for the Future”. According to early economic theory, the total value of an economic good consists of option value, existence value, and bequest value [2]. Option value expresses the preferences for the protection of the environment against some probability that the environmental asset will be used in the future. Existence value derives from the payment for an asset that individuals will never see or use directly while bequest value is paid to see that environment will be preserved for future generations. Scientists currently use the combination of bequest and existence value to financially evaluate environmental goods and resources. Option value does not affect the motivation of an individual when valuing an environmental good [3].

Economists believed that an asset has economic value if consumers get utility from it [3]. Furthermore; pure neoclassic theorists indicate the dependence of utility on self-interested preferences [4]. They argue that consumers can only get utility from an asset just by physically using it. However, currently there are many economists defending the possibility of getting utility from an asset without physically using it. Especially, environmental philosophers define another approach which is called rubric

intrinsic [5, 6, 7]. Intrinsic value, disregarding human usefulness, evaluates an asset based on its intrinsic property. This kind of evaluation earns importance when a unique ecosystem or endangered species are the subject of study. Intrinsic values are measured according to existence values or expert evaluations.

Other than the intrinsic value method, a variety of techniques have been developed to value environmental goods and resources. Basically, these techniques depend on two main approaches by which individual preferences for environmental assets are directly or indirectly revealed. Indirect approaches are called revealed preferences and based on observed behaviors of individuals. Direct approaches use stated preferences that are displayed on surveys. The Hedonic Price Method (HPM) and Travel Cost Method (TCM) are examples of the indirect approach while Contingent Valuation Method (CVM) employs a direct approach.

2.1.1. Hedonic Price Method

The Hedonic Price Method uses the hypothesis that value of development in an environmental asset or services is exposed in land prices. The value of an environmental asset or resource is collectively measured by calculating the increase in land prices after the implementation of the proposed change. Since the method is based on actual market prices, its application is relatively easy and there is nothing controversial. However, when the environmental asset cannot be identified and measured, HPM is not an appropriate method. For example, if the value of a wildlife area or a lake view is not determined, there is no implicit price for the good assigned by HPM. Therefore, the only way for HPM to assign an environmental asset a market value is to identify and measure it.

Early hedonic studies were often formed according to owner estimates of the property value [8, 9, 10]. Ridker and Henning [8] suggested that the value of air pollution mitigation could be calculated by identifying the land's hedonic price before and after being polluted. This triggered a variety of new research and discussion in the field. Harrison and Rubinfeld [11]; Graves, Murdoch, Thayer, and Waldman [12];

Dunn [13]; Smith and Huang [14]; Chay and Greenstone [15]; Kim, C. W., T. Phipps, and L. Anselin [16] and Palmquist, R. B., and A. Israngkura [17] are among researchers who contributed to the air pollution issue in the HPM literature.

2.1.2. Travel Cost Method

The Travel Cost Method uses the hypothesis that travel expenses, including transportation plus time and spent by people to visit a specific facility, reflect the public's evaluation about the facility. Accordingly, TCM measures the value of an environmental facility by using the travel costs to reach that specified facility. In TCM surveys numerous questions related to transportation are asked to respondents such as the distance they travel, how much time they spent to reach the site, how much time they spent at the site, the expenses they spent for traveling, which places they visited before reach the site, their opinions about the site's environmental quality, and demographic information. Like the HPM, the TCM uses revealed preferences to assign monetary values for a non-marketed asset. With this information, an estimated demand curve for the environmental asset can be constructed [18].

Harold Hotelling [19] was the first researcher who came up with the idea of the TCM. Trice and Woods [20] and Clawson [21] credited Hotelling's suggestions and used TCM for the first time to evaluate a specified facility. Since then, TCM was used many times to value various non-market valuation problems [22].

Although the method was often used to value environmental assets [23, 24, 25, 26, 27], TCM has vital disadvantages. The method assumes that the only aim of the people to come to a specific site is touristic. However, if the visit has more than one purpose, determining the transportation cost may be difficult and so the value of the site may be overestimated. Moreover, measuring the value of time spent traveling may not be easy. Especially, if people enjoy the travel itself, then travel time becomes a benefit, not a cost, and in that situation the value of the site will be overestimated. The availability of substitute sites also affects the value but most of the TCM models cannot realize the substitutes. Furthermore, people choose to live nearby the sites they

value. This leads to low travel costs but higher values for the site. The TCM approach tends to ignore such effects.

Since they can only measure so-called use values, as can be understood, the revealed preferences techniques are of limited use. So-called use values indicate the values of non-marketed assets that are generated from direct use of those assets. To overcome the disadvantages of the revealed preference methods, Contingent Valuation approach was suggested by Ciriacy-Wantrup in 1947.

2.1.3. Contingent Valuation Method

Contingent valuation is a direct survey technique that is widely used by economists to value non-marketed assets [28, 29, 30]. The underlying stated preference approach directly asks respondents the amount they would be willing to pay for a non-marketed good through survey questions [31, 32, 33]. Respondents display their feelings or choices in terms of willingness to pay for the non-marketed good. Willingness to pay can be defined as the maximum amount of money which an individual is ready to pay in order to maintain a specified good or service.

Scenarios that include hypothetical markets for non-marketed goods are constructed and survey respondents are asked to specify their WTPs with respect to those scenarios. Because CVM determines the preferences of consumers based on hypothetical markets rather than observing the actual market behavior, there remains some criticism about the technique [4, 34]. Unlike CVM, traditional data surveys simply ask respondents to specify their own characteristics or actual expenditures rather than a hypothetical value.

In 1947, Ciriacy-Wantrup proposed the contingent valuation technique to evaluate the value of preventing soil erosion. It was the first reference which suggested calculating the value of an environmental asset without applying traditional pricing mechanisms. However, it took more than a decade up to the first implementation when Robert K. Davis [35, 36] used a CVM survey to value the outdoor recreation

to hunters and wilderness lovers. After the sixties, it has been the most employed evaluation technique to value environmental assets in various fields.

CVM is generally used to value environmental goods, services and resources [37, 38]. Through a CVM survey, Wang and Whittington [39] investigated the WTP value to improve air quality in Sofia, Bulgaria. According to the survey results, Sofia residents were willing to pay 4.7 per cent of their incomes for a program promising an improvement in air quality. In 2004, Mark Wardman and Abigail L. Bristow [40] evaluated changes in air quality in Edinburgh by using the CVM approach. They found out that 40.4 per cent of survey respondents were willing to pay for 50 per cent improvement in air pollution and an average WTP value of 1.5 pounds per week which was corresponding to 0.35 per cent of their income levels. James K. Hammitt and Ying Zhou [41] examined the health effects of air pollution by using contingent valuation in three different locations of China. Three different health problems (cold, chronic bronchitis, and fatality) caused by air pollution were used to determine the WTP for an improvement in air quality. In 2003, Noboru Hidano and Takaaki Kato [42] investigated the WTP value of Japanese households for the implementation of anti-global warming policies. According to the results, Japanese people were willing to pay 0.045 per cent of their GDP as tax to prevent global warming if the survey was conducted by mail and 0.015 per cent if the survey was conducted by interview over the period of 2008 to 2012. Both of these numbers are smaller than the average WTP value mentioned in the 2003 report of Japanese Central Environment Council which is approximately 0.06 percent of GDP values over the same period.

Three general survey techniques are used for CVM questionnaires: in-person interviews, telephone interviews, and mail surveys. In-person interviews allow for the use of visual aids and accelerate the pace of the interview. They support the motivation of respondents and are useful for managing biases caused by the complexity of scenarios [31]. The only drawback of in-person interviewing is the high expense associated with it. The primary advantage of telephone and mail surveys starts from this point. They are relatively cheaper than in person interviews. However; motivation and attention of respondents decreases. Especially, telephone interviews are more suitable for short

and simple questionnaires and CVM scenarios. When it comes to mail surveys, like in-person interviews, they allow the use of visual aids. However, there are a few vital drawbacks, particularly related with respondents' reading and understanding level of questions and scenarios. Furthermore; mail surveys are particularly vulnerable to sampling bias. Moreover, whether respondents fill out the survey or not is a chance.

To increase the possibility of valid and reliable answers, a typical CVM study starts by making the respondent familiar about the environmental topic. Explanations about the contents and the range of the environmental issue are given as an introduction. The information about the proposed change and the procedure to finance it are also clearly explained in a hypothetical scenario. Establishment of the scenario is a crucial issue in CVM studies. This is because respondents should be believed that hypothetical situations described in the survey could really happen. Once the information is given, respondents are asked to indicate their WTP's for the asset in question. The questions about WTP values can be arranged in different ways. The main forms are as follows:

- Open-ended: Respondents are directly asked the maximum amount they would be willing to pay for a specified change in an environmental asset.
- Dichotomous choice: This format arranges the questioning in two parts. The first one investigates whether the respondent is willing to pay for a specified change in an environmental asset. There are two choices for this question; yes or no. If willingness exists, then a second question asks whether the WTP is equal to a specified amount.
- Bidding games: In this format, respondents are asked whether they are willing to pay a specified amount of money. If the answer is yes, then the question is again asked with a higher amount. This process continues until a no answer is obtained.

- Payment card: Respondents are shown a card having a range of payment alternatives and then expected to identify their preferences on the card.

The questions related to WTP are followed by a series of socioeconomic and demographic questions. In this way, it is possible to investigate the relationship between WTP and demographic and socioeconomic information.

After the survey is completed and data are collected, non-responsive answers (zero WTPs) in which respondents indicate their opposition to the scenario, payment method or policy are removed. The value of the environmental good can therefore only be estimated on the basis of a sample having valid responses.

CVM results are affected by provision and payment methods in the scenarios. Payment mechanism is a simple tool assessing the monetary value of an environmental good. However; characteristics of the payment mechanisms may seriously impact the WTP values of respondents [43]. For example; payment vehicle (e.g., sales taxes, fees), payment timing (e.g., monthly payment, annually payment) and reliability to the funding source in the payment method can affect the answers of the respondents. Diamond/Hausman [44] and Rowe/Chestnut [45] have identified such differences. Most of the economists and researchers acknowledge that changes into the CVM scenarios can draw out different WTP responses but this situation does not damage the reliability of the CVM technique.

Biases of CVM are discussed in [46, 47, 44, 48, 49]. Some objections to the method are as follows:

- Pure neoclassic economists argue that this method expresses the preferences of respondents based on ethical and altruistic attitudes rather than economic value of assets. Because the non-marketed goods are not both sold or bought in actual markets, there is no market-based instrument that can measure their economic value [50].

- It is argued that individuals may actually not pay the amount they indicate they are willing to pay. Since CVM scenarios are hypothetical, people evaluate them in a hypothetical manner. Researchers cannot ensure that respondents would pay the amounts they indicated when they were actually faced with the situation. Champ et al. [51] demonstrates on an example that hypothetical WTP is significantly higher than the actual value. In most cases there is no ability to observe the respondents' actual behavior. That means the value from a survey cannot exactly reflect the real economic value and cannot be verified. Therefore, using hypothetical markets rather than real ones creates hypothetical bias that led to intense discussions among economists [52, 53, 54].
- Free riding and strategic bias are two other biases frequently criticized by economists. Free riding represents the contradiction between the answers. It occurs due to the understanding level of respondents. Strategic behavior is especially build on the participation expectations of the respondents [52, 55]. That means individuals would enjoy paying for an environmental asset if they knew there are others also paying for it. An overview matrix of various types of strategic behaviors was developed by Mitchell and Carson [31].
- Another bias occurs when individuals do not realize the differences between the specific good that is analyzed (which is the part) and the groups of goods in which that specified good falls (which is the whole) [56, 57, 58]. That problem may lead to a part-whole bias which is also called the mental account bias [58, 59, 60, 61]. Respondents evaluate the environmental good in question while they are actually considering a much wider range of environmental goods [49]. In 1989, Navrud [62] made a CVM study that investigates the effects of mental account bias. He found a large gap in part and whole WTP values indicating the importance of mental account bias.

- It is argued that the quality of information affects the results of CVM surveys. Hanley/Munro [63] and Bergstrom et al. [64] examined the information bias in their CVM surveys by dividing respondents into two groups with differing level of information. A weak bias was found in the first, a stronger bias in the latter study.

Scope of the method and embedding effects are further controversial topics discussed in the CVM literature [59, 65, 66, 67]. However; despite these criticisms, many economists agree that the CVM method offers satisfactory results. The surveys can be designed to reduce the mentioned problems to acceptable levels and come up with reliable results. In 1994 Hanemann [68], and in 1995 Carson et al. [69] and also in 1994 Smith [70] credited the reliability of the method. Some researchers replicated a specific CVM survey a few times to test the reliability of the method [31, 71]. According to Kristm [72], “If the same experiment is repeated a number of times with different samples and careful statistical analysis reveals no correlation between the variables collected then this is a warning flag” indicating low reliability. In 1986, Heberlein and Bishop [73] retested the CVM questionnaire after one year of actual test. They found a substantial correlation between WTP amounts. Loehman and De [74] and Loomis [75] also support the reliability of the CVM approach.

2.2. APPROACHES USED IN ENERGY AND ENVIRONMENTAL POLICY MODELING

The approaches and methodologies used in energy and environmental policy modeling show a wide variety. Even though the models are quite different with respect to their structure and focus, most of them share a common core by inheriting an optimization methodology and elaborating energy-economy interactions.

There are two broad classes of models describing the relationships between the energy sector and the rest of the economy: top-down and bottom-up. The first category approaches the problem from a macro-economic perspective with an aggregate energy sector representation whereas the second one proposes a technology-rich description of energy activities including cost structures, conversion efficiencies and technological limitations from primary to final energy. Top-down label derives from how modelers applied macro-economic theory and econometric techniques to historical data on consumption, prices, incomes and factor costs to model supply and final demand for goods and services. Therefore, top-down models evaluate the system from an economic viewpoint, in contrast to bottom-up models which consider energy systems and conversions in detail. Bottom-up models include technological and engineering details in the analysis.

A bottom-up model determines typically the financially cheapest way of reaching a final demand for energy services. These models describe energy use patterns, technologies and processes in great detail. However, they tend to provide results affected by technological progress rather than the market threshold or non-technical barriers. Top-down models, on the other hand, typically represent technology using relatively aggregated production functions for various sectors of the economy. The common form includes a neoclassical production function with a constant elasticity of substitution between energy service demands, capital, and labor. Continuous substitution among inputs represent what is in the bottom-up approach; a discrete shift from one technology to another. Market and economy-wide feedbacks and interactions between the energy sector and the rest of the economy is the particular focus of the top-down

methodology. However, the models in this category often sacrifice the technological richness of the bottom-up approach.

Both types of models are used to estimate the potential economic effects of energy and environmental policy. Bottom-up models determine the cost of emission reductions by comparing the costs and emissions of different technologies while top-down models use aggregated market data to estimate the overall economic effects of a policy. As can be understood, these two models are actually complementary. They range from single sector models to multi sectoral ones that capture inter-sectoral transactions. An overview of the main modeling approaches is provided in Figure 2.1 below.

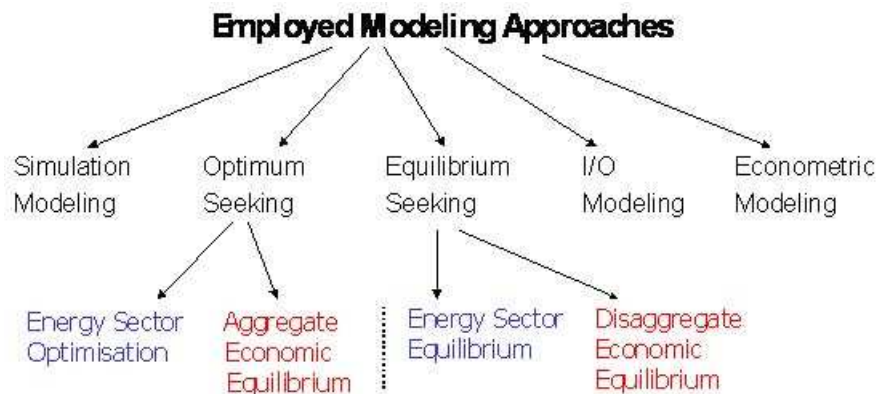


Figure 2.1. Approaches Employed in Energy and Economy Modelling [76]

Energy sector equilibrium models are of the bottom-up type employing partial equilibrium approach. They compute a market equilibrium for all the different end-use sectors included in the model. Costs are embodied as a total of investment, operation and maintenance costs for all sectors including also factor costs and environmental costs like damage assessment and emission taxation. Prices are determined so as to equilibrate supply and demand at least cost. The rich technology information in the models is helpful to assess capital stock turnover. The models MARKAL/TIMES [77], ETP [78], SAGE [79], and MESSAGE [80] can be classified in this category.

Energy sector optimization/simulation models have a detailed representation of energy demand and supply technologies, including end-use, conversion, and production facilities. They are also of the bottom-up type. The detailed technology information

supports explanation of a major part of energy needs. Exogenous scenario assumptions are often developed based on technology vintage models and econometric forecasts and affect the demand and technology developments in the model. There are various versions of this kind of model representation including LEAP [81], ISTUM [82], and CIMS [83].

Aggregate economic equilibrium models are classified under the top-down approach. They describe investment and consumption patterns, and emphasize short-run energy policy dynamics associated with emission reduction. Final demand determines the size of the economy and the models work to balance quantity based on exogenous price. Capital stock turnover and new technology introduction rates are explicitly represented in the model. However, the economy representation is aggregate. There is an economy-wide production function relating capital, labor, energy and other inputs. Because of temporary disequilibrium, underutilization of production capacity, unemployment, and current account imbalances are possible. The models are generally country specific and implicitly reflect past behavior through econometric techniques on time-series data. In the literature, there are various macroeconomic models including MERGE [1], CETA [84], MARKAL-MACRO [85], NEMS [86], MEEET [87], GLOBAL 2100 [88], MIS [89], RICE [90], and GRAPE [91]. These models are widely used to reflect the economic effects of greenhouse gas (GHG) emission reduction policies in a medium to long planning horizon. None of these models, except MERGE, considers the consumer's WTP for CO₂ emission reduction. MERGE computes a WTP value by multiplying GDP with temperature increase. However, the great deal of uncertainty involved and lack of empirical evidence may induce misleading policy implications.

Disaggregate economic equilibrium models are another model category employing the top-down approach. They simulate a sectorally disaggregated market equilibrium for the economy based on microeconomic principles. Wages, prices, and exchange rates are determined so as to bring the market into equilibrium. The parameters are partially calibrated and partially statistically or econometrically determined. The models allow inter-industry interactions and international trade. ABARE [92], G-Cubed [93], GREEN [94], MS-MRT [95], IGEN [96], MIT-EPPA [97], ENVEEM [98],

MOBI-DK [99], GOULDER [100], PESTES [101], JW [102], MULTI [103], DREAM [104] and WorldScan [105] can be given as examples.

Both disaggregated and aggregated economic equilibrium models allow investment levels to be chosen endogenously. However, the disaggregated equilibrium models consider markets by industry category, and allow GDP to be determined by these interindustry interactions. Aggregate equilibrium models, on the other hand, usually include markets for factors in a broader sense (like capital, labor, and energy) and determine GDP from an aggregate production function. The main advantage of the disaggregated approach is that it allows a closer look at non-energy sectors while the aggregate approach allows more detailed analysis of energy markets.

There are also top-down/bottom-up hybrids as technologically detailed computable general equilibrium models such as AIM [106], ABARE-GTEM [92], and SCREEN [107].

3. A CVM APPLICATION TO VALUE CO₂ EMISSION REDUCTION

The objective of the study presented in this chapter is to approximate the WTP of Turkish citizens for CO₂ emission reduction based on a CVM pilot study. The overall flow followed in the survey application is presented in Table 3.1. Details are explained in the following.

3.1. CVM Planning

The purpose of the survey is to determine the WTP of Turkish citizens for CO₂ emission reduction by the help of questions directing them to overview their perceptions, beliefs, attitudes, and actual and intentional behaviors about the reduction. The respondents are asked to value CO₂ emission reduction, which is described as follows: *The residential sector contributes to 38 per cent of CO₂ emissions originating from the production of electricity that is used in the households and from fossil fuel consumption used for cooking, space and water heating. Data from the State Statistics Institute shows that the 8 per cent reduction in CO₂ emissions will provide the same environmental benefits as not driving a car a total of 215 kilometers.*

The questionnaires were arranged in five separate sections including twenty-three questions in total. Most of the questions, to increase the knowledge of respondents, were prepared in Likert-scale¹ format. Rest was formed into multiple-choice format to guide respondents through the survey and also facilitate their understanding of the questions. The questionnaire is provided in Appendix B. In the analysis and evaluation phase, multiple regression analysis is used to examine the results of the survey.

¹A method of measuring attitudes that asks respondents to indicate their degree of agreement or disagreement with statements. The most common scale is 1 to 5, e.g., 1=strongly disagree, 2=disagree, 3=not sure, 4=agree, and 5=strongly agree.

Table 3.1. Steps of the Survey Application

1. CVM Planning
Clarifying survey purpose
Describing the good to be valued in the CVM application (CO ₂ emission)
Determining survey procedures and evaluation approaches
2. Preparation of Questionnaires
Defining scenarios and payment levels
Determining variables
Determining question types
Determining the questionnaire structure
Preparing of survey questionnaire
3. Survey Implementation
Defining survey sample
Forwarding and collecting questionnaires
4. Analyzing Survey Data
Converting responses into soft data
Removing non-responsive answers
Determining results of the survey
Obtaining willingness-to-pay function
5. Verifying Survey Results
Analysis of results
Validity and Reliability Check
6. Conclusion of Survey Results

3.2. Preparation of Questionnaires

There are, with respect to the valuation of CO₂ emission reduction, a number of methodological issues associated with the survey design. In this part, survey scenario, variables concerning WTP, question types and questionnaire structure are defined.

3.2.1. Scenarios, Payment Levels and Variables

CO₂ emission reduction can be supported through many ways such as mandatory or voluntary tax on electricity bills. The collection and expenditure of CO₂ emission reduction fund can be done by public institutions, NGOs or other non-profit organizations. In this study, the payment is assumed to be mandatory collected and controlled by governmental institutions. The scenario created for CO₂ emission reduction is as follows:

“The government is considering a program where all homes and businesses in Turkey would be required to pay X per cent of their electricity bills for three years to decrease the CO₂ emission level. This surcharge will be collected by the government and used by a research institution such as TUBITAK to help fund for the construction of environmentally friendly technologies. Because the proposed surcharge is mandatory, all homes and businesses will be required to pay.

Remembering that all homes and businesses in Turkey will have to pay the same amount if this policy is adopted, would your household support the adoption of this proposed monthly surcharge of X per cent of your electricity bill for three years?”

Two different scenarios including two different payment levels are arranged with respect to the scenario definition above: five per cent and ten per cent of electricity bills (shown as X per cent above). The people who are not willing to pay the value questioned are asked to pay a lower value: one per cent and five per cent, depending on the scenario. In addition, the respondents accepting to the payment are asked to pay a higher value: ten per cent and fifteen percent, depending on the scenario.

Socioeconomic and demographic variables are determined as possible explanatory variables to be included in the WTP function. Hence, income class distribution, age, education, and gender are also investigated to support the understanding of why individuals are willing to pay or why they are not.

3.2.2. Question Types and Questionnaire Structure

The questionnaire is organized of five sections. The first part includes a half-page introductory information describing CO₂ emissions and also explaining the purpose of the survey. The second section provides warm-up questions which make respondents familiar to the energy and CO₂ emission topics. Questions in this section are not related to the primary purpose of the study. Five point likert-scale questions are applied to increase the knowledge of respondents.

The third section begins with background information to make respondents think carefully about their responses. It then continues with the related CVM scenario. This part also provides knowledge for respondents about potential environmental impacts of the scenario. The choice of WTP question type is a methodological issue that significantly affects the responses of individuals. The WTP questions located at the end of the scenario are developed as a combination of dichotomous choice and bidding game formats as mentioned in the foregoing section. These formats are preferred to obtain more information from the respondents. Dichotomous choice format used to understand the validity of the responses. Respondents are asked to mention their reasons for “no” answers. Some of the no answers reflecting opposition to something else not CO₂ emissions are not accepted as valid (e.g. “I am opposed to all new government programs”). Bidding game format is, nevertheless, combined to determine the maximum amount of money an individual can pay. The questions investigating the respondent’s WTP response begin with a yes/no question organized at the end of the scenario. That yes/no question asks respondent whether he/she would be willing to pay a specified amount of money for three years to reduce CO₂ emission. The reason why the payment limited to three years is to make the payment more definite and tangible. The respondents who are not willing to pay for CO₂ emission reduction were asked to give their reasons. If the answer is yes, then the question is again asked with a higher amount. If the answer is no, then the question is again asked with a lower amount.

The questions in the forth section try to determine the environmental consciousness and also attitudes of respondents using again a five-point likert-scale questioning. The final section then examines demographic and socioeconomic data of respondents such as age, gender, education, and income class.

3.3. Survey Implementation

One hundred and ten surveys² were delivered through mail in a two-month period to different locations in Turkey. Seventy-nine surveys responded back. The locational diversity featured to explore the differences in perceptions and behaviors of people from different regions.

3.4. Analyzing Survey Data

3.4.1. Data Input

All the people who were interviewed were actually contributing to their electricity bill payments. The respondents of interest for this research are Turkish residents who pay their own electric bills. However, not all sampled respondents pay their own electricity bill. There is therefore a screening question which directly identifies those respondents who do not pay their electricity bill. Those surveys are removed from the analysis.

Socio economic and demographic backgrounds of respondents are statistically summarized in Table 3.2-3.4. Nine different income class categories are defined in the survey. As evident from Table 3.2, 24.1 per cent, the largest part of the respondents, belongs to the lowest income class category. The second, third and forth income class categories includes 20.3 per cent, 16.5 per cent and 19 per cent of the respondents, respectively. The other categories have a total share of 20.3 per cent. The average household income of the sample is calculated as 1912.5 YTL per month. According to

²The sample size was inevitably limited due to financial restrictions. However, the response rate was high enough to provide input data for the current modeling study. It is hoped that this questionnaire developed for this thesis will serve as a pilot study for a wider application.

data from TSI, this value is around 1050 YTL. In categorical regression analysis, the ranking and grouping options are selected according to an optional distribution. In this analysis the number of categories are determined as data follows normal distribution. Firstly, fifth, sixth and seventh categories and then eighth and ninth categories were combined in two new levels and the resulted group number turns to six.

Table 3.2. Income Classes of Respondents

Category	Income Classes	Number of	Percentage
		Respondents	Distribution
1	less than 1000	19	24.1%
2	1000-1500	16	20.3%
3	1500-2000	13	16.5%
4	2000-2500	15	19.0%
5	2500-3000	2	2.5%
6	3000-3500	3	3.8%
7	3500-4000	3	3.8%
8	4000-4500	3	3.8%
9	more than 4500	5	6.3%
TOTAL		79	100.0%

Table 3.3 specifies the distribution of respondents with respect to gender and education categories. There are six different education categories investigated in the CVM survey. University graduates have the largest share with 31.6 per cent. High school and master graduates follow it with 26.6 per cent and 22.8 per cent, respectively. As primary and secondary education graduates have a very low share, they are merged. Similarly, the category of master was combined with PhD. At the end, four education levels were used in the regression analysis.

Table 3.3. Education Levels of Respondents

	Female		Male		Total	
primary	4	(5.1%)	5	(6.3%)	9	(11.4%)
secondary	0	(0.0%)	2	(2.5%)	2	(2.5%)
high school	11	(13.9%)	10	(12.7%)	21	(26.6%)
university	11	(13.9%)	14	(17.7%)	25	(31.6%)
master	7	(8.9%)	11	(13.9%)	18	(22.8%)
PhD	2	(2.5%)	2	(2.5%)	4	(5.1%)
TOTAL	35	(44.3%)	44	(55.7%)	79	(100.0%)

Table 3.4 presents the age profile of respondents. Respondents' ages were examined under six different categories. 48.1 per cent fall into the second category. The first category follows with 25.3 per cent. The age categories, above 35, have a low share and are grouped to feature a meaningful analysis in the upcoming regression part.

Table 3.4. Age Profile of Respondents

Category	Age	Number of Respondents	Percentage Distribution
1	18-24	20	25.3%
2	25-34	38	48.1%
3	35-44	9	11.4%
4	45-54	8	10.1%
5	55-64	3	3.8%
6	more than 65	1	1.3%
TOTAL		79	100.0%

3.4.2. Specifying and Removing Non-responsive Answers

One of the critical methodological issues of CVM is to identify non-responsive answers (protest zero values) from legitimate zero values and exclude them from further analysis. This can be done by identifying the reasons why respondents refuse to pay for CO₂ emission reduction. Protest zero values are given by respondents because of their opposition to the context (it can be opposition to the scenario, payment method, provision arrangements or interview technique), although they actually value the CO₂ emission reduction. Legitimate zero values, on the other hand, can be defined as the values that respondents refuse to pay because either they do not consider the good in question important or they do not have enough income to be able to pay it. To separate the protest zero values from legitimate ones, respondents are asked to specify their reasons for why they disagree with stating a WTP value. In this study, a total of fifteen respondents gave zero value to the CO₂ emission reduction. Seven of them were evaluated as protest zero values.

3.4.3. Determining Results of the Survey

The primary objective of this study is to define a WTP function based on the defined independent variables. The systematic differences among the responses according to several variables are evaluated using multiple regression analysis. Since a respondent's income class, his/her age and education level may constrain his or her WTP, such demographic and socioeconomic indicators are considered as independent variables that can affect the WTP.

The statistical analysis tool NCSS/PASS solver was used for the regression analysis. The method of ordinary least squares is applied to estimate the regression coefficients.

A step wise linear regression is performed to determine the model which best fits the set of observed data. The independent variables which give the highest explanatory power (R-square value) are explored. The variables are evaluated in categorical manner. The highest R-square result is reached when age, education and income class are all included in the model as categorical independent variables. The R-square value obtained in this manner is 0.6101 but the adjusted R-square value turns out to be 0.4656. The significant difference between those two values indicates the good chance that non-significant terms have been included in the model. Analysis of Variance (ANOVA) and hypothesis testing are then applied to check the significance of variables. According to both t-test and ANOVA results, age and education are determined as the insignificant terms of the model. Therefore, they are eliminated from the analysis and WTP is displayed as a function of income classes only. The new R-square and adjusted R-square values are obtained as 0.5718 and 0.5049, respectively. This can be considered as a good fit when compared to similar studies.

The t-test, confidence intervals on the individual regression coefficients, and ANOVA results are illustrated in Table 3.5 and 3.6. According to the t-test results, all null hypotheses related with the individual regression coefficients are rejected.

That is the regressor variables significantly contribute to the model. The Confidence Interval test also indicate the significance of the variables.

Table 3.5. T-test and Confidence Interval Results of The Model

Independent Variable	Regression		T-Value	Reject	Power	Lower-95%	Upper-95%
	Coefficient	Standard	to test	H0 at	of Test	Confidence	Confidence
	B(i)	Error	H0: B(i)=0	5%?	at 5%	Limit	Limit
Intercept	7.262	0.791	9.182	Yes	1.000	5.651	8.873
Iclass ₁	-5.575	0.928	-6.011	Yes	0.999	-7.464	-3.686
Iclass ₂	-5.243	0.945	-5.546	Yes	0.999	-7.168	-3.317
Iclass ₃	-4.708	0.969	-4.860	Yes	0.997	-6.682	-2.735
Iclass ₄	-5.527	0.945	-5.846	Yes	0.999	-7.453	-3.601
Iclass ₅	-4.329	0.945	-4.579	Yes	0.993	-6.254	-2.403

(Note: The T-Value used to calculate these confidence limits was 2.037.)

Table 3.6. Analysis of Variance

Model			Sum of	Mean		Prob	Power
Term	DF	R ²	Squares	Square	F-Ratio	Level	-5%
Intercept	1		249.782	249.782			
Model	5	0.572	80.212	16.042	8.548	0.000	0.999
Iclass	5	0.572	80.212	16.042	8.548	0.000	0.999
Error	32	0.428	60.058	1.877			
Total(Adjusted)	37	1.000	140.269	3.791			

As evident from the ANOVA Table, the fitted model explains 57 per cent variation in data. There is an F-value of 8.548 and only a 0.001 per cent chance that a Model F-value this large could occur due to noise. According to the results of this analysis, it is clear that there is no need to be suspicious about the significance of the variable “income class”.

3.5. Verifying The Survey Results

After testing the significance of the model, the adequacy of independent variables, and conducting an analysis of variance, underlying assumptions on the residuals (assumed to be normally and independently distributed) were checked. Both mathematical and graphical analysis were applied to check the normality of the residuals. Results of some normality tests are given in Table 3.7.

Table 3.7. Normality Test Results

Test Name	Test Value	Probability	Reject H0: ($\mu=0$)	Decision
		Level	At Alpha = 20%?	
Shapiro Wilk	0.984	0.862	No	Accept Normality
Anderson Darling	0.276	0.657	No	Accept Normality
D'Agostino Skewness	-0.418	0.676	No	Accept Normality
D'Agostino Kurtosis	-0.531	0.595	No	Accept Normality
D'Agostino Omnibus	0.457	0.796	No	Accept Normality

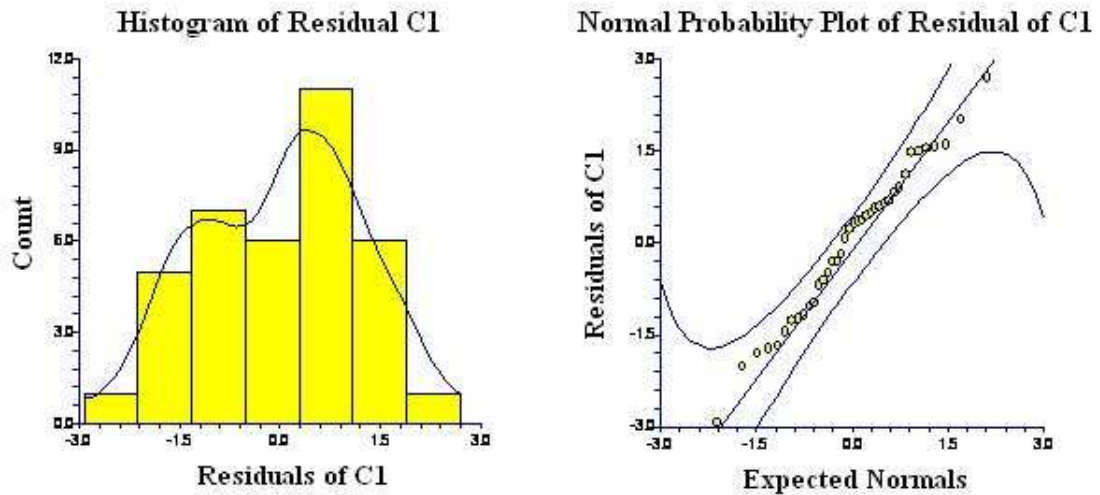


Figure 3.1. Histogram and Normal Probability Plot of Residuals
(C1: Willingness to Pay)

Histogram and normal probability plot of residuals are used to check normality. The confidence bands shown in Figure 3.1, serve as a visual reference for departures from normality. One data point falling outside the bands did not pass the outlier test and was eliminated from the analysis. As the remaining points fall along the straight line the underlying appropriate distribution can assumed to be normal. The independence assumption on the residuals is checked from this plots in time sequence and versus fitted values (see Appendix B). As can be seen from Appendix B, no particular fitted structure and no correlation between residuals can be identified. Moreover, the homogeneity of variance is verified through statistical tests (see Appendix B).

The equation obtained from the multiple regression analysis of the data is as follows:

$$\begin{aligned}
WTP &= 7,262 - 5,575 \cdot IClass_1 - 5,243 \cdot IClass_2 \\
&- 4,708 \cdot IClass_3 - 5,527 \cdot IClass_4 - 4,329 \cdot IClass_5 + e \quad (3.1)
\end{aligned}$$

where

WTP : willingness to pay of a representeting household to increase RET use for CO₂ reduction so as to comply with European regulations,

$IClass_1$: percentage of respondents in Income Class₁, i.e. having a monthly income of 1000 YTL or below,

$IClass_2$: percentage of respondents Income Class₂, i.e. having a monthly income between 1000 YTL and 1500 YTL,

$IClass_3$: percentage of respondents Income Class₃, i.e. having a monthly income between 1500 YTL and 2000 YTL,

$IClass_4$: percentage of respondents Income Class₄, i.e. having a monthly income between 2000 YTL and 2500 YTL,

$IClass_5$: percentage of respondents Income Class₅, i.e. having a monthly income of 2500 YTL and above,

e : normal and independent distributed random error.

The negative effect of income classes on WTP value depends on the regression coefficients coming from multiple regression analysis. As it can be seen from Equation 3.1, the regression coefficients have declining trends as income classes increase. Since the coefficients are negative, there is an inverse proportion between income class categories and the WTP value. Moreover, it can be observed from the coefficients that

higher income households have a higher WTP. However, income class four is different from the others as it does not harmonize the declining trend. An explanation for this might be the effect of education. For this income class only 33 per cent are university and master/PhD graduates whereas the share of university and master/PhD graduates is at least 61 per cent in other categories except the lowest income class.

4. THE MODEL

4.1. Model Interactions

This chapter presents an energy-economy-environment integrated policy analysis model that is developed to study economically sustainable energy and environmental policies for Turkey. The model is composed of three main modules, namely energy, economy and environmental sub models.

The model aggregates energy demands, capital requirements and labor inputs under an economy-wide nested CES (Constant Elasticity of Substitution) production function. Growing energy demand is met by increased supply produced by various alternatives including a variety of renewable energy technologies. The associated environmental sub model includes feedback links both to the energy sector and economy as defined by the WTP of customers. Figure 4.1 provides an illustration of model interactions.

The sub models are linked to obtain equilibrium solutions through utility maximization over a planning horizon of T periods. The utility function is the totality of the discounted logarithm of consumption (C_t) which is compounded periodically. Each individual time period identifies a representative year, t . The objective function is as follows:

$$\max \sum_t^T \Delta_t \log C_t \quad (4.1)$$

where Δ_t is the annual discount rate.

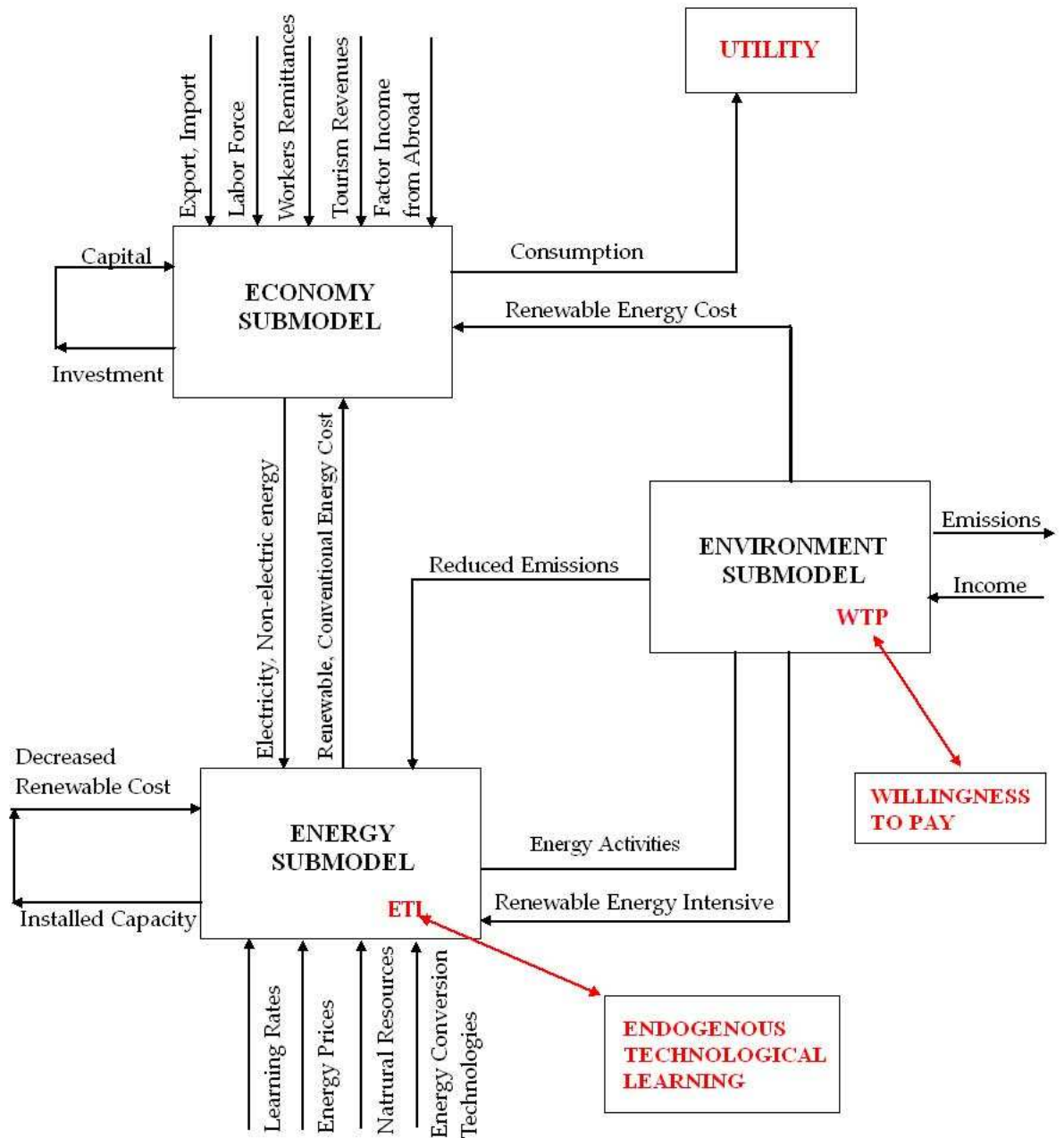


Figure 4.1. Illustration of Model Interactions

4.2. The Economy Submodel

The economy is represented by an aggregate production function in which capital, labor, and different energy forms are intermediate inputs to determine GDP. GDP for period t is computed by the basic macroeconomic identity.

$$GDP_t = C_t + I_t + X_t - M_t \quad (4.2)$$

where I_t , X_t , and M_t represent investments, exports, and imports, respectively. Production is described within a nested structure of an economy-wide neoclassical production function aggregating energy service demands (E_t , NE_t), and primary factors (K_t , L_t) at a constant elasticity of substitution (the elasticity of substitution between the primary and energy aggregate pairs, $\sigma = 1/(1 - \rho)$). Energy comes up from the aggregation of electricity (E_t) and non-electric energy (NE_t) at a unitary elasticity of substitution (Cobb-Douglas). Capital (K_t) and labor (L_t) are combined in Cobb-Douglas form to yield the primary aggregates. A putty-clay representation is adapted in the production function, i.e. substitution is allowed only among newly added variables whereas the remaining stocks remain unchanged. The incremental production in period t is then

$$YN_t = \gamma_t \left[\alpha_t \left[KN_t^{sk} \cdot LN_t^{sl} \right]^\rho + \beta_t \left[EN_t^{se} \cdot NEN_t^{sne} \right]^\rho \right]^{1/\rho} \quad (4.3)$$

where γ_t , α_t , β_t are scale parameters. The letter N , added to the end of all variables, indicates the representation of the incremental values newly added to existing stocks. The parameters sl , sk , se , and sne stand for the value shares of labor, capital, electricity and non-electric energy, respectively. Total production for period t is calculated from the addition of new production to the stock surviving from the previous period, i.e.

$$Y_t = YN_t + \lambda^p \cdot Y_{t-1} \quad (4.4)$$

where p is the number of years between two time periods. The constant λ is the annual survival factor which reflects the rate of decline in existing stocks due to retirement.

The same relations are also established for the new stocks of other inputs (K_t , E_t , NE_t).

$$K_t = KN_t + \lambda^p \cdot K_{t-1} \quad (4.5)$$

$$E_t = EN_t + \lambda^p \cdot E_{t-1} \quad (4.6)$$

$$NE_t = NEN_t + \lambda^p \cdot NE_{t-1} \quad (4.7)$$

Increments in capital during a p year period are defined as a function of investments of previous and current periods.

$$KN_t = 1/2 \cdot p \cdot (I_t + I_{t-1}) \quad (4.8)$$

A foreign trade constraint restricts imports so as not to exceed the sum of exports (X_t), imports (M_t), factor incomes from abroad (F_t), worker remittances (W_t), and tourism revenues (TR_t).

$$X_t \geq M_t - F_t - W_t - TR_t \quad (4.9)$$

By setting upper and lower bounds for import and export as a fraction of GDP, foreign trade values are restricted so as to be able to follow the optimal time path anticipated by utility maximization. In this way a possible distortion due to market imperfection is overcome.

$$\begin{aligned} X_t &\geq \eta_1 \cdot GDP_t \\ M_t &\leq \eta_2 \cdot GDP_t \end{aligned} \quad (4.10)$$

Energy demand and cost relationships establish the link between the energy and economy sub models. For example, gross production (Y_t) is defined as the sum of GDP, total costs for conventional energy (ECC_t), and total costs for new renewable energy (ECR_t).

$$Y_t = GDP_t + ECC_t + ECR_t \quad (4.11)$$

4.3. The Energy Submodel

The energy sub model differentiates primarily between two groups of energy consumption: electricity (E_t) and non-electric energy (NE_t).

$$E_t = \sum_k ELEC_{k,t} \quad (4.12)$$

$$NE_t = \sum_m NELEC_{m,t} \quad (4.13)$$

$ELEC_{t,k}$ and $NELEC_{t,m}$, represent technology type k and fuel type m used for generating electricity and non-electric energy, respectively. Power plant technologies using coal, lignite, oil, natural gas, uranium and hydro are included in the model. Coal, lignite, oil, and natural gas are chosen as the main sources for non-electric energy.

Conventional energy cost (ECC_t) is computed as the totality of the all fossil fuels and hydroelectric energy costs producing both electricity and non-electric energy while renewable energy cost (ECR_t) is the sum of the four different new renewable energy types used in the model.

$$ECC_t = \sum_k ELEC_{t,k} \cdot ELECPR_{t,k} + \sum_m NELEC_{t,m} \cdot NELECPR_{t,m} \quad (4.14)$$

$$ECR_t = \sum_l REN_{t,l} \cdot RENPR_{t,l} \quad (4.15)$$

in which $REN_{t,l}$ shows the consumption in each type of the renewable energy carriers (l) into period t . All conventional power plants (oil, coal, lignite, natural gas, hydroelectric

energy) are assumed to have a useful life of 30 years and $p/30$ of initial capacities ($ELEC0_k$ and $NELEC0_k$) is depreciated at each time period of p years. The new stock relation for each type of power plants producing electricity is as in Equation 4.16. $ELECINC_{k,t}$ represents the incremental capacity for k type of electric energy in period t . Similarly, these incremental relationships are valid for non-electric energy plants. $NELECINC_{k,t}$ represents the incremental capacity for k type of non-electric energy in period t as it happened in electricity case. The same relations are also established for renewable energy technologies (RET) with a useful life of 30 years.

$$\begin{aligned}
& \text{if } t \leq 30/p, \\
& ELEC_{k,t+1} = ELEC_{k,t} + p \cdot ELECINC_{k,t+1} - p/30 \cdot ELEC0_k \\
& NELEC_{k,t+1} = NELEC_{k,t} + p \cdot NELECINC_{k,t+1} - p/30 \cdot NELEC0_k \\
& REN_{k,t+1} = REN_{k,t} + p \cdot RENINC_{k,t+1} - p/30 \cdot REN0_k \\
& \text{if } t > 30/p, \\
& ELEC_{k,t+1} = ELEC_{k,t} + p \cdot ELECINC_{k,t+1} - p \cdot ELECINC_{k,t-(30/p)} \\
& NELEC_{k,t+1} = NELEC_{k,t} + p \cdot NELECINC_{k,t+1} - p \cdot NELECINC_{k,t-(30/p)} \\
& REN_{k,t+1} = REN_{k,t} + p \cdot RENINC_{k,t+1} - p \cdot RENINC_{k,t-(30/p)} \quad (4.16)
\end{aligned}$$

The technical and economic performance and productivity of a technology substantially increases as producers and consumers gain more experience with that technology. This empirical artifact [109, 110, 111, 112, 113] is implemented in the current model setting to evaluate the prices of renewable energy technologies. Investment and thus production costs are reduced by the learning rate for each doubling of cumulative installed capacity (Equation 4.17). The price reduction for solar, wind, bioenergy and geothermal energy is computed using a typical learning curve [114, 115] as

$$RENPR_{t,k} = RENPR0_k \cdot CUM_{t,k}^{b_k} \quad (4.17)$$

where $RENPR_{t,k}$ is the cost for each type of renewable energy in time period t . $RENPR0_k$, $CUM_{t,k}$, and b_k represent the initial price, cumulative production, and

learning index for each type of renewable energy, respectively. In the energy sub model, particular emphasis is given on new RET.

$$CUM_{t,k} = REN_{t,k}/REN0_k \quad (4.18)$$

Their cost is related to a WTP function which defines the willingness of consumers to pay an additional cost for the reduction in CO₂ emissions via an increased use of RET-based electricity. The WTP equation is defined in the environmental sub model.

4.4. The Environmental Submodel

The WTP equation is based on data gathered from a pilot survey conducted on a randomly selected set of 86 individuals across different parts of Turkey. The CVM was employed as a generally favored survey technique for assigning monetary values on non-marketed assets such as environmental goods and services not bought or sold in a marketplace. People were directly asked how much their households would be willing to pay for CO₂ reduction to be reflected in their electricity bills. Survey results are evaluated using multiple regression analysis and the resulting WTP equation is integrated into the model.

The WTP function emerging from the regression analysis assigns a WTP value for a representative household, which is defined as a group of one or more people living in the same house, pooling their incomes and expenditures and paying the electricity bill collectively. In order to obtain a nationwide WTP value, the result is multiplied by the total number of households.

$$\begin{aligned} WTP_t = & HN_t \cdot (7,262 - 5,575 \cdot IClass_{1,t} - 5,243 \cdot IClass_{3,t} \\ & - 4,708 \cdot IClass_{3,t} - 5,527 \cdot IClass_{4,t} - 4,329 \cdot IClass_{5,t}) \quad (4.19) \end{aligned}$$

$$HN_{t+1} = HN_t \cdot (1 + \omega)^p \quad (4.20)$$

where HN_t and $IClass_{z,t}$ respectively represent the total number of households and the percentages of the households entering income class z in period t . The parameter ω symbolizes the annual household growth rate. Average monthly incomes of the households are disaggregated into five sequential classes as defined by the regression equation (see Equation 4.19). Each income class is represented by an independent variable. Since the analysis was done using categorical variables, the income classes do not represent actual monetary quantities, but percentages. The percentage of a class is obtained by dividing the number of households entering a particular category to the total number of households surveyed.

Since income classes are related to each other, a growth in one class implies a decline in another one. It is assumed that an increase in one class is caused by the increase in income of people coming from a subjacent class (not from other higher or lower classes). In this way, there is an order of growth. While the number of people belonging to an income class increases because of the people coming from a subjacent group, there is also a decrease caused by the people shifting to the upper class. Therefore, there is a need to calculate the net growth value. The net growth value equation for each period t is as follows.

$$IClass_{z+1,t+1} = IClass_{z+1,t} \cdot (1 + \psi)^p - IClass_{z+2,t} \cdot ((1 + \psi)^p - 1) \quad (4.21)$$

where ψ is the annual growth rate of income. In the first income class, the population growth rate is used as the enlarging factor since there is no subjacent group anymore. The relationship of first income class is represented as follows.

$$IClass_{1,t+1} = IClass_{1,t} \cdot (1 + v)^p - IClass_{2,t} \cdot ((1 + \psi)^p - 1) \quad (4.22)$$

where v is the annual growth rate of population.

The WTP value is used as a lower bound for ECR_t so as to ensure the new RETs installations are at least as high as the consumers' WTP, ie.

$$ECR_t \geq WTP_t \quad (4.23)$$

CO₂ emissions originating from the use of fossil fuels are calculated as follows.

$$CO_2 = EN E_{k,t} \cdot ef_k \quad (4.24)$$

$EN E_{k,t}$ represents the conventional energy consumption both from electricity and non-electric energy in period t and ef_k reflects the emission factors for these energies.

4.5. Model Calibration

The model has been calibrated for the case of Turkey using year 2000 as the reference data. Furthermore, in year 2000, there were no extra ordinary political, social or economic events that could affect energy consumption habits and/or economic balances.

4.5.1. The Database

Base year macroeconomic and energy data values are as follows.

Table 4.1. Macroeconomic Data for Base Year 2000

Macroeconomic Data	Value (10 ⁹ dollar)
GDP	205.07 (1)
Investment	135.84 (2)
Consumption	95.88 (2)
Export	27.78 (1)
Import	54.50 (1)
Factors coming from abroad	0.98 (1)
Workers Remittances	4.56 (1)
Tourism Revenues	7.64 (1)

Data Sources: (1) SPO, 2005; (2) TSI, 2005.

4.5.2. Basic Assumptions and Model Parameters

The planning horizon covers ten successive five year periods starting from year 2000. All power plants are assumed to have a useful life of 30 years and straight-line depreciation is employed, i.e. 1/6 of each plant's capacity is depreciated at every period. The basic macroeconomic assumptions used in the base scenario are illustrated on Table 4.3. These are essentially based on historical estimates and expert guess. The learning rates for new RETs are taken from [116].

As mentioned in Section 4.4, the income classes used in the WTP equation represent the percentages of certain income groups. The distribution of these groups for the BAU scenario is computed using the clusters formed by questionnaire results. The

Table 4.2. Energy Data for Base Year 2000

Electric Energy Use	TWh	cent/KWh
Oil	7.19 (1)	4.22 (1)
Coal	3.60 (1)	4.55 (1)
Lignite	35.63 (1)	3.46 (1)
Hydro	30.09 (1)	2.00 (1)
Natural Gas	42.60 (1)	4.22 (1)
Others	1.89 (1)	6.00 (1)
Non-electric Energy Use	Mtoe	\$/tonne
Oil	8.21 (1)	164.93 (1)
Coal	29.83 (1)	100.52 (1)
Lignite	13.58 (1)	100.52 (1)
Natural Gas	13.58 (1)	169.21 (1)
Others	5.08 (1)	81.40 (1)
Renewable Energy Use	TWh	cent/KWh
Wind	0.03 (2)	3.36 (3)
Solar	0.00 (2)	25.88 (3)
Biomass	0.13 (2)	7.33 (3)
Geothermal	0.08 (2)	3.05 (3)

Data Sources: (1) TSI, 2005; (2) MENR, 2003; (3) NREL, 2005.

number of households falling into a particular income class is divided by the total number of households surveyed in order to determine the distribution. The results are shown in Table 4.3. First order optimality conditions are used to determine the parameters of the production function.

$$YN_t = \gamma_t \left[\alpha_t \left[KN_t^{sk} \cdot LN_t^{sl} \right]^\rho + \beta_t \left[EN_t^{se} \cdot NEN_t^{sne} \right]^\rho \right]^{1/\rho} \quad (4.25)$$

For the first period γ is equal to one; then it grows at an exogenous growth rate referred to as productivity growth rate. Other parameters for the base year are calculated as follows.

$$YN_t = \left[\alpha_t \left[KN_t^{sk} \cdot LN_t^{sl} \right]^\rho + \beta_t \left[EN_t^{se} \cdot NEN_t^{sne} \right]^\rho \right]^{1/\rho} \quad (4.26)$$

Table 4.3. BAU Assumptions

Macroeconomic Assumptions:		Energy Price Growth Rates:	
Marginal Productivity of Capital	11.5%	<i>Electric Price Growth Rate</i>	2.9%
Cost and Utility Discount Rate	3.0% per year	<i>Non-electric Price Growth Rate:</i>	
Productivity Growth Rate	1.0% per year	Oil	1.9%
Labor Force Growth Rate	1.0% per year	Solid	0.0%
Income Growth Rate	3.0% per year	Natural gas	2.6%
Population Growth Rate	1.3% per year	Others	1.4%
Household Growth Rate	3.7% per year	Learning Rates:	
Upper Limit on Imports	30.0% of GDP	Solar	20.0%
Lower Limit on Exports	20.0% of GDP	Bioenergy	15.0%
Value Share of Capital* (<i>sk</i>)	40.0%	Wind	8.0%
Value Share of Labor* (<i>sl</i>)	60.0%	Geothermal	3.0%
Value Share of Electricity** (<i>se</i>)	45.0%	Income Distribution Share:	
Value Share of Non-electricity** (<i>sne</i>)	55.0%	Income ₁	25.0%
Capital/Output Ratio	3.0	Income ₂	20.0%
Elasticity of Substitution***	0.3	Income ₃	17.5%
		Income ₄	20.0%
		Income ₅	17.5%

* in capital-labor pair

** in energy aggregates

*** between energy pairs and primary factors

When the function is differentiated with respect to capital, resulting partial derivative represents the marginal productivity of capital.

$$\frac{\partial Y}{\partial K} = Y^{1-\rho} \cdot K^{sk \cdot (\rho-1)} \cdot L^{sl \cdot \rho} sk \cdot \alpha \quad (4.27)$$

The function is similarly differentiated with respect to electricity, and the resulting partial derivative is equal to the price of electricity.

$$\frac{\partial Y}{\partial E} = Y^{1-\rho} \cdot E^{sk \cdot (\rho-1)} \cdot NE^{sl \cdot \rho} se \cdot \beta \quad (4.28)$$

Given the marginal productivity of capital (11.5 per cent) and price of electricity (4.06 cent/kWh) for the base year, the parameters α and β are easily computed from the above two equations as follows.

$$\alpha = 0.020$$

$$\beta = 0.149$$

$$\gamma = 1.000$$

Finally, the emission factors [116] used in the model to obtain the CO₂ emissions from each scenario are presented in Table 4.4. The parameter values given in this

Table 4.4. CO₂ Emission Factors

Technology	Electricity	Non-Electric Energy
	Generation	Generation
	(kg CO₂/KWh)	(kg CO₂/KWh)
Coal	0.97	0.33
Lignite	0.98	0.33
Oil	0.85	0.27
Natural Gas	0.56	0.20
Other	0.80	0.31

subsection are the assumptions of the base year. In the next section, results of various scenarios, some of which are obtained from different limitations on the base scenario while some of them are reached with the differentiation in the basic parameters are evaluated.

5. EMPIRICAL ANALYSIS

The programming environment GAMS (General Algebraic Modeling System) has been used as the formulation outlet and the solver MINOS (Modular In-core Nonlinear Optimization System), which relies on a reduced gradient algorithm, has been utilized to obtain model results. The model was run until 2050. However, the last three periods have been discarded and only results until 2035 are reported in order to eliminate end-of-horizon distortions.

The model is calibrated for a Business-As-Usual (BAU) reference scenario with year 2000 being the base year and solved in five year time steps. It is calibrated such that the results for the first period coincide with actual realizations in year 2005 (with a tolerance limit of ∓ 1 per cent). Various environmental scenarios including different CO₂ emission limits for conventional energy plants and different learning indices for new renewable energy plants, different income class growth rates and distribution dynamics for the WTP function are run in addition to the BAU scenario. The scenarios are listed in Table 5.1. In the scenarios, all changes from reference assumptions become effective in year 2010 as the model is calibrated so as to yield the realized values of year 2005. In the emission stabilization scenarios, the emission levels are bound to 2000, 2005 and 2010 emissions of the BAU scenario. The scenario EM4 limits BAU emissions with a 10 per cent growth trajectory, which is approximately half of the reference growth rate.

Learning Index scenarios are defined to see the effects of cost reductions on the diffusion prospects of new renewable energy technologies. In LID, initial learning rates are doubled for all new RETs while LIS, LIW, LIB, and LIG scenarios examine the doublings separately and there by allow to explore the effects of relative price changes.

The scenarios IG1, IG2, and IG3 examine the results of sharp and moderate increases in annual income growth, which is three per cent in the BAU scenario. The other group of scenarios, IP1, IP2, and IP3 reflects the effects of distributional changes among income classes. These changes are constructed around the proposition that

as years go on individuals pass to higher income classes (not to a low-income one). Therefore, shares of the high-income classes are increased while the low-income ones are decreased. In the nuclear energy scenario, NUC, an installed capacity of 5000 MW nuclear power becomes operational (in accordance with official plans/declarations) at a cost of 6.7 cent per kWh [117].

Table 5.1. Scenario Definitions

Scenario	Description
BAU	Business-As-Usual (Baseline)
EM1	CO ₂ Emission Stabilization at 2000 levels
EM2	CO ₂ Emission Stabilization at 2005 levels
EM3	CO ₂ Emission Stabilization at 2010 levels
EM4	10% Growth in CO ₂ Emission per period
LIS	Solar Energy Learning Rate of 40%
LIW	Wind Energy Learning Rate of 16%
LIB	Biomass Energy Learning Rate of 30%
LIG	Geothermal Energy Learning Rate of 6%
LID	Doubling in All Learning Indexes
IG1	Annual Average Income Growth of 6.0%
IG2	Annual Average Income Growth of 9.5%
IG3	Annual Average Income Growth of 12.5%
IP1	I.Class _k : 0.15, 0.20, 0.20, 0.20, 0.25 for k:1,2,3,4,5
IP2	I.Class _k : 0.02, 0.03, 0.05, 0.40, 0.50 for k:1,2,3,4,5
IP3	I.Class _k : 0.00, 0.00, 0.00, 0.50, 0.50 for k:1,2,3,4,5
No-WTP	No Willingness to Pay (Baseline)
NUC	Nuclear Energy Included (Baseline)
MIX1	Combination of EM1 - LID - IG1 - IP1
MIX2	Combination of EM2 - LID - IG1 - IP2
MIX3	Combination of EM3 - LID - IG1 - IP3
MIX4	Combination of EM4 - LID - IG1 - IP1
EM1-NUC	Combination of EM1 - NUC
EM2-NUC	Combination of EM2 - NUC
EM3-NUC	Combination of EM3 - NUC
EM4-NUC	Combination of EM4 - NUC

5.1. BAU Results

GDP, investment, consumption, export and import are the main economic indicators in the model. Their values for the BAU scenario are given in Table 5.2.

Table 5.2. Main Economic Indicators (10^9 dollar): BAU Scenario

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	366.69	204.40	198.96	73.34	110.01
2010	547.30	261.76	340.27	109.46	164.19
2015	752.73	376.92	451.09	150.55	225.82
2020	989.63	498.13	590.47	197.93	296.89
2025	1,265.57	700.77	691.36	253.11	379.67
2030	1,610.72	941.82	829.97	322.14	483.22
2035	2,017.58	1,308.67	910.68	403.52	605.28

Figure 5.1 illustrates the annual growth rates of economic indicators for each period. The high growth rates of the first period represent the economic boom in the corresponding years.

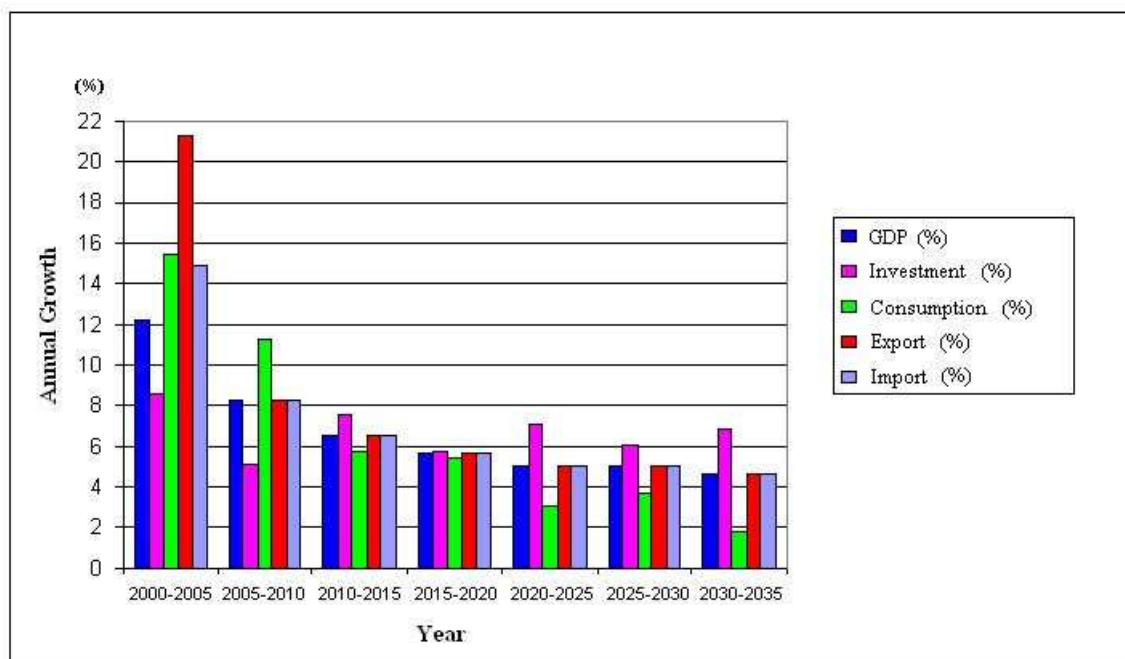


Figure 5.1. Growth Rates of Economic Indicators: BAU Scenario

Main indicators of energy use are presented in Table 5.3 and Table 5.4. As current trends continue, total electricity consumption will rise with an average growth of 4.3 per cent annually. There is a significant increase in electricity production from natural gas and hydroelectricity in the long run. The consumption pattern of non-electric energy is depicted in Table 5.4.

Table 5.3. Electricity Generation by Primary Energy Source (Twh): BAU Scenario

Year	Hydroelectric	Oil	Coal	Lignite	Natural gas	Other ³	TOTAL
2000	30.09	7.19	3.59	35.63	42.59	1.89	120.99
2005	47.65	10.66	12.89	35.04	61.06	1.67	168.97
2010	66.35	14.37	22.69	34.72	80.82	1.45	220.41
2015	86.27	18.34	33.03	34.68	101.95	1.24	275.51
2020	107.45	22.56	43.92	34.95	124.53	1.04	334.45
2025	129.98	27.06	55.39	35.53	148.61	0.84	397.42
2030	158.92	33.05	68.09	42.39	181.39	0.96	484.79
2035	189.34	39.35	81.43	49.59	215.84	1.08	576.63

(3) Other: animal waste

Table 5.4. Non-Electric Energy Generation by Primary Energy Source (Mtoe): BAU Scenario

Year	Oil	Coal	Lignite	Naturalgas	Other ⁴	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.29
2005	37.40	13.01	12.00	21.50	4.21	88.12
2010	45.61	18.11	10.45	29.94	3.34	107.45
2015	54.50	23.55	8.93	38.93	2.46	128.37
2020	64.09	29.33	7.46	48.49	1.58	150.95
2025	74.42	35.48	6.02	58.65	0.71	175.28
2030	90.50	43.38	6.89	71.72	0.67	213.16
2035	107.41	51.68	7.81	85.44	0.64	252.98

(4) Other: animal waste

Oil, coal and natural gas consumptions grow from period to period with different growth rates as it happened in electricity composition. CO₂ emissions from electricity and non-electric energy production rise between 2000 and 2035 with growth rates of 22.2 per cent and 19 per cent. These growth trends correspond to the increase in consumption of both electricity and non-electric energy. Figure 5.2 shows total CO₂

emissions results from BAU scenario. Lignite is the energy source contributing most significantly to the emissions, followed by coal and oil.

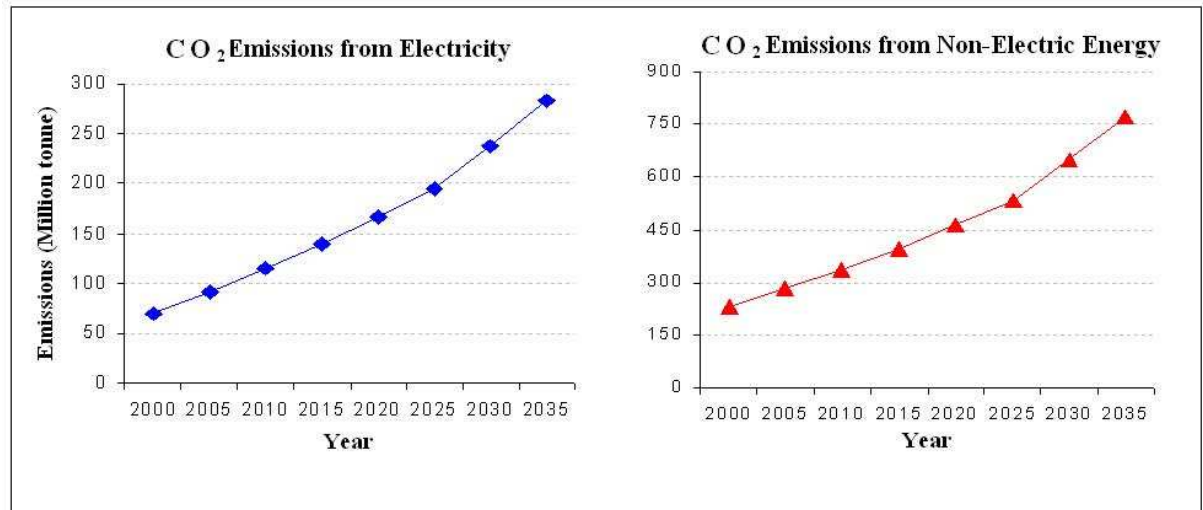


Figure 5.2. CO₂ Emission in the BAU Scenario

Consumption values of renewable energy sources other than hydro (referred to as new renewables in the following) for the interval 2000-2035 are given at Table 5.5. Wind energy is the most preferred renewable energy investment as would be expected (its initial price is lower than others). Bioenergy follows wind as the second most consumed renewable energy form. Currently, there is no electricity production from solar energy in Turkey. The relatively high investment cost of solar PV makes it an unfavorable energy source. Prices remain high and therefore, there is no additional installation of solar power in later periods.

Table 5.5. Renewable Energy Consumption (TWh): BAU Scenario

Year	Solar	Wind	Bioenergy	Geothermal	TOTAL
2000	0.000	0.033	0.127	0.076	0.237
2005	0.000	0.060	0.131	0.139	0.331
2010	0.000	1.145	0.137	0.283	1.566
2015	0.000	1.490	0.144	0.354	1.989
2020	0.000	1.523	0.318	0.430	2.272
2025	0.000	1.557	0.569	0.510	2.637
2030	0.000	1.600	0.913	0.607	3.121
2035	0.000	1.644	1.397	0.710	3.752

The relationship between WTP for CO₂ emission reduction and GDP in the 35 year time horizon is illustrated in Figure 5.3. The plot exhibits an exponential decline in WTP as a per cent of GDP. It shows that, although the WTP increases as an absolute value, its share in GDP declines. However, as GDP grows, WTP stabilizes at about 0.065 per cent of GDP.

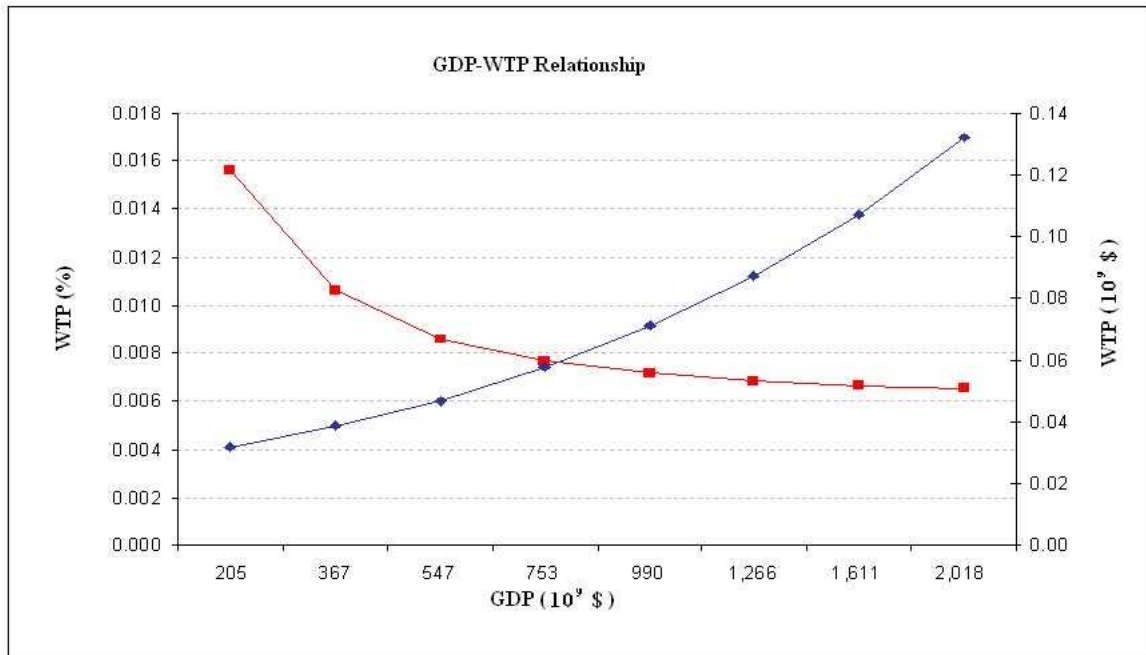


Figure 5.3. Willingness to Pay to Reduce CO₂ Emission

5.2. Results of Emission Stabilizing Scenarios

Emission restrictions give rise to changes in baseline macroeconomic and energy balances. As Table 5.6 shows, scenario EM1 with emission stabilization at 2000 levels leads to great losses in macroeconomic and energy demand values as compared to other emission scenarios. The GDP loss reaches 13.8 per cent in 2010 and 23.7 per cent in 2020.

Emission scenarios lead to shrinkages in economy as well as to technological changes in the energy sector. Changes in energy composition are shown in Figure 5.4. As can be observed, stabilization of emissions gives rise to significant decreases in coal and oil utilization while there are significant increases in natural gas and hy-

Table 5.6. Percentage Reductions in GDP and Fossil Fuel Energy Demand of Emission Restricting Scenarios Compared to BAU

Year	EM1		EM2		EM3		EM4	
	%GDP loss	%demand reduction	%GDP loss	%demand reduction	%GDP loss	%demand reduction	%GDP loss	%demand reduction
2005	6.1	14.9	4.0	12.7	-0.6	0.0	1.9	7.8
2010	13.8	28.6	4.7	21.0	0.2	0.5	4.7	14.8
2015	18.7	39.1	12.7	33.8	5.7	13.5	5.8	19.8
2020	23.7	47.5	17.8	42.7	9.1	23.8	6.7	23.5
2025	28.5	54.4	20.7	48.4	12.9	32.0	7.5	26.3
2030	33.4	62.0	23.8	55.1	17.3	42.2	9.1	32.3
2035	38.6	68.0	26.3	59.6	21.9	49.9	10.6	36.4

hydroelectric energy use (compared to the BAU scenario). In scenario EM1, fossil fuel utilization declines by 28.6 per cent in 2010, 47.5 per cent in 2020, and 62 per cent in 2030. These declines are met by an increase in the demand for RETs (including hydroelectricity). RET utilization grows by 22 per cent, 29 per cent, and 31 per cent in 2010, 2020, and 2030, respectively. However, since the utilization of new renewable energy sources (excluding hydroelectricity) remains below 0.3 per cent of total electricity consumption, they can not be observed in Figure 5.4. 30 per cent growth in the share of new RETs from 2010 to 2020 and 64 per cent growth from 2010 to 2030 are other essential results of the EM1 scenario (see Appendix F).

The results of scenario EM2 differ from EM1 in several aspects. Since emission limits are higher in EM2, additional consumption of hydroelectricity and natural gas is lower than the ones in EM1 as can be seen in Figure 5.4. There are 21 per cent, 42.7 per cent and 55.1 per cent reductions in fossil fuel utilization in response to 22 percent, 30 percent, and 33 per cent increases in RET demand in years 2010, 2020, and 2030, respectively. In addition, the share of new RETs grows 1.2 times from 2010 to 2020 as it happens in EM1, but 3.4 times from 2010 to 2030 (which is significantly higher than the EM1; see Appendix F). Scenario EM3 leads to very similar energy composition trends as EM2. The shrinkage in fossil fuel use in year 2020 and 2030 is lower than in EM2 (by 23.8 per cent and 42.2 per cent, respectively). RET utilization levels are very close to EM2 results with the levels of 29 per cent and 32 percent in years 2020 and 2030 (see Figure 5.4). The share of new RETs grows 43 per cent from 2010 to 2020.

Scenario EM4, where emission limits are allowed to grow by 10 per cent each period, significantly affects the level and mix of energy consumption. The fossil fuel utilization levels in EM4 are higher than in other emission limitation scenarios, except EM3. When EM3 and EM4 results are compared, it is seen that fossil fuel consumption results from scenario EM3 are higher than the ones from EM4 until 2020. However, the consumption levels of EM4 exceed those EM3's after 2020. Fossil fuel utilization decreases by 23.5 per cent in 2020 which is quite close to EM3 results while the number grows by 32.3 per cent in 2030. RET utilization results are very similar in all emission scenarios. Obviously, economic shrinkages leads to higher utility than RET increase. In the emission scenarios, there are constant growths in RET consumptions but floating reductions in macroeconomic indicators. Therefore, similar to other emission restricting scenarios, EM4 leads to 22 per cent, 30 per cent, and 32 per cent increases in RET consumptions in years 2010, 2020, and 2030, respectively.

5.3. Results of Learning Index Scenarios

A doubling in learning rates leads to increases in new RET consumptions compared to the BAU scenario. However, changes in macroeconomic variables and conventional energy demands are very small (in the order of 1/1000). Therefore, they are not sufficient to achieve emission reductions without any decline in conventional energy consumption even though there are increases in new RET utilizations. The increasing trend of new RETs is summarized in Figure 5.5. The share of new RETs grows 10 per cent from 2010 to 2020 when all learning rates double (LID). The growth value reaches 17.7 per cent when the increase is calculated until 2030 (Appendix D and F).

5.4. Results of Income Class Growth Scenarios

Income growth is another parameter that has control on the consumption of new RETs. In scenario IG1, income classes increase with an annual average value of six per cent (instead of three per cent). This increase is 9.5 per cent in IG2 and 12.5 per cent in IG3. However, since the dynamics are complex, there is no direct relation between income class growth and resulting WTP. This is the reason why RET consumption do

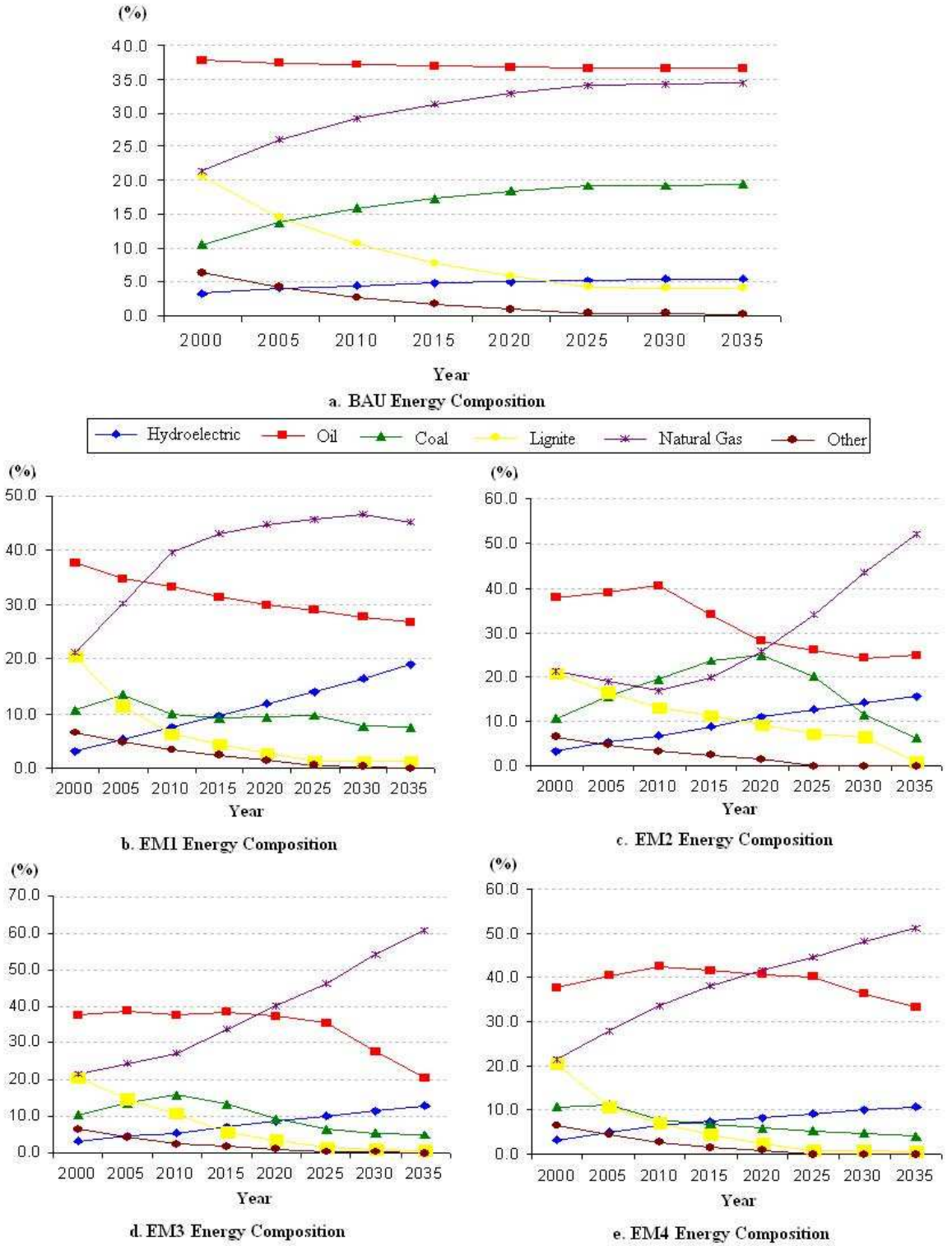


Figure 5.4. Energy Compositions of Emission Scenarios

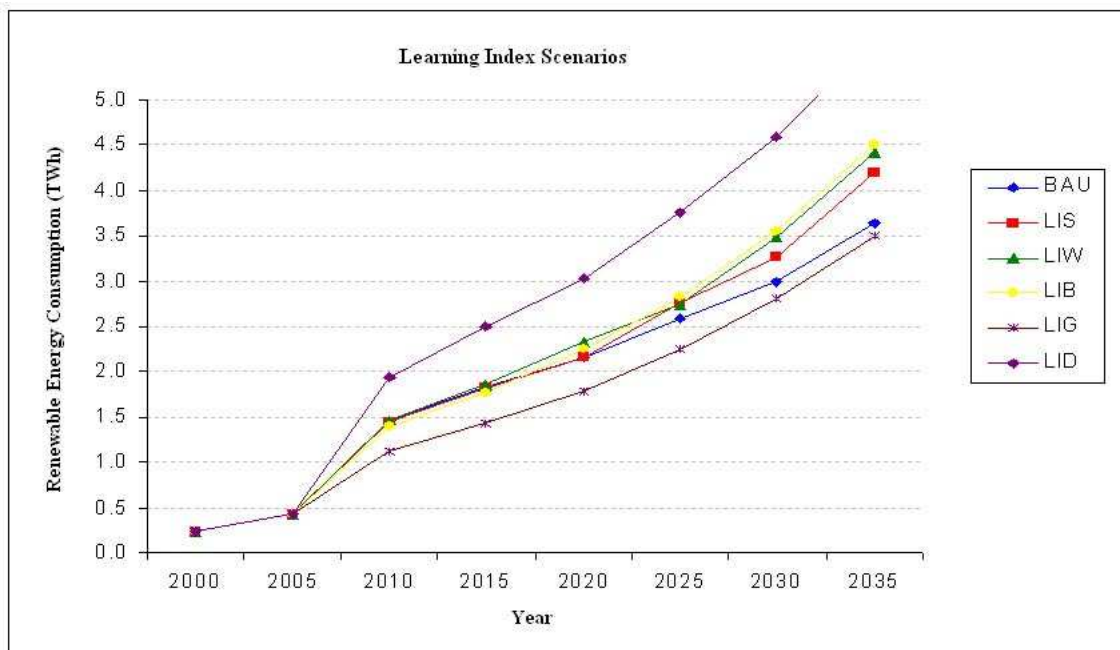


Figure 5.5. Development of New RET (non-hydro) Consumption (TWh): Learning Index Scenarios

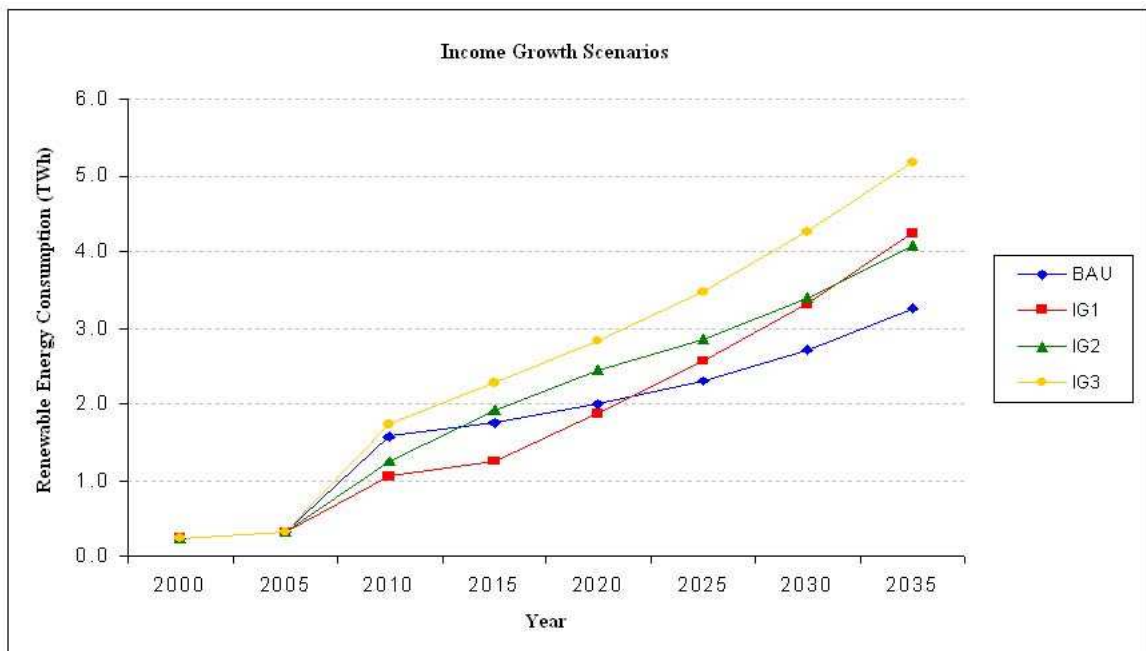


Figure 5.6. Development of New RET (non-hydro) Consumption (TWh): Income Growth Scenarios

not follow an increase path with respect to income class growth increases as can be observed at Figure 5.6. 12.5 per cent growth in income classes per period leads 13.5 per cent increases in the share of new RETs from 2010 to 2020 (Appendix D and F).

5.5. Results of Income Class Distribution Scenarios

The BAU income class distribution percentages are 0.25, 0.20, 0.175, 0.20, and 0.175 as mentioned in sub section 4.5.2. The increase in the share of higher income classes, while the lower ones decline, does not result in a direct proportion of RET utilization. When looking at Figure 5.7, it can be observed that scenario IP2 is the one which follows a higher trend, especially after 2020. The share of new RETs increases by 16.7 per cent from 2010 to 2020 and 36.7 per cent from 2010 to 2030 (Appendix D and F). The increase trends of IP2 and IP3 are very close to each other, but the gap between two curves is opened as time goes to 2035.

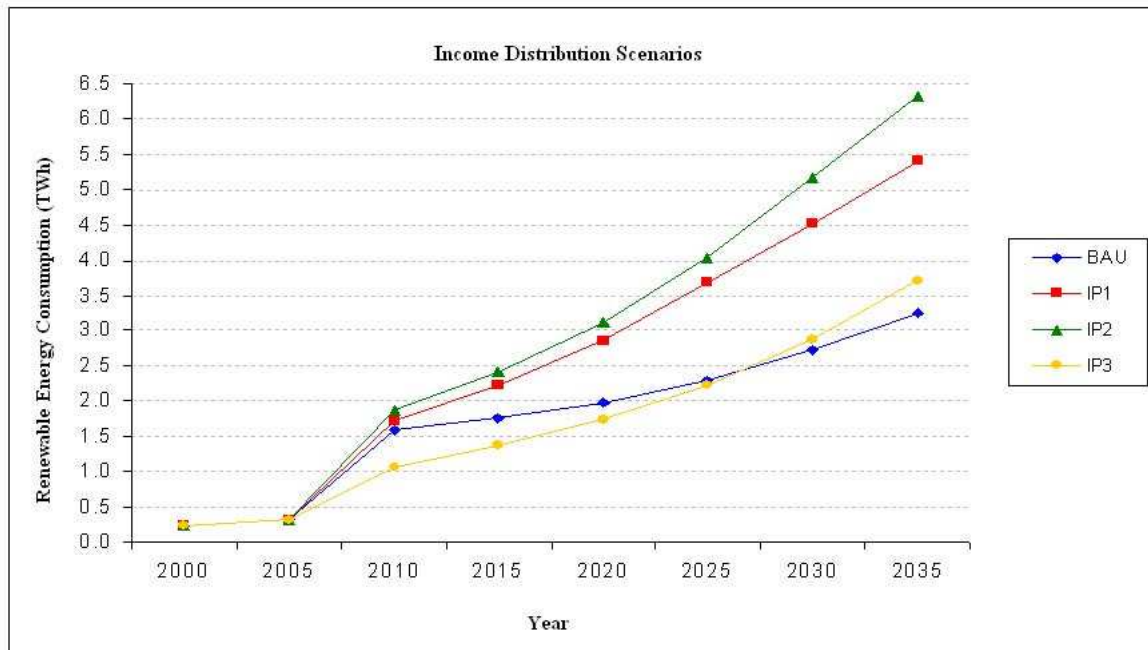


Figure 5.7. Development of New RET (non-hydro) Consumption (TWh): Income Distribution Scenarios

5.6. Results of No-Willingness to Pay Scenario

To examine the impact of WTP on model results, scenario No-WTP is applied. Results show that the changes in macroeconomic values are negligibly small and there is no change in conventional energy consumption values which would be expected as the WTP value does not affect energy consumption except new RETs; see Appendix

C and D for results. Table 5.7 shows RET consumption values. Favorable decrease in new RET consumption, however, is observed when compared to scenario BAU. In each period new RET consumption declines with an average factor of 3.43.

Table 5.7. Renewable Energy Consumption (TWh): No-WTP Scenario

Year	Solar	Wind	Bioenergy	Geothermal	TOTAL
2000	0.001	0.033	0.127	0.076	0.237
2005	0.001	0.060	0.131	0.139	0.331
2010	0.001	0.090	0.137	0.207	0.435
2015	0.001	0.121	0.144	0.278	0.544
2020	0.001	0.153	0.152	0.353	0.659
2025	0.001	0.188	0.162	0.433	0.784
2030	0.001	0.231	0.194	0.531	0.957
2035	0.001	0.275	0.229	0.633	1.138

5.7. Results of Nuclear Energy-Emission Stabilizing Scenarios

Since nuclear energy investments have a long construction lead time of nearly ten years, nuclear power is not consumed until 2015. As a baseline including nuclear power, 5000 MW initial capacity is enforced in 2015 so as to stay in accordance with official declarations. Nuclear energy comprises seven per cent of total electricity demand between 2015 and 2035 (see Appendix D). The baseline scenario including nuclear energy consumption (NUC) is evaluated under the four emission stabilization scenarios. Results are similar to those obtained from the stabilization of emissions in BAU scenario (EM1-EM2-EM3-EM4). Restrictions of emissions induce significant declines in macroeconomic results and energy demand values. Particularly, scenario NUC-EM1 leads to the greatest losses in GDP with 13.8 per cent reduction in 2010 and 21.8 per cent reduction in 2020 (Table 5.8).

As Figure 5.8 shows, emission stabilizing scenarios lead to serious declines in coal, lignite and oil consumptions while hydroelectricity and natural gas demands significantly increase. Coal is the fossil fuel which is mostly affected by the nuclear energy consumption. Particularly after 2015, considerable reduction in coal consumptions are

Table 5.8. Percentage Reductions in GDP Caused by Emission Restrictions

	EM1	NUC-EM1	EM2	NUC-EM2	EM3	NUC-EM3	EM4	NUC-EM4
Year	%GDP	%GDP	%GDP	%GDP	%GDP	%GDP loss	%GDP	%GDP
	loss	loss	loss	loss	loss	loss	loss	loss
2005	6.1	6.1	4.0	4.1	-0.6	-0.7	1.9	1.9
2010	13.8	13.8	4.7	7.2	0.2	-0.6	4.7	4.7
2015	18.7	17.4	12.7	12.6	5.7	3.6	5.8	4.8
2020	23.7	21.8	17.8	17.4	9.1	8.0	6.7	5.9
2025	28.5	26.4	20.7	20.9	12.9	11.9	7.5	6.9
2030	33.4	31.8	23.8	24.1	17.3	16.2	9.1	8.5
2035	38.6	37.1	26.3	26.3	21.9	20.8	10.6	10.0

observed. In scenario NUC-EM1, total fossil fuel utilization declines 23.1 per cent and 45.6 per cent in years 2010 and 2020, respectively. There is 22.7 per cent increase for RET demand (including hydroelectricity) in 2010 and 29.6 per cent increase in 2020. In addition, the share of new RETs grows 42.4 per cent from 2010 to 2020 and also doubles from 2010 to 2030 (see Appendix F). Scenario NUC-EM2 causes serious declines in total fossil fuel consumptions. The reductions become clear especially after 2015, in which nuclear energy starts to be consumed. Demand reduction for fossil fuels reaches 51.1 per cent in 2030. 38 per cent growth in the share of new RETs from 2010 to 2020 and 86 per cent growth from 2010 to 2030 are other important results. Since scenario NUC-EM3 stabilizes emissions at 2010 levels, energy consumption values start to change after 2010 (Figure 5.8). There are 28.8 per cent and 59.7 per cent decreases in fossil fuel consumptions in 2020 and 2030. Parallel to these decreases, there is 42 per cent increase in the share of new RETs from 2010 to 2020 and also a doubling from 2010 to 2030.

Results of scenario NUC-EM4 show that 10 per cent growth in emissions induces 23.2 per cent growth in 2010, 30.2 per cent growth in 2020, and 32.3 per cent growth in 2030. The decreases in coal and lignite consumptions become attractive while oil consumption declines in smaller steps. The share of new RETs gradually increases; 24 per cent between 2010 and 2020, 44 per cent between 2020 and 2030.

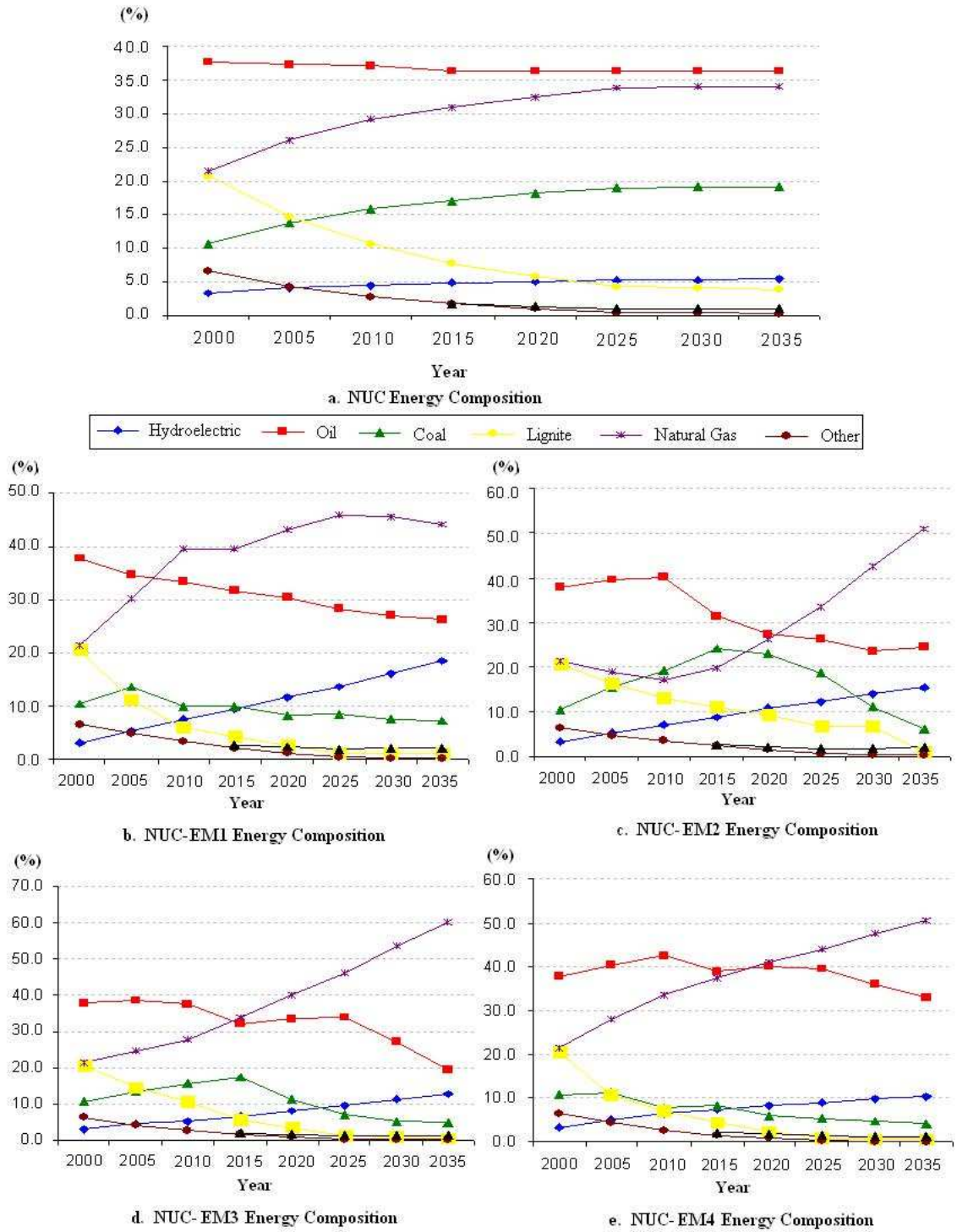


Figure 5.8. Energy Compositions of Emission Scenarios (Nuclear Energy Included)

5.8. Combination Scenario Results

Various combinations of scenarios including different emission limitations, technological learning, and income dynamics are also applied. MIX1 is the combination of scenarios EM1, LID, IG1, and IP1 while MIX2 combines scenarios EM2, LID, IG1, IP2. MIX3 and MIX4 merge scenarios EM3, LID, IG1, IP3 and EM4, LID, IG1, IP1, respectively. The differences between EM1 and MIX1, EM2 and MIX2, EM3 and MIX3, and EM4 and MIX4 are minimal when macroeconomic and conventional energy consumption results are compared. This shows that emission limitation scenarios lead to the most dominating effects. However, there are attractive increases in new renewable energy consumptions because of the total effect of learning index doubling and income changes. Figure 5.9 illustrates these increasing trends of new RETs. Wind energy is the most preferred renewable source in scenario MIX1 with an average growth factor of 6.05 per period while others grow in less rates. Wind energy changes its place with geothermal energy in scenarios MIX2, MIX3, and MIX4. The average geothermal growth factors for MIX2, MIX3, and MIX4 are 2.18, 1.27, and 2.52, respectively (see also Appendix F).

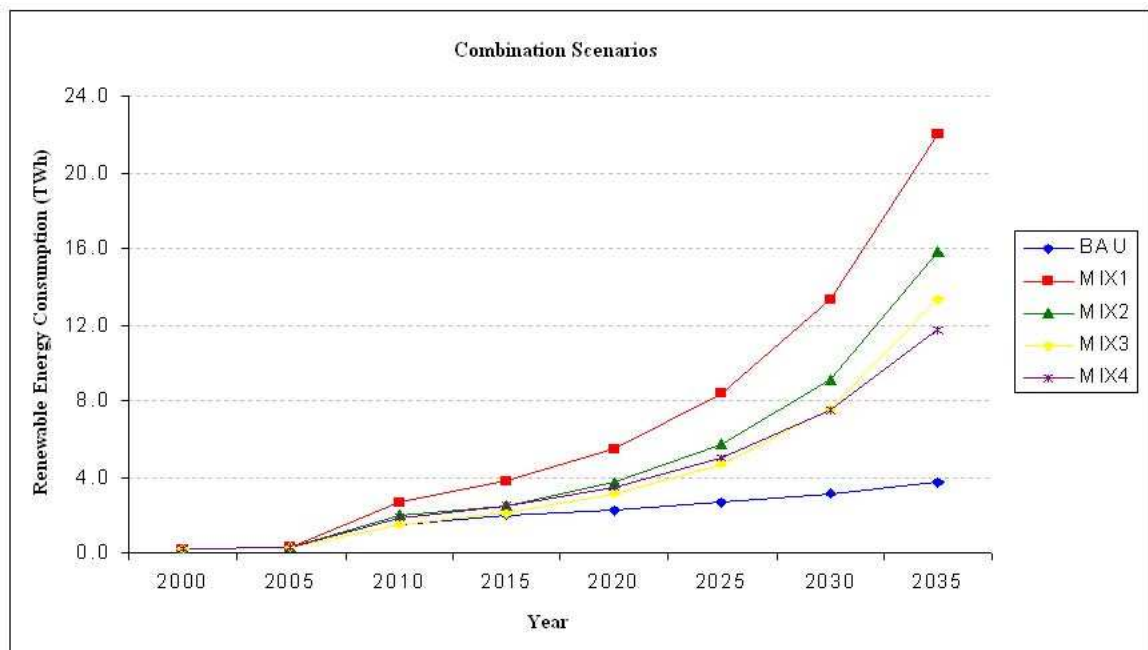


Figure 5.9. Development of New RET (non-hydro) Consumption (TWh):
Combination Scenarios

5.9. Sensitivity Analysis

This section reports on the sensitivity of the results to changes in crucial parameters as well as on the sensitivity to variation in the right hand side of the model. Model sensitivity to cost and utility discount rate; labor force growth rate; oil, gas, and electricity price growth rates; and WTP value is explored.

Firstly, the model has been run with higher and lower discount rates, the value of which is five per cent and one per cent, and then the results have been reported for GDP between 2005-2035. The differences between the new results and BAU are larger in latter periods due to the reflections in utility (Figure 5.10). As expected, the lower the utility discount rate, the higher value is placed on the future utility and the higher the growth in consumption.

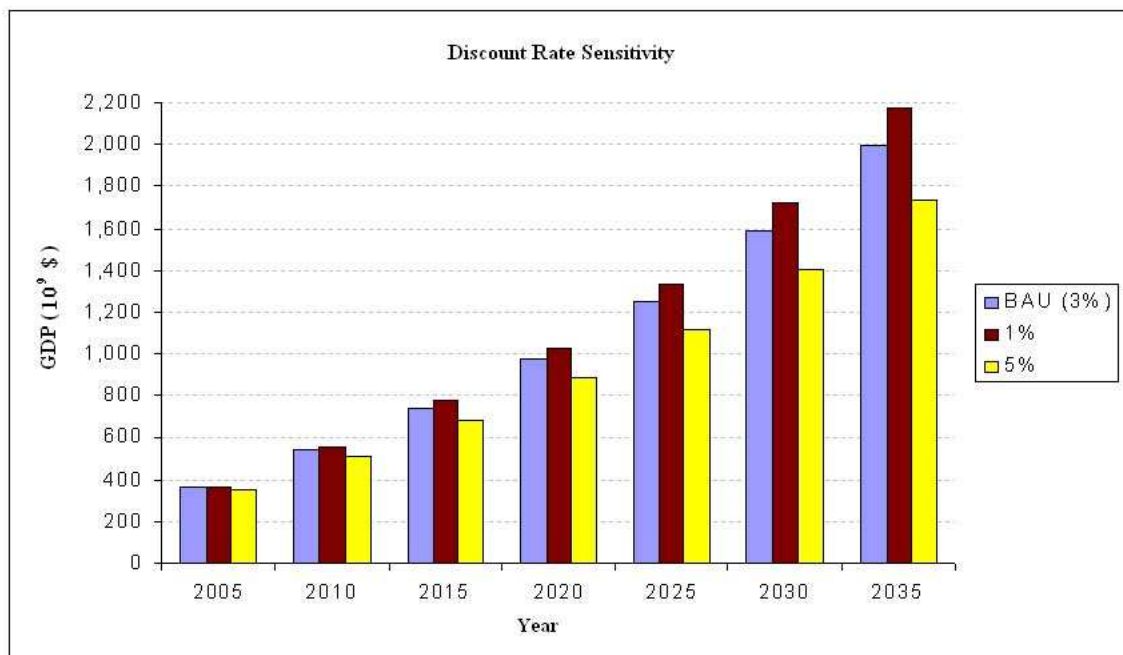


Figure 5.10. Model Sensitivity to Discount Rate

Table 5.9. BAU Values of Major Variables and Their Percentage Deviations in Response to Changes on Parameter Assumptions

			GDP	Electricity	Non-electric	CO₂
					Energy	Emissions
			(\$)	(TWh)	(Mtoe)	(Mt)
2010	Discount rate	BAU	542.190	208.350	106.050	1087.450
		Low	0.029	0.000	0.000	0.000
		High	-0.055	0.000	0.000	0.000
	Labor Force	Low	-0.020	-0.010	-0.010	-0.010
		High	0.030	0.020	0.030	0.040
	High Price	Electricity	0.003	0.000	0.000	0.000
		Oil	0.002	0.000	0.000	0.000
		Natural Gas	0.001	0.000	0.000	0.000
	2020	Discount rate	BAU	977.290	309.070	148.020
Low			0.055	0.000	0.000	0.000
High			-0.092	0.000	0.000	0.000
Labor Force		Low	-0.040	-0.030	-0.040	-0.040
		High	0.090	0.070	0.090	0.130
High Price		Electricity	0.006	0.000	0.000	0.000
		Oil	0.003	0.000	0.000	0.000
		Natural Gas	0.003	0.000	0.000	0.000
2030		Discount rate	BAU	1590.550	444.710	208.540
	Low		0.080	0.000	0.000	0.000
	High		-0.118	0.000	0.000	0.000
	Labor Force	Low	-0.060	-0.060	-0.070	-0.070
		High	0.140	0.140	0.160	0.240
	High Price	Electricity	0.012	0.000	0.000	0.000
		Oil	0.005	0.000	0.000	0.000
		Natural Gas	0.006	0.000	0.000	0.000

Labor force growth is another parameter whose impact on model results is explored. Its growth is changed to two per cent and 0.5 per cent in high and low growth scenarios respectively. The deviations from BAU results are given in Table 5.9. As expected, labor force increase leads to higher GDP. Moreover, greater purchasing power causes higher electric and non-electric energy consumptions.

Price growth change is also used in the model sensitivity analysis. Figure 5.11 summarizes the GDP results of the various price growth scenarios. Price growths are increased 50 per cent separately to check the differences in basic variables. The most significant differences are observed in GDP values. There are no changes in conventional energy consumptions (Table 5.9).

When Figure 5.11 is analyzed in detail, it is understood that doubling of electricity price growth leads to the major changes from BAU. This situation has two explanations: First, this growth rate contributes to all prices of sources used in electricity production. Secondly, it has the largest original growth value. Therefore, its contribution to the results is greater. Contribution of natural gas and oil follow with respect to their initial values. Per cent change caused by natural gas is higher.

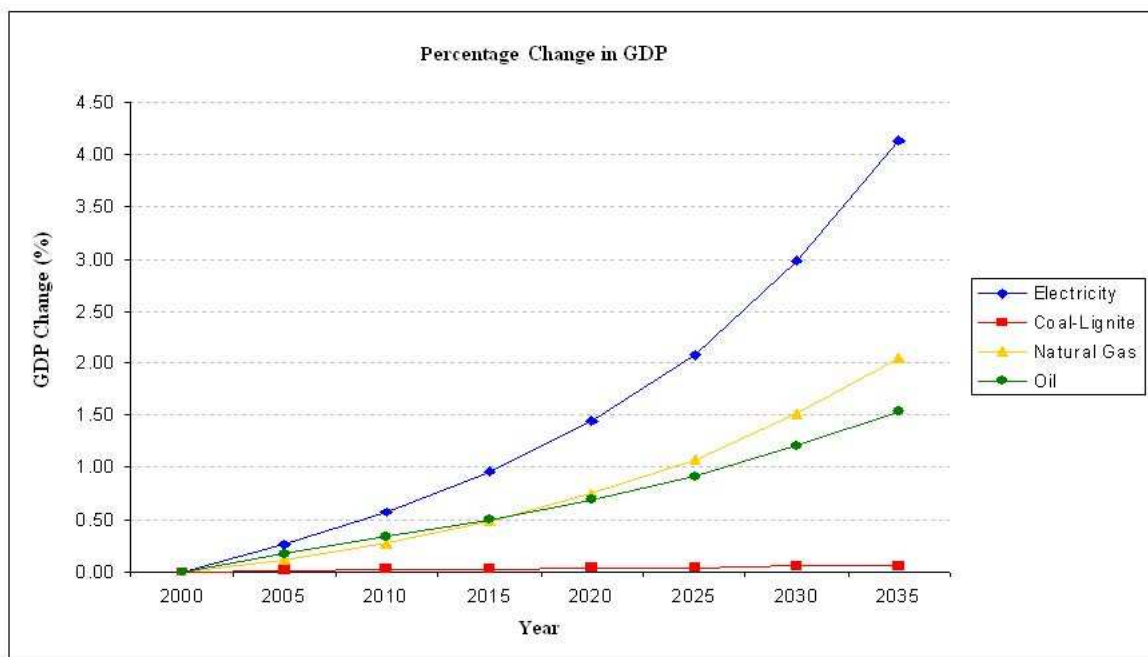


Figure 5.11. Model Sensitivity to Various Energy Price Growths

Since the nature of the WTP function is highly limited and subjective due to the limited coverage of the underlying questionnaire, there is a need to explore the sensitivity of results to WTP assumptions. Figure 5.12 shows the model sensitivity to various WTP values. The WTP function is equalized to four different constant values. Model runs with these four alternatives to BAU and results are evaluated separately.

It is clear that constant WTP values have direct impacts on new RET demands. The effect is to lower or higher the new RET consumption as WTP is lower or higher. When consumers are willing to pay 0.01 billion dollar to reduce CO₂ emissions, there is almost 70 per cent reduction of new RET demand in each time period. This reduction goes down with increasing trends when the WTP value is higher. Constant values 0.1 and 0.15 lead to increases in new RET consumption compared to BAU. It is found that new RET installation increases by 102 per cent when there is a doubling in WTP, but the change in macroeconomic indicators is negligibly small. Hence it can be said that the distortion of results due to the high average income of the survey population (which is about twice as much as the actual average income in Turkey) is insignificant for macroeconomic indicators. But there is an inflated RET installation which is based on the WTP of the survey population. It should be noted, however, that even in the inflated case new RET installation remains below 0.32 per cent of new capacity additions.

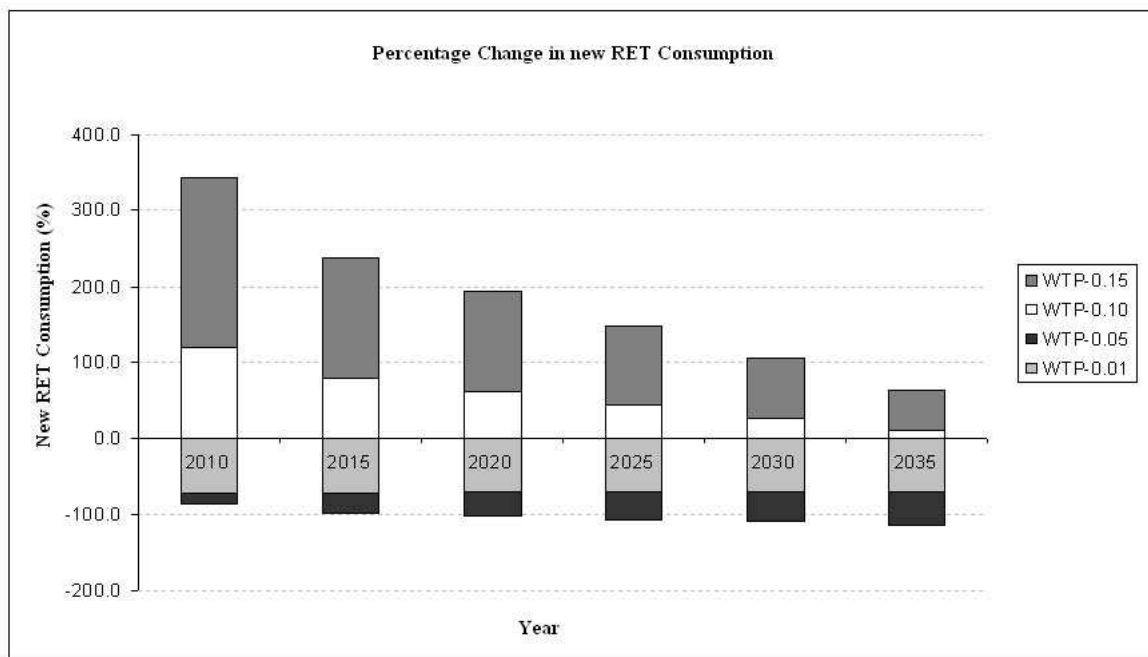


Figure 5.12. Model Sensitivity to Constant WTP Values

6. CONCLUSIONS

In this study, an energy-economy-environment aggregate equilibrium model is developed and calibrated to elaborate sustainable energy policies for Turkey. Particular emphasis is given to CO₂ emission reduction. Interactions among the energy sector, economy and environment are investigated with respect to various emission restricting scenarios. Learning by doing for renewable energy technologies (RETs) is included in the model reducing the cost of RETs as installed capacity increases. The Willingness to Pay (WTP) of consumers for CO₂ emission reduction is also included in the model. The WTP curve is derived as a function of income classes from a survey application based on the contingent valuation methodology.

Since Turkey has not completed her industrialization stage yet, the country has a rapidly growing energy demand parallel to economic growth. The results of various scenarios used in this study suggest various useful policy implications for an environmentally and economically sustainable development of the country and provide long-term prospects for effective and applicable energy policy solutions to foster investment into new renewable energy technologies, and thereby comply with the energy and environmental acquis of the EU.

According to Business-As-Usual (BAU) scenario, CO₂ emissions from energy production rise with an average growth rate of 20.5 per cent in thirty-five years. The main findings from the scenario analysis show that emission restrictions change the energy mix and lead to economic shrinkage. Since oil and coal are the major sources contributing to CO₂ emissions, emission limitations significantly reduce coal and oil consumption. Natural gas and hydroelectric power, in contrast, face rapid growth as cleaner energy sources. Emission stabilization at year 2000 levels leads to the greatest losses in macroeconomic and energy demand values as compared to other emission scenarios. The GDP loss reaches 13.8 per cent and 23.7 per cent in the years 2010 and 2020, respectively. Fossil fuel utilization almost halves in 2020. The shrinkage in fossil fuel use leads to significant increase (of about 30 per cent) in the consumption

of RETs. Similar RET growth results are observed in other emission stabilization scenarios. Emission scenarios increase particularly the usage of new RETs. In the most favorable scenario, the share of new RETs almost triples from 2010 to 2030.

The use of renewable energy sources is fostered by technological learning and changing income class dynamics. It has been found that effects of the learning index and income class scenarios on macroeconomic growth and conventional energy consumption are minimal. However, they trigger new renewable energy technology installations. The scenario in which all learning indices are doubled gives naturally the most favorable renewable energy consumption results. According to results of this scenario, the share of new renewables in total energy consumption increases around 10 per cent for the next fifteen years. A rapidly growing demand for renewable energy sources is also observed in income class growth and distribution scenarios. Since the dynamics are complex, there is no direct relation between income class growth, distribution and resulting WTP. The scenario, in which 12.5 per cent annual income growth is implemented, leads to approximately 13.5 per cent growth in the share of new RETs between the years 2010 and 2020.

A nuclear energy scenario is defined enforcing nuclear power to the baseline in 2015 so as to stay in accordance with official plans. In this scenario, nuclear energy comprises around seven per cent of total energy demand between 2015 and 2035. Emission restrictions are also applied to this baseline including nuclear energy. The results show great similarities with those obtained from the stabilization of emissions in BAU scenario. Particularly, the scenario stabilizing emissions at 2000 levels, leads to the greatest losses in GDP with 14.4 per cent reduction in 2010 and 22.5 per cent reduction in 2020. Fossil fuel utilization almost halves in 2020. However, there is a significant increase in the demand for RETs. It reaches 37.1 per cent in year 2010 and 78.1 per cent in year 2020. In addition, the share of new RETs doubles from 2010 to 2030.

Combinations of alternative scenarios are also run under various mix scenario definitions. The findings emphasize that emission stabilization scenarios dominate the results. Differences between the economic and energy consumption results of the

emission scenarios and combination scenarios are almost zero. The new renewable energy consumptions rise, nevertheless, due to the improvements in learning indexes and income levels. Geothermal energy is the most consumed renewable energy source in all combination scenarios except the one, which combines the scenarios of emission stabilization at 2000 levels, doubling in all learning indexes, doubling of annual income growth and an average distribution in all income classes. In this mix scenario, wind energy turns out to be as the most preferred renewable sources with a periodic growth factor of 6.05.

As further research, a more detailed representation of future energy technologies including learning-by-doing for all technologies is required for model refinement. Since sample size of the CVM survey was inevitably limited due to financial restrictions, further research is also needed to widen the survey application and include a more realistic WTP equation. Another direction for the improvement of the model is the endogenization of income growth. Establishment of a linkage between income classes in the WTP function with consumption or GDP in the macroeconomic submodel will be a methodological improvement in the modelling framework.

APPENDIX A: CONTINGENT VALUATION SURVEY

This appendix gives the CVM Questionnaire that were conducted randomly selected 86 individuals. Since it is applied in Turkey on Turkish citizens, the original language of the survey is Turkish.

CO₂ EMİSYONU AZALTIM ANKETİ

Ülkemizde CO₂ emisyonunun büyük kısmı %28 elektrik ve ısı üretiminden kaynaklanmaktadır. Konutlarda kullanılan fosil kaynaklı yakıtlarda (kömür, doğal gaz gibi) eklenince, konutların CO₂ emisyonun yaptığı katkı %38'lere ulaşmaktadır. Bu oran, sanayi ve ulaşım sektörlerinin yaptıkları katkılardan çok daha büyüktür. Elektrik üretiminde ortaya çıkan CO₂ emisyonunun azaltılması, sanayi veya ulaşım nedeniyle ortaya çıkan emisyonun azaltılmasından çok daha kolaydır. Bu durumda elektrik üretiminin temiz kaynaklardan elde edilmesi için gösterilecek çabalar önem kazanmaktadır. Bireysel olarak sera gazlarının azaltımına yaptığımız katkının yanında, devletin bu yönde sistemli olarak gerçekleştireceği yatırımlara, sanayi sektörüyle beraber halkın da yapacağı katkı çok değerlidir. Sera gazı emisyonlarının azaltılabilmesi için UNFCCC (Birleşmiş Milletler İklim Değişikliği Çerçeve Sözleşmesi)" kapasite artırımı ve çevre dostu teknolojilere geçişinin önemini ortaya koymuştur. Ayrıca Avrupa Birliği üye ülkeleri Kyoto Protokolü'ne taraf olarak CO₂ emisyonunu 1990 seviyelerine çekme yükümlülüğünü kabul etmişlerdir. Avrupa Birliğine uyum sürecinde Türkiye'de CO₂ emisyonunun azaltmak ve belli seviyelere düşürmek durumunda kalacaktır. Şu anda, Boğaziçi Üniversitesi'nde "CO₂ emisyonlarının Türkiye Ekonomisi üzerine getireceği yükün, ve Kyoto Protokolü emisyon hedefleri ışığında bu emisyonların azaltılmasının ortaya çıkaracağı maliyetlerin ve tüketicilerin ödeme istekliliğinin araştırılması" üzerine bir proje yapılmaktadır. Aşağıda bu proje kapsamında oluşturulan anketi bulacaksınız. Anket sonuçlarının değerlendirilmesi sonucu elde edilen bulgular Türkiye'de çevre ve enerji politikalarının şekillendirilmesine yardımcı olacaktır. Cevaplarınız bizim için son derece değerlidir. Bu önemli çalışmadaki yardımlarınız için teşekkür ederiz.

Bölüm 1: Türkiye ve Enerji

Başlangıç olarak, sizin kendi hakkınızda ve elektrik endüstrisi ve çevre dostu teknolojiler üzerine görüşlerinizi belirten birkaç soru sormak istiyoruz.

1. Türkiye'nin elektrik ihtiyacının karşılanması açısından aşağıdaki konuların önem derecesini belirtiniz.

Table A.1. First Question of CVM Survey

	çok önemli				son derece
	değil				önemli
Elektrik hizmetinin güvenilirliğinden emin olmak (kesinti, voltaj, frekans, vs.)	1	2	3	4	5
Çevre dostu teknolojilerden sağlanan elektriğin toplamdaki yüzdesini artırmak (rüzgar, güneş, filtreleme sistemleri gibi)	1	2	3	4	5
Elektriğin fiyatını asgari düzeye çekmek	1	2	3	4	5
Enerji tasarrufu ve verimli kullanımı için yapılan yatırımları artırmak	1	2	3	4	5

2. Ülkemizde elektirik %29,4 kömür ve petrol, %45,2 doğal gaz, %25,1 hidrolik ve %0,3 yenilenebilir enerji kaynaklı üretilmektedir. Elektrik üretimi CO₂ emisyonuna ve dolayısıyla küresel ısınmaya en büyük ölçüde katkıda bulunan sektördür. Elektrik üretiminin çevresel etkileri hakkında ne kadar bilgi sahibisiniz?

Table A.2. Second Question of CVM Survey

Hiç		çok		
1	2	3	4	5

3. Elektrik üretiminin çevresel etkilerini azaltmak için birkaç yöntem kullanılmaktadır. Sizce aşağıdaki üç yaklaşımın çevresel etkiyi azaltmaktaki katkısına kadar önemlidir?

Table A.3. Third Question of CVM Survey

	çok önemli				son derece
	değil				önemli
Enerji Verimliliği enerji tasarrufu sağlayan birtakım cihazlarla veya başka yöntemlerle evlerdeki ve işyerlerindeki elektrik kullanımını azaltmak	1	2	3	4	5
Kirlilik Kontrolü doğal gaz ve kömür tesislerinde emisyon azaltıcı teknolojiler kullanmak	1	2	3	4	5
Yenilenebilir Enerji elektrik üretimini rüzgar türbinleri, güneş enerjisi gibi yenilenebilir enerji kaynaklarından sağlamak	1	2	3	4	5

4. Elektrikli daha az CO₂ emisyonuna neden olarak üreten teknolojiler (çevre dostu teknolojiler) diğer elektrik üretim yöntemlerine kıyasla daha fazla maliyetli olmasına rağmen, bir takım üstünlüklere sahiptir. Aşağıdaki muhtemel üstünlüklerin sizin için önem derecesini belirtiniz

Table A.4. Forth Question of CVM Survey

	çok önemli				son derece
	değil				önemli
Diğer elektrik üretim yöntemlerine kıyasla daha az CO ₂ emisyonu sağlaması	1	2	3	4	5
Türkiyenin elektrik üretiminde dışa bağımlılığını azaltılması	1	2	3	4	5
Yeni teknolojilere yatırımı canlandırması	1	2	3	4	5
Petrol, doğal gaz ve kömür kaynaklarının gelecek nesillere ömrünü uzatılması	1	2	3	4	5

5. Elektriđi daha az CO₂ emisyonuna neden olarak üreten teknolojileri (çevre dostu teknolojileri) kullanarak üretmenin birtakım muhtemel dezavantajlarında görülebilir. Aşağıdaki muhtemel dezavantajların sizin için önem derecesini belirtiniz.

Table A.5. Fifth Question of CVM Survey

	çok önemli				son derece
	değil				önemli
Geleneksel yollarla elektrik üretmeye kıyasla daha yüksek maliyetli olması	1	2	3	4	5
Yaygın kullanım için yeterli kaynak olmaması	1	2	3	4	5
Çevresel birtakım dezavantajlara sahip olabilecek olması	1	2	3	4	5
Rüzgar gibi birtakım dışsal etkenlere bağlı olabildiğinden güvenirliliğinin düşük olması	1	2	3	4	5

Bölüm 2: CO₂ Emisyonunun Azaltılması için Ödeme Yapmak

6. Hükümet CO₂ emisyonunun azaltılması için Türkiye'deki bütün ev ve iş yerlerinden her ay bir ek ücretin isteneceği ve bu ücretin aylık olarak elektrik faturalarına yansıtılacağı bir programı uygulamayı düşünmektedir. Elektrik faturalarının %10'u olarak belirlenen bu ek ücret hükümet tarafından toplanacak ve toplanan parayla Tübitak gibi bir araştırma kurumunda çevre dostu teknolojilere yatırım yapılmasına destek olunacaktır. Önerilen ek ücretin ödenmesi zorunlu olduğundan tüm ev ve iş yerleri ödeme yapmak durumunda olacaktır.

Uluslararası Enerji Ajansının yayınladığı verilere göre CO₂ emisyonunun %8 azaltılması durumu, her bireyin 215 km. araba kullanmamasına karşılık gelen bir çevresel fayda sağlamaktadır.

Eğer bu politika uygulanırsa, Türkiye'deki tüm ev ve işyerlerinin aynı miktarda parayı ödemek zorunda olduğunu ve daha az CO₂ emisyonuna neden olan teknolojilere (çevre dostu teknolojilere) yatırım yapılması adına 3 yıl boyunca her ay elektrik faturanızın %10'unun ek ücret olarak alınacağını aklınızda tutarak; bu programın uygulanmasını kabul eder misiniz? (lütfen tek bir seçenek işaretleyiniz)

- 1 Hayır 8 NUMARALI SORUYA GEÇİNİZ
- 2 Evet 7 NUMARALI SORUYA GEÇİNİZ

7. Bu ek ücret her ay elektrik faturanızın %15'u olarak belirlenseydi, bu programın uygulanmasını hala kabul eder miydiniz? (lütfen tek bir seçenek işaretleyiniz)

- 1 Hayır 10 NUMARALI SORUYA GEÇİNİZ
- 2 Evet 10 NUMARALI SORUYA GEÇİNİZ

8. (Hayır ise) Bu ek ücret her ay elektrik faturanızın %5'i olarak belirlenseydi, bu durumda programın uygulanmasını kabul eder miydiniz? (lütfen tek bir seçenek işaretleyiniz)

- 1 Hayır 9 NUMARALI SORUYA GEÇİNİZ
- 2 Evet 10 NUMARALI SORUYA GEÇİNİZ

9. CO₂ emisyonunu azaltmak için alınacak ek ücretin desteklenmemesinin pek çok sebebi olabilir. Olabilecek muhtemel sebepler aşağıda listelenmiştir, lütfen size ve hane halkınıza uygun olanları işaretleyiniz. (lütfen size uyan tüm seçenekleri işaretleyiniz)

- 1 Gelir düzeyim CO₂ emisyonunu azaltmak için bu kadar para vermeye uygun değil.
- 2 CO₂ emisyonunun azaltılmasından sağlayacağım faydanın verdiğim parayı karşılamaması.
- 3 Tüketicilerin gereken ödemeleri zorunlu değil gönüllü yapması gerektiğine inanmam.
- 4 Devletin toplanan geliri etkin olarak kullanabileceğine inanmamam.
- 5 Bu programın finansmanının tüketiciler yerine çevreyi kirleten diğer sektörler (sanayi, ulaşım) olması gerektiğine inanmam.
- 6 Tüm yeni hükümet programlarına karşıyım.
- 7 Karar vermeden önce daha fazla bilgiye ihtiyaç duyuyorum.
- 8 Önceliğin kaçak elektrik problemini halletmek olduğunu düşünüyorum.
- 9 Diğer (Lütfen Belirtiniz)

10. Aylık ortalama elektrik faturanız hangi aralıktadır?

- 1 10-20 YTL
- 2 20-30 YTL
- 3 30-40 YTL
- 4 40-50 YTL
- 5 50-60 YTL
- 6 60-70 YTL
- 7 70-80 YTL
- 8 80-90 YTL
- 9 90-100 YTL
- 10 100-110 YTL
- 11 110-120 YTL
- 12 120-130 YTL

11. Eđer bu politika uygulanırsa, Tırkiye'deki tım ev ve işyerlerinin aynı miktarda parayı ödemek zorunda olduğunu aklınızda tutarak; Türk halkının yüzde kaçının her ay elektrik faturasının %10'unu ek ücret olarak ödemeyi destekleyeceğini düşünöyorsunuz?

- 1 % 20'sinden daha azı
- 2 %20 - %40 arası
- 3 %40 - %60 arası
- 4 %60 - %80 arası
- 5 %80 - %100 arası

12. Paranın toplanması ve çevre dostu teknolojiler adına kullanılması devlet yerine küresel ısınmayı önlemek amacıyla kurulan bir vakıf veya sivil toplum kuruluşu tarafından yapılsaydı, bu durumda bu programın uygulanmasını desteklermiydiniz?

- 1 Hayır
- 2 Evet

13. Eđer bu program kapsamındaki ek ücretlerin toplanması zorunlu yerine gönüllü (bu durumda ödememeyi seçebilecek ev ve işyerlerinin olabileceğini de aklınızda tutarak)olsaydı bu durumda bu programın uygulanmasını destekler miydiniz?

- 1 Hayır
- 2 Evet

Bölüm 3: Çevresel konulardaki eğilimleriniz

14. Aşağıdaki ifadelere ne kadar katıldığınızı belirtiniz.

Table A.6. Fourteenth Question of CVM Survey

	Hiç katılmıyorum	Biraz katılıyorum	Fark etmez	Oldukça katılıyorum	Tamamen katılıyorum
Tanıdığım insanlar arasında, yeni ürünleri ilk deneyenler arasındayım.	1	2	3	4	5
İnsanların kişisel olarak çevre için pek bir şey yapabileceğini sanmıyorum.	1	2	3	4	5
Diğer insanların da aldığını bilirim, çevre dostu ürünler alma isteğim artar.	1	2	3	4	5
Çevre dostu ürünler sunan şirketlerin iddialarına güvenmiyorum.	1	2	3	4	5
Diğer insanların çevreyi korumak için kişisel fedakarlık yapacağına inanmıyorum.	1	2	3	4	5
Devletin para toplayarak bu parayı yararlı işler için kullanacağına inanmıyorum.	1	2	3	4	5
Devlet, herkesin çevresel gelişim için ödeme yapmasını zorunlu kılmalı.	1	2	3	4	5
Çevre dostu ürünlere daha fazla para vermeyi ancak onlardan doğrudan bir fayda sağlarsam kabul ederim.	1	2	3	4	5
Piyasadaki ürünlerin ne denli çevre dostu olduğu konusunda şüphelerimin olması	1	2	3	4	5
Ailemin ve arkadaşlarımla seçme şansları olursa, çevre dostu teknolojileri destekleyeceklerine inanıyorum.	1	2	3	4	5

15. Siz ve hane halkı aşağıdakilerden hangilerini düzenli olarak yapıyorsunuz?

- 1 Çevre dostu ürünlerden satın almaya gayret göstermek
- 2 Çevre dostu ürünlere daha fazla bedel ödemek
- 3 Gazete, metal, plastik ve cam maddeleri geri dönüştürmek
- 4 Organik gıdalar almak
- 5 Evdeki enerji tüketimini azaltmak
- 6 Çevresel işlere para yardımı yapmak
- 7 Çevresel işlere gönüllü vakit ayırmak

16. Sizin gibi insanların aşağıdakilerin gerçekleşmesi için ne kadar katkı yapabileceğini düşünüyorsunuz?

	Hiç	Az	Oldukça	Çok
Kamuya açık yerlerdeki çöpleri azaltmak	1	2	3	4
Dolgu alanlarındaki (landfill) katı atık miktarını azaltmak	1	2	3	4
Sis yaratan hava kirliliğini azaltmak	1	2	3	4
Ozon tabakasının tahribatını azaltmak	1	2	3	4
CO ₂ emisyon seviyesini azaltmak	1	2	3	4
Kullanılan yenilenebilir enerji miktarını artırmak	1	2	3	4
Küresel ısınma tehdidini azaltmak	1	2	3	4
Tabii bölgelerin kaybını azaltmak	1	2	3	4

17. Hükümet programlarının ve hukuki düzenlemelerin aşağıdakilerin gerçekleşmesi için ne kadar katkı yapabileceğini düşünüyorsunuz?

	Hiç	Az	Oldukça	Çok
Kamuya açık yerlerdeki çöpleri azaltmak	1	2	3	4
Dolgu alanlarındaki (landfill) katı atık miktarını azaltmak	1	2	3	4
Sis yaratan hava kirliliğini azaltmak	1	2	3	4
Ozon tabakasının tahribatını azaltmak	1	2	3	4
CO ₂ emisyon seviyesini azaltmak	1	2	3	4
Kullanılan yenilenebilir enerji miktarını artırmak	1	2	3	4
Küresel ısınma tehdidini azaltmak	1	2	3	4
Tabii bölgelerin kaybını azaltmak	1	2	3	4

Bölüm 4: Sizin hakkınızda

Bu son bir kaç soru sizin ve anketi cevaplayan diğerlerinin Türkiye'yi ne kadar iyi yansıttığını anlamamıza yardım edecek. Bu bölümdeki (ve anketin tamamındaki) bilgiler gizlidir. Lütfen adınızı ve diğer kimlik bilgilerinizi vermeyiniz.

18. Yaşınız?

- 1 17 yaş veya altı
- 2 18 24 yaş
- 3 25 34 yaş
- 4 35 44 yaş
- 5 45 54 yaş
- 6 55 64 yaş
- 7 65 yaş veya üstü

19. Cinsiyetiniz?

- 1 Bay
- 2 Bayan

20. Çocuğunuz var mı?

- 1 Hayır
- 2 Evet

21. Eğitim durumunuz?

- 1 Yok
- 2 İlkokul (1-5 yıl)
- 3 Ortaokul (6-8 yıl)
- 4 Lise (9-12 yıl)
- 5 Yüksek okul (13-15 yıl)
- 6 Üniversite
- 7 Yüksek Lisans
- 8 Doktora

22. Aşağıda bir ev halkına ait olabilecek toplam gelir düzeyi kategorileri verilmektedir. Hangi kategori sizin ev halkınızın net 2004 yılı için ortalama aylık gelir düzeyini en iyi şekilde yansıtmaktadır?

- 1 500 YTL veya daha
- 2 500 YTL-1000 YTL
- 3 1000 YTL-1500 YTL
- 4 1500 YTL-2000 YTL
- 5 2000 YTL-2500 YTL
- 6 2500 YTL-3000 YTL
- 7 3000 YTL-3500 YTL
- 8 3500 YTL-4000 YTL
- 9 4000 YTL-4500 YTL
- 10 4500 YTL den daha fazla

(İşbirliğiniz için teşekkürler! Anketi cevaplamak için ayırdığınız zaman bizim için çok kıymetlidir.)

APPENDIX B: CVM MULTIPLE REGRESSION REPORT

The appendix B provides the multiple regression report of the NCSS/PASS solver. Although the completed survey number is 79, since the R-square value obtained from the combinations of the same factor gives the highest result, combinations of the same factors, 38 rows, are used in the reports. All reports prove the assumption that the residuals being analyzed come from normal distribution. The solver gives the residual reports, outlier test results and residual vs. fitted value plots. The residual represents the difference between the actual and the regression model predicted values of the dependent variable. A residual having a value larger than three is assumed as outlier and the normality assumption is vanished. Since there is no residual above three, the normality assumption of residuals accepted as valid.

Standardized residuals are used to manage the comparison difficulties among residuals. They should lie in the interval ∓ 3 to escape from outliers. R-Student and hat matrix are other useful tools, often used to check outliers. R-student values above two should be accepted as uncommon and those above three should be thought as rare. Hat diagonals greater than $2(m + 1)/n$, which is 0.21 in this analysis, are considered influential on results. However, a high-leverage observation of hat diagonals does not mean a bad observation. Rather, it necessitates extra attention about their correctness. A Cooks D value greater than one indicates an observation that has large influence on results. Results from the NCSS/PASS solver, as can be seen on Table B.2, show that there is nothing to worry about residuals.

Residual versus independent variable plots are given at Figure B.1. As illustrated on Figure B.1, none of the plots follow a random pattern.

Table B.1. Residual Report

Row	Actual WTP	Predicted WTP	Residual	Absolute Percent Error	Sqrt(MSE) Without This Row
1	4.500	2.934	1.566	34.807	1.358
2	0.688	1.735	-1.048	152.381	1.377
3	2.250	2.020	0.230	10.238	1.391
4	3.333	1.735	1.598	47.946	1.357
5	0.000	2.020	-2.020		1.336
6	1.100	2.554	-1.454	132.170	1.362
7	3.563	2.020	1.543	43.308	1.359
8	2.583	1.687	0.896	34.694	1.381
9	1.375	1.687	-0.312	22.697	1.391
10	2.375	2.020	0.355	14.962	1.390
11	1.938	2.554	-0.616	31.813	1.387
12	0.000	2.934	-2.934		1.270
13	2.125	1.687	0.438	20.608	1.389
14	2.250	2.934	-0.684	30.385	1.386
15	2.375	1.735	0.640	26.942	1.386
16	0.750	2.554	-1.804	240.516	1.346
17	2.283	1.687	0.596	26.113	1.387
18	3.180	1.687	1.493	46.947	1.362
19	4.036	2.554	1.482	36.718	1.361
20	3.286	2.934	0.352	10.714	1.390
21	2.700	2.020	0.680	25.198	1.386
22	0.750	2.020	-1.270	169.286	1.370
23	2.250	2.554	-0.304	13.505	1.391
24	1.500	1.687	-0.187	12.472	1.391
25	0.450	1.687	-1.237	274.907	1.371
26	1.250	1.735	-0.485	38.810	1.389
27	5.250	2.554	2.696	51.355	1.287
28	0.000	1.687	-1.687		1.354
29	2.500	2.020	0.480	19.214	1.389
30	0.750	1.735	-0.985	131.349	1.379
31	0.000	1.735	-1.735		1.351
32	3.500	2.934	0.566	16.181	1.388
33	3.250	2.934	0.316	9.733	1.391
34	3.750	2.934	0.816	21.769	1.383
35	3.750	1.735	2.015	53.730	1.336
36	8.375	7.262	1.113	13.287	1.370
37	7.333	7.262	0.071	0.966	1.392
38	6.079	7.262	-1.184	19.472	1.367

(Dependent variable = WTP)

Table B.2. Outlier Test Report

Row	Standardized		Hat		Dffits
	Residual	RStudent	Diagonal	Cook's D	
1	1.235	1.246	0.143	0.042	0.509
2	-0.826	-0.822	0.143	0.019	-0.336
3	0.182	0.179	0.143	0.001	0.073
4	1.260	1.272	0.143	0.044	0.519
5	-1.592	-1.633	0.143	0.070	-0.667
6	-1.163	-1.169	0.167	0.045	-0.523
7	1.216	1.226	0.143	0.041	0.501
8	0.699	0.694	0.125	0.012	0.262
9	-0.244	-0.240	0.125	0.001	-0.091
10	0.280	0.276	0.143	0.002	0.113
11	-0.493	-0.487	0.167	0.008	-0.218
12	-2.313	-2.495	0.143	0.149	-1.018
13	0.342	0.337	0.125	0.003	0.127
14	-0.539	-0.533	0.143	0.008	-0.218
15	0.505	0.499	0.143	0.007	0.204
16	-1.442	-1.468	0.167	0.069	-0.657
17	0.465	0.460	0.125	0.005	0.174
18	1.165	1.172	0.125	0.032	0.443
19	1.185	1.193	0.167	0.047	0.533
20	0.278	0.274	0.143	0.002	0.112
21	0.536	0.530	0.143	0.008	0.217
22	-1.001	-1.001	0.143	0.028	-0.409
23	-0.243	-0.239	0.167	0.002	-0.107
24	-0.146	-0.144	0.125	0.001	-0.054
25	-0.965	-0.964	0.125	0.022	-0.365
26	-0.383	-0.377	0.143	0.004	-0.154
27	2.156	2.295	0.167	0.155	1.026
28	-1.317	-1.332	0.125	0.041	-0.504
29	0.379	0.374	0.143	0.004	0.153
30	-0.777	-0.772	0.143	0.017	-0.315
31	-1.368	-1.388	0.143	0.052	-0.567
32	0.447	0.441	0.143	0.006	0.180
33	0.249	0.246	0.143	0.002	0.100
34	0.644	0.638	0.143	0.012	0.260
35	1.589	1.629	0.143	0.070	0.665
36	0.995	0.995	0.333	0.083	0.703
37	0.063	0.062	0.333	0.000	0.044
38	-1.058	-1.060	0.333	0.093	-0.750

(Dependent variable = WTP)

Scatter Plots

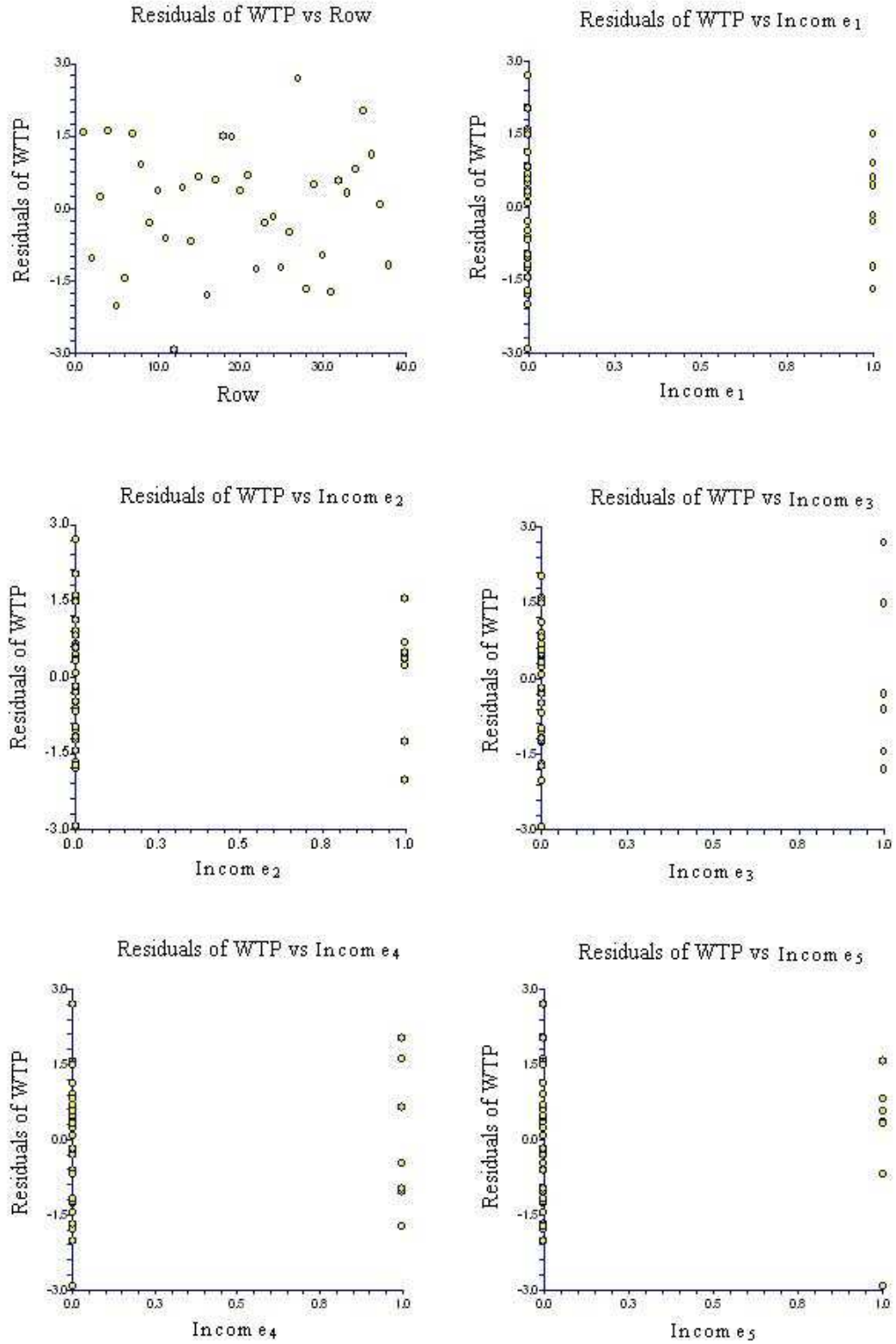


Figure B.1. Scatter Plots of Residuals

APPENDIX C: MACROECONOMIC RESULTS OF THE SCENARIOS

Growth rate results of different scenarios are given from Table C.1 to Table C.6.

Table C.1. Scenario BAU Macroeconomic Growth Results

Year	GDP	Investment	Consumption	Export	Import
	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)
2000-2005	12.33	8.51	15.72	21.42	15.08
2005-2010	8.33	5.07	11.33	8.33	8.33
2010-2015	6.58	7.56	5.80	6.58	6.58
2015-2020	5.62	5.73	5.53	5.62	5.62
2020-2025	5.04	7.06	3.20	5.04	5.04
2025-2030	4.94	6.09	3.72	4.94	4.94
2030-2035	4.61	6.80	1.87	4.61	4.61

Table C.2. Scenario EM1 Macroeconomic Growth Results

Year	GDP	Investment	Consumption	Export	Import
	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)
2000-2005	10.92	8.52	12.69	19.91	13.64
2005-2010	6.51	5.07	8.10	6.51	6.51
2010-2015	5.34	7.57	2.87	5.34	5.34
2015-2020	4.29	6.25	1.56	4.29	4.29
2020-2025	3.68	6.17	-0.86	3.68	3.68
2025-2030	3.48	7.39	-8.45	3.48	3.48
2030-2035	2.91	5.19	-13.44	2.91	2.91

Table C.3. Scenario EM2 Macroeconomic Growth Results

Year	GDP	Investment	Consumption	Export	Import
	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)
2000-2005	11.42	11.88	9.23	20.44	14.14
2005-2010	8.18	8.15	8.24	8.18	8.18
2010-2015	4.74	2.75	7.61	4.74	4.74
2015-2020	4.34	8.21	-1.54	4.34	4.34
2020-2025	4.30	6.82	-1.69	4.30	4.30
2025-2030	4.10	5.72	-1.57	4.10	4.10
2030-2035	3.91	6.98	-17.51	3.91	3.91

Table C.4. Scenario EM3 Macroeconomic Growth Results

Year	GDP	Investment	Consumption	Export	Import
	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)
2000-2005	12.47	8.52	16.01	21.58	15.22
2005-2010	8.34	5.07	11.29	8.34	8.34
2010-2015	5.42	7.57	3.66	5.42	5.42
2015-2020	4.65	5.74	3.62	4.65	4.65
2020-2025	4.15	7.07	0.82	4.15	4.15
2025-2030	3.86	6.09	0.46	3.86	3.86
2030-2035	3.41	6.80	-4.11	3.41	3.41

Table C.5. Scenario EM4 Macroeconomic Growth Results

Year	GDP	Investment	Consumption	Export	Import
	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)
2000-2005	11.89	8.52	14.79	20.95	14.63
2005-2010	7.71	5.07	10.28	7.71	7.71
2010-2015	6.35	7.57	5.28	6.35	6.35
2015-2020	5.43	5.74	5.13	5.43	5.43
2020-2025	4.86	7.07	2.54	4.86	4.86
2025-2030	4.57	6.09	2.62	4.57	4.57
2030-2035	4.27	6.80	0.22	4.27	4.27

Table C.6. Scenario NUC Macroeconomic Growth Results

Year	GDP	Investment	Consumption	Export	Import
	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)	Growth rate(%)
2000-2005	12.45	8.51	15.97	21.55	15.20
2005-2010	8.38	5.07	11.38	8.38	8.38
2010-2015	6.76	7.56	6.14	6.76	6.76
2015-2020	5.60	5.73	5.49	5.60	5.60
2020-2025	5.03	7.06	3.24	5.03	5.03
2025-2030	4.91	6.09	3.70	4.91	4.91
2030-2035	4.59	6.80	1.93	4.59	4.59

Basic macroeconomic variables from different scenarios are summarized from Table C.7 to Table C.20.

Table C.7. Scenario EM1 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	344.26	204.40	174.28	68.85	103.27
2010	471.85	261.75	257.27	94.37	141.55
2015	612.03	376.92	296.31	122.40	183.61
2020	755.12	510.40	320.22	151.02	226.53
2025	904.67	688.48	306.65	180.93	271.40
2030	1,073.51	983.59	197.26	214.70	322.05
2035	1,238.88	1,266.89	95.88	247.77	371.66

Table C.8. Scenario EM2 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	351.99	238.10	149.09	70.39	105.59
2010	521.60	352.23	221.53	104.32	156.48
2015	657.36	403.46	319.64	131.47	197.21
2020	813.11	598.59	295.83	162.62	243.93
2025	1,003.75	832.42	271.70	200.75	301.12
2030	1,227.36	1,099.08	251.01	245.47	368.20
2035	1,487.14	1,539.97	95.88	297.42	446.14

Table C.9. Scenario EM3 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	368.93	204.40	201.42	73.78	110.68
2010	550.55	261.75	343.85	110.11	165.16
2015	716.81	376.92	411.56	143.36	215.04
2020	899.80	498.12	491.65	179.96	269.94
2025	1,102.53	700.76	512.02	220.50	330.76
2030	1,332.46	941.82	523.88	266.49	399.73
2035	1,575.81	1,308.66	424.72	315.16	472.74

Table C.10. Scenario EM4 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	359.57	204.40	191.12	71.91	107.87
2010	521.35	261.75	311.73	104.27	156.40
2015	709.14	376.92	403.14	141.83	212.74
2020	923.59	498.12	517.82	184.71	277.07
2025	1,170.66	700.76	586.96	234.13	351.20
2030	1,463.38	941.82	667.90	292.67	439.01
2035	1,803.61	1,308.66	675.30	360.72	541.08

Table C.11. Scenario No-WTP Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	366.69	204.40	198.96	73.34	110.01
2010	547.33	261.76	340.30	109.47	164.20
2015	752.77	376.92	451.12	150.55	225.83
2020	989.67	498.13	590.52	197.94	296.90
2025	1,265.63	700.77	691.42	253.13	379.69
2030	1,610.79	941.82	830.05	322.16	483.24
2035	2,017.67	1,308.67	910.78	403.54	605.30

Table C.12. Scenario NUC Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.000	135.840	95.880	27.780	54.500
2005	366.696	204.402	198.963	73.339	110.009
2010	547.301	261.759	340.272	109.460	164.190
2015	759.732	376.922	458.783	151.946	227.920
2020	996.195	498.126	597.688	199.239	298.858
2025	1,271.746	700.766	698.155	254.349	381.524
2030	1,617.890	941.820	837.858	323.578	485.367
2035	2,026.216	1,308.665	920.172	405.243	607.865

Table C.13. Scenario NUC-EM1 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	344.26	204.40	174.28	68.85	103.27
2010	471.85	261.75	257.27	94.37	141.55
2015	627.83	376.92	313.69	125.56	188.35
2020	779.22	508.61	348.53	155.84	233.76
2025	935.83	690.28	339.13	187.16	280.74
2030	1,103.39	960.93	252.80	220.67	331.01
2035	1,274.10	1,289.55	111.95	254.82	382.23

Table C.14. Scenario NUC-EM2 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	351.62	204.40	182.38	70.32	105.48
2010	508.05	267.77	291.08	101.61	152.41
2015	664.35	370.91	359.88	132.87	199.30
2020	822.95	504.13	401.11	164.59	246.88
2025	1,005.59	694.75	411.40	201.11	301.67
2030	1,227.69	947.83	402.62	245.53	368.30
2035	1,492.39	1,476.11	165.51	298.47	447.71

Table C.15. Scenario NUC-EM3 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	369.26	204.40	201.79	73.85	110.78
2010	550.59	261.75	343.89	110.11	165.17
2015	732.35	376.92	428.66	146.47	219.70
2020	916.11	498.12	509.60	183.22	274.83
2025	1,119.80	700.76	531.01	223.96	335.94
2030	1,355.51	941.82	549.24	271.10	406.65
2035	1,604.74	1,308.66	456.55	320.94	481.42

Table C.16. Scenario NUC-EM4 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	359.63	204.40	191.19	71.92	107.89
2010	521.30	261.75	311.67	104.26	156.39
2015	723.39	376.92	418.80	144.67	217.01
2020	937.56	498.12	533.19	187.51	281.27
2025	1,183.67	700.76	601.27	236.73	355.10
2030	1,479.63	941.82	685.78	295.92	443.89
2035	1,823.92	1,308.66	697.64	364.78	547.17

Table C.17. Scenario MIX1 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	344.26	204.40	174.28	68.85	103.27
2010	471.84	261.75	257.27	94.36	141.55
2015	611.97	376.92	296.25	122.39	183.59
2020	755.04	510.41	320.13	151.00	226.51
2025	904.58	688.47	306.56	180.91	271.37
2030	1,073.46	983.72	197.08	214.69	322.03
2035	1,238.76	1,266.75	95.88	247.75	371.62

Table C.18. Scenario MIX2 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	344.26	204.40	174.28	68.85	103.27
2010	471.84	261.75	257.27	94.36	141.55
2015	611.97	376.92	296.25	122.39	183.59
2020	755.04	510.41	320.13	151.00	226.51
2025	904.58	688.47	306.56	180.91	271.37
2030	1,073.46	983.72	197.08	214.69	322.03
2035	1,238.76	1,266.75	95.88	247.75	371.62

Table C.19. Scenario MIX3 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	368.89	204.40	201.38	73.77	110.66
2010	550.54	261.75	343.83	110.10	165.16
2015	716.74	376.92	411.50	143.34	215.02
2020	899.69	498.12	491.53	179.93	269.90
2025	1,102.41	700.76	511.89	220.48	330.72
2030	1,332.33	941.82	523.74	266.46	399.69
2035	1,575.63	1,308.66	424.53	315.12	472.69

Table C.20. Scenario MIX4 Basic Macroeconomic Results (10^9 dollar)

Year	GDP	Investment	Consumption	Export	Import
2000	205.00	135.84	95.88	27.78	54.50
2005	359.57	204.40	191.12	71.91	107.87
2010	521.34	261.75	311.72	104.27	156.40
2015	709.13	376.92	403.13	141.82	212.74
2020	923.56	498.12	517.79	184.71	277.07
2025	1,170.62	700.76	586.92	234.12	351.18
2030	1,463.31	941.82	667.82	292.66	438.99
2035	1,803.47	1,308.66	675.15	360.69	541.04

APPENDIX D: ENERGY RESULTS OF THE SCENARIOS

Electricity consumption values from different scenarios are given from Table D.1 to Table D.14.

Table D.1. Electricity Consumption Results of Scenario EM1 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	55.17	10.66	3.60	31.47	61.06	1.67	0.00	0.06	0.13	0.10	163.91
2010	81.78	14.37	11.60	0.04	80.82	1.45	0.04	0.09	0.13	1.09	191.40
2015	110.01	10.50	3.60		101.58	0.78	0.05	0.12	0.13	1.40	228.15
2020	139.93	7.19	3.60		106.89	0.58	0.12	0.15	0.22	1.43	260.09
2025	171.63	7.19	3.60		107.17	0.38	0.32	0.19	0.21	1.46	292.15
2030	210.22	7.19	3.60		107.17	0.38	0.32	0.23	0.55	1.51	331.16
2035	250.78	7.19	3.60		107.17	0.38	0.32	0.28	1.03	1.56	372.30

Table D.2. Electricity Consumption Results of Scenario EM2 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	55.17	10.66	12.90	34.86	42.60	1.21	0.00	0.06	0.13	0.14	157.72
2010	81.78	13.06	22.70	34.35	42.60	0.99	0.00	1.14	0.14	0.28	197.04
2015	110.01	17.03	15.13	34.12	50.40	0.78	0.00	1.49	0.14	0.35	229.45
2020	139.93	9.81	13.33	34.18	64.66	0.58	0.00	1.52	0.32	0.43	264.75
2025	171.63	7.19	3.60	32.49	88.74	0.38	0.00	1.56	0.57	0.51	306.66
2030	210.22	7.19	3.60	19.67	111.21	0.38	0.00	1.60	0.92	0.61	355.37
2035	250.78	7.19	3.60		145.65	0.38	0.00	1.64	1.40	0.71	411.35

Table D.3. Electricity Consumption Results of Scenario EM3 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	55.17	10.66	12.90	36.82	61.06	1.67	0.00	0.06	0.13	0.14	178.60
2010	81.78	14.37	22.70	38.37	75.08	0.99	0.00	0.09	0.67	0.21	234.26
2015	110.01	18.34	5.24	40.30	96.21	0.78	0.00	0.12	0.83	0.28	272.10
2020	139.93	22.56	3.60	25.55	118.78	0.58	0.00	0.15	1.04	0.35	312.54
2025	171.63	27.06	3.60	8.06	142.87	0.38	0.00	0.19	1.33	0.43	355.55
2030	210.22	11.85	3.60	2.53	175.65	0.38	0.00	0.23	1.71	0.53	406.69
2035	250.78	7.19	3.60		187.16	0.38	0.23	0.28	1.74	0.63	451.99

Table D.4. Electricity Consumption Results of Scenario EM4 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	55.17	10.66	7.72	35.04	61.06	1.67	0.00	0.06	0.13	0.10	171.60
2010	81.78	14.37	3.60	22.91	80.82	1.45	0.02	0.12	0.13	1.12	206.32
2015	110.01	18.34	3.60	16.21	101.95	1.24	0.02	0.15	0.13	1.47	253.11
2020	139.93	22.56	3.60	9.32	124.53	1.04	0.02	0.19	0.13	1.91	303.21
2025	171.63	27.06	3.60	2.26	148.61	0.84	0.03	0.77	0.13	1.95	356.87
2030	210.22	21.21	3.60		181.39	0.96	0.03	0.81	0.14	2.62	420.98
2035	250.78	12.97	3.60		215.84	1.08	0.03	0.86	0.16	3.51	488.82

Table D.5. Electricity Consumption Results of Scenario No-WTP (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	47.65	10.66	12.90	35.04	61.06	1.67	0.00	0.06	0.13	0.14	169.30
2010	66.35	14.37	22.70	34.72	80.82	1.45	0.00	0.09	0.14	0.21	220.85
2015	86.27	18.34	33.03	34.68	101.95	1.24	0.00	0.12	0.14	0.28	276.05
2020	107.45	22.56	43.92	34.95	124.53	1.04	0.00	0.15	0.15	0.35	335.11
2025	129.98	27.06	55.40	35.53	148.61	0.84	0.00	0.19	0.16	0.43	398.20
2030	158.92	33.05	68.09	42.39	181.39	0.96	0.00	0.23	0.19	0.53	485.75
2035	189.34	39.35	81.43	49.59	215.84	1.08	0.00	0.28	0.23	0.63	577.77

Table D.6. Electricity Consumption Results of Scenario NUC (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Nuclear	Solar	Wind	Biomass	Geothermal
2000	30.09	7.19	3.60	35.63	42.60	1.89		0.00	0.03	0.13	0.08
2005	47.65	10.66	12.90	35.04	61.06	1.67		0.00	0.06	0.13	0.09
2010	66.35	14.37	22.70	34.72	80.82	1.45		0.00	0.12	0.13	1.22
2015	86.27	18.34	33.03	34.68	101.95	1.24	31.21	0.00	0.15	0.13	1.57
2020	107.45	22.56	43.92	34.95	124.53	1.04	28.35	0.00	0.19	0.13	2.01
2025	129.98	27.06	55.40	35.53	148.61	0.84	25.61	0.00	0.22	0.13	2.58
2030	158.92	33.05	68.09	42.39	181.39	0.96	28.19	0.00	0.26	0.14	3.28
2035	189.34	39.35	81.43	49.59	215.84	1.08	30.91	0.00	0.31	0.14	4.18

Table D.7. Electricity Consumption Results of Scenario NUC-EM1 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Nuclear	Solar	Wind	Biomass	Geothermal
2000	30.09	7.19	3.60	35.63	42.60	1.89		0.00	0.03	0.13	0.08
2005	55.17	10.66	3.60	31.51	61.06	1.67		0.00	0.06	0.13	0.10
2010	81.78	14.37	11.60	0.04	80.82	1.45		0.00	0.09	0.13	1.24
2015	110.01	18.07	20.43		60.92	0.78	31.21	0.00	0.12	0.13	1.59
2020	139.93	22.30	3.60	0.27	83.49	0.58	28.35	0.00	0.15	0.13	2.04
2025	171.63	7.19	3.60		107.17	0.38	25.61	0.01	0.72	0.13	2.07
2030	210.22	7.19	3.60		107.17	0.38	28.19	0.01	0.77	0.14	2.75
2035	250.78	7.19	3.60		107.17	0.38	30.91	0.01	0.81	0.57	2.80

Table D.8. Electricity Consumption Results of Scenario NUC-EM2 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Nuclear	Solar	Wind	Biomass	Geothermal
2000	30.09	7.19	3.60	35.63	42.60	1.89		0.00	0.03	0.13	0.08
2005	55.17	10.66	12.90	34.86	45.40	1.67		0.00	0.06	0.13	0.14
2010	81.78	14.37	18.66	34.35	46.95	1.45		0.23	0.26	0.16	0.28
2015	110.01	7.19	28.26	34.12	42.60	0.78	31.21	0.34	0.29	0.17	0.35
2020	139.93	11.41	11.63	34.18	65.17	0.58	28.35	0.49	0.32	0.18	0.43
2025	171.63	15.92	3.60	24.63	89.26	0.38	25.61	0.71	0.36	0.19	0.51
2030	210.22	7.19	3.60	19.67	111.21	0.38	28.19	0.85	0.40	0.34	0.61
2035	250.78	7.19	3.60		145.65	0.38	30.91	0.96	0.44	0.65	0.71

Table D.9. Electricity Consumption Results of Scenario NUC-EM3 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Nuclear	Solar	Wind	Biomass	Geothermal
2000	30.09	7.19	3.60	35.63	42.60	1.89		0.00	0.03	0.13	0.08
2005	55.17	10.66	12.90	36.82	61.06	1.67		0.00	0.06	0.13	0.14
2010	81.78	14.37	22.70	38.37	75.08	0.99		0.01	0.12	0.62	0.21
2015	110.01	18.34	5.24	40.30	96.21	0.78	31.21	0.01	0.15	0.78	0.28
2020	139.93	22.56	3.60	25.55	118.78	0.58	28.35	0.01	0.19	0.99	0.35
2025	171.63	27.06	3.60	8.06	142.87	0.38	25.61	0.03	0.22	1.23	0.43
2030	210.22	12.91	3.60	1.61	175.65	0.38	28.19	0.03	0.26	1.60	0.53
2035	250.78	7.19	3.60		187.16	0.38	30.91	0.28	0.31	1.65	0.63

Table D.10. Electricity Consumption Results of Scenario NUC-EM4 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Nuclear	Solar	Wind	Biomass	Geothermal
2000	30.09	7.19	3.60	35.63	42.60	1.89		0.00	0.03	0.13	0.08
2005	55.17	10.66	7.86	35.04	61.06	1.67		0.00	0.06	0.13	0.10
2010	81.78	14.37	3.60	22.91	80.82	1.45		0.01	0.09	0.13	1.22
2015	110.01	18.34	3.60	16.21	101.95	1.24	31.21	0.01	0.46	0.13	1.25
2020	139.93	22.56	3.60	9.32	124.53	1.04	28.35	0.01	0.95	0.13	1.28
2025	171.63	27.06	3.60	2.26	148.61	0.84	25.61	0.01	1.61	0.13	1.31
2030	210.22	21.21	3.60		181.39	0.96	28.19	0.01	1.65	0.45	1.36
2035	250.78	12.97	3.60		215.84	1.08	30.91	0.01	1.69	0.47	2.24

Table D.11. Electricity Consumption Results of Scenario MIX1 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	120.99
2005	55.17	10.66	12.90	36.82	61.06	1.67	0.00	0.06	0.13	0.10	178.27
2010	81.78	14.37	22.70	38.37	75.08	0.99	0.00	2.39	0.13	0.13	233.29
2015	110.01	18.34	5.24	40.30	96.21	0.78	0.00	3.48	0.13	0.16	270.88
2020	139.93	22.56	3.60	25.55	118.78	0.58	0.00	5.21	0.13	0.19	311.00
2025	171.63	27.06	3.60	8.06	142.87	0.38	0.00	8.06	0.13	0.22	353.60
2030	210.22	11.85	3.60	2.53	175.65	0.38	0.00	12.89	0.14	0.27	404.22
2035	250.78	7.19	3.60		187.16	0.38	0.00	21.47	0.23	0.32	449.10

Table D.12. Electricity Consumption Results of Scenario MIX2 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	55.17	10.57	12.90	34.86	42.60	1.21	0.00	0.06	0.13	0.14	157.63
2010	81.78	13.06	22.70	34.35	42.60	0.99	0.00	0.09	0.14	1.76	197.47
2015	110.01	17.03	15.21	34.12	50.27	0.78	0.00	0.12	0.41	2.01	229.94
2020	139.93	9.59	13.55	34.18	64.62	0.58	0.00	0.15	0.42	3.15	266.16
2025	171.63	7.19	3.60	32.51	88.70	0.38	0.00	0.19	0.43	5.10	309.72
2030	210.22	7.19	3.60	19.67	111.21	0.38	0.00	0.23	0.66	8.28	361.42
2035	250.78	7.19	3.60		145.65	0.38	0.00	0.28	0.69	14.90	423.47

Table D.13. Electricity Consumption Results of Scenario MIX3 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.19	3.60	35.63	42.60	1.89	0.00	0.03	0.13	0.08	121.23
2005	55.17	10.66	12.90	36.82	61.06	1.67	0.00	0.06	0.13	0.14	178.60
2010	81.78	14.37	22.70	38.37	75.08	0.99	0.00	0.12	1.19	0.21	234.81
2015	110.01	18.34	5.24	40.30	96.21	0.78	0.00	0.15	1.70	0.28	273.01
2020	139.93	22.56	3.60	25.55	118.78	0.58	0.00	0.19	2.62	0.35	314.16
2025	171.63	27.06	3.60	8.06	142.87	0.38	0.00	0.22	2.63	1.85	358.30
2030	210.22	11.39	3.60	2.93	175.65	0.38	0.00	0.26	2.66	4.66	411.75
2035	250.78	7.19	3.60		187.16	0.38	0.01	0.31	2.70	10.33	462.45

Table D.14. Electricity Consumption Results of Scenario MIX4 (TWh)

Year	Hydro	Oil	Coal	Lignite	N.gas	Other	Solar	Wind	Biomass	Geothermal	TOTAL
2000	30.09	7.18	3.59	35.63	42.59	1.88	0.00	0.03	0.13	0.08	121.23
2005	55.16	10.66	7.72	35.03	61.05	1.66	0.00	0.06	0.13	0.10	171.60
2010	81.78	14.37	3.60	22.91	80.82	1.45	0.00	0.12	0.13	1.61	206.79
2015	110.00	18.33	3.60	16.20	101.95	1.24	0.00	0.15	0.13	2.24	253.87
2020	139.92	22.56	3.60	9.31	124.52	1.03	0.00	0.19	0.13	3.19	304.47
2025	171.62	27.06	3.60	2.26	148.61	0.83	0.00	0.22	0.13	4.69	359.04
2030	210.21	21.21	3.60		181.39	0.95	0.00	0.26	0.14	7.09	424.88
2035	250.77	12.96	3.60		215.84	1.08	0.00	0.31	0.16	11.21	495.95

Non-electric energy consumption values from different scenarios are given from Table D.15 to Table D.24.

Table D.15. Non-Electric Energy Consumption Results of Scenario EM1 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	29.83	11.72	7.33	21.49	4.19	74.58
2010	29.83	8.21	5.78	29.89	3.08	76.79
2015	29.83	8.63	4.26	33.12	2.21	78.06
2020	29.83	9.14	2.79	36.15	1.33	79.25
2025	29.83	9.79	1.36	38.87	0.45	80.31
2030	29.83	8.21	1.36	42.02	0.11	81.53
2035	29.83	8.21	1.36	42.08	0.07	81.55

Table D.16. Non-Electric Energy Consumption Results of Scenario EM2 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	34.56	13.00	11.93	13.58	4.21	77.27
2010	40.19	18.11	10.31	13.58	3.32	85.51
2015	34.42	23.54	8.72	16.44	2.45	85.57
2020	29.83	25.98	7.16	22.59	1.57	87.13
2025	29.83	23.10	5.65	32.13	0.14	90.85
2030	29.83	14.39	6.43	45.19	0.11	95.95
2035	33.62	8.21	1.36	58.92	0.07	102.18

Table D.17. Non-Electric Energy Consumption Results of Scenario EM3 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	38.97	13.00	11.99	19.80	4.21	87.97
2010	46.87	18.11	10.45	28.24	3.34	106.99
2015	50.03	17.25	4.27	37.23	2.46	111.23
2020	51.02	12.98	2.79	46.79	1.58	115.17
2025	50.55	9.50	1.36	56.95	0.71	119.06
2030	42.45	8.21	1.36	70.01	0.67	122.69
2035	32.93	8.21	1.36	83.73	0.07	126.30

Table D.18. Non-Electric Energy Consumption Results of Scenario EM4 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	37.64	10.23	7.33	21.49	4.22	80.91
2010	45.49	8.21	5.78	29.94	2.77	92.19
2015	50.56	8.21	4.27	38.92	1.89	103.86
2020	56.04	8.21	2.79	48.48	1.02	116.55
2025	61.99	8.21	1.36	58.64	0.14	130.35
2030	64.07	8.21	1.36	71.70	0.11	145.45
2035	66.82	8.21	1.36	85.43	0.07	161.89

Table D.19. Non-Electric Energy Consumption Results of Scenario No-WTP (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.829	8.212	13.580	13.577	5.081	70.280
2005	37.398	13.003	11.995	21.498	4.209	88.102
2010	45.606	18.107	10.446	29.937	3.335	107.432
2015	54.487	23.542	8.933	38.923	2.460	128.345
2020	64.074	29.324	7.458	48.482	1.584	150.922
2025	74.404	35.471	6.023	58.644	0.706	175.248
2030	90.487	43.369	6.893	71.703	0.674	213.126
2035	107.389	51.671	7.809	85.429	0.639	252.937

Table D.20. Non-Electric Energy Consumption Results of Scenario NUC (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	37.39	13.00	11.99	21.49	4.21	88.10
2010	45.61	18.11	10.45	29.94	3.34	107.43
2015	54.49	23.54	8.93	38.92	2.46	128.35
2020	64.07	29.32	7.46	48.48	1.58	150.92
2025	74.40	35.47	6.02	58.64	0.71	175.25
2030	90.49	43.37	6.89	71.70	0.67	213.13
2035	107.39	51.67	7.81	85.43	0.64	252.94

Table D.21. Non-Electric Energy Consumption Results of Scenario NUC-EM1 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	29.83	11.76	7.33	21.46	4.19	74.57
2010	29.83	8.21	5.78	29.89	3.08	76.79
2015	29.83	8.21	4.27	33.93	2.14	78.38
2020	29.83	8.31	2.79	37.64	1.26	79.83
2025	29.83	9.01	1.36	40.28	0.38	80.86
2030	29.83	8.21	1.36	42.02	0.11	81.53
2035	29.83	8.21	1.36	42.08	0.07	81.55

Table D.22. Non-Electric Energy Consumption Results of Scenario NUC-EM2 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.829	8.212	13.580	13.577	5.081	70.280
2005	35.472	13.003	11.928	13.577	4.209	78.189
2010	40.194	18.107	10.307	13.577	3.322	85.507
2015	33.680	23.542	8.718	17.431	2.447	85.819
2020	29.829	25.184	7.164	23.898	1.571	87.646
2025	29.829	22.492	5.647	32.269	0.693	90.930
2030	29.829	14.396	6.430	45.190	0.107	95.953
2035	33.620	8.212	1.358	58.915	0.073	102.179

Table D.23. Non-Electric Energy Consumption Results of Scenario NUC-EM3 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	38.97	13.00	11.99	20.31	4.21	88.49
2010	46.49	18.11	10.45	28.75	3.34	107.13
2015	42.17	23.35	4.27	37.74	2.46	109.99
2020	46.49	16.36	2.79	47.29	1.58	114.53
2025	48.85	10.58	1.36	57.46	0.71	118.95
2030	42.05	8.23	1.36	70.52	0.67	122.83
2035	32.55	8.21	1.36	84.25	0.07	126.43

Table D.24. Non-Electric Energy Consumption Results of Scenario NUC-EM4 (Mtoe)

Year	Oil	Coal	Lignite	Naturalgas	Other	TOTAL
2000	29.83	8.21	13.58	13.58	5.08	70.28
2005	37.77	10.13	7.33	21.49	4.21	80.94
2010	45.49	8.21	5.78	29.94	2.77	92.19
2015	48.04	10.27	4.27	38.92	1.89	103.39
2020	56.04	8.21	2.79	48.48	1.02	116.54
2025	61.99	8.21	1.36	58.64	0.14	130.35
2030	64.07	8.21	1.36	71.70	0.11	145.45
2035	66.82	8.21	1.36	85.43	0.07	161.89

APPENDIX E: CO₂ EMISSIONS FROM BAU SCENARIO

CO₂ emission values of BAU scenario are summarized at Table E.1.

Table E.1. BAU Scenario CO₂ Emission Results (MtC)

Year	Electricity	Non-Electricity
2000	69.92	229.27
2005	91.47	280.54
2010	114.71	336.38
2015	139.76	397.01
2020	166.63	462.69
2025	195.49	533.67
2030	238.07	648.42
2035	282.82	769.03

APPENDIX F: RENEWABLE ENERGY RESULTS OF THE SCENARIOS

Table F.1. Renewable Energy Consumption Results of Scenario LIS (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.077	0.131	0.215
2010	0.001	0.124	0.137	1.191
2015	0.001	0.173	0.144	1.509
2020	0.001	0.225	0.265	1.673
2025	0.001	0.280	0.275	2.197
2030	0.001	0.343	0.528	2.392
2035	0.001	0.410	0.562	3.225

Table F.2. Renewable Energy Consumption Results of Scenario LIW (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.077	0.131	0.215
2010	0.001	0.124	0.137	1.208
2015	0.001	0.173	0.144	1.534
2020	0.001	0.225	0.152	1.952
2025	0.001	0.280	0.333	2.125
2030	0.001	0.343	0.366	2.768
2035	0.001	0.410	0.400	3.617

Table F.3. Renewable Energy Consumption Results of Scenario LIB (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.077	0.131	0.215
2010	0.010	0.173	0.162	1.050
2015	0.010	0.222	0.169	1.372
2020	0.010	0.274	0.177	1.784
2025	0.016	0.329	0.187	2.286
2030	0.016	0.393	0.220	2.927
2035	0.016	0.459	0.254	3.775

Table F.4. Renewable Energy Consumption Results of Scenario LIG (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.077	0.131	0.215
2010	0.008	0.124	0.471	0.515
2015	0.008	0.173	0.573	0.670
2020	0.007	0.225	0.724	0.834
2025	0.007	0.280	0.944	1.007
2030	0.007	0.343	1.249	1.202
2035	0.007	0.410	1.686	1.406

Table F.5. Renewable Energy Consumption Results of Scenario LID (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.077	0.131	0.215
2010	0.001	1.412	0.162	0.362
2015	0.001	1.813	0.169	0.518
2020	0.001	1.864	0.177	0.984
2025	0.501	1.919	0.187	1.157
2030	0.501	1.983	0.220	1.895
2035	0.501	2.05	0.254	2.881

Table F.6. Renewable Energy Consumption Results of Scenario IG1 (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.060	0.131	0.139
2010	0.001	0.090	0.667	0.283
2015	0.096	0.121	0.673	0.354
2020	0.096	0.153	0.682	0.950
2025	0.096	0.188	0.692	1.588
2030	0.096	0.231	0.724	2.265
2035	0.096	0.275	0.758	3.113

Table F.7. Renewable Energy Consumption Results of Scenario IG2 (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.060	0.131	0.139
2010	0.004	0.507	0.540	0.207
2015	0.004	1.085	0.547	0.278
2020	0.004	1.118	0.555	0.759
2025	0.004	1.152	0.863	0.839
2030	0.004	1.195	1.262	0.937
2035	0.004	1.239	1.793	1.039

Table F.8. Renewable Energy Consumption Results of Scenario IG3 (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.060	0.131	0.139
2010	0.001	0.505	0.137	1.104
2015	0.001	0.536	0.144	1.599
2020	0.001	0.568	0.152	2.098
2025	0.002	0.603	0.162	2.711
2030	0.002	0.646	0.194	3.423
2035	0.018	0.690	0.229	4.235

Table F.9. Renewable Energy Consumption Results of Scenario IP1 (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.060	0.131	0.139
2010	0.001	1.384	0.137	0.207
2015	0.001	1.794	0.144	0.278
2020	0.001	2.343	0.152	0.353
2025	0.001	3.083	0.162	0.433
2030	0.001	3.125	0.194	1.187
2035	0.001	3.169	0.229	2.006

Table F.10. Renewable Energy Consumption Results of Scenario IP2 (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.060	0.131	0.139
2010	0.001	1.529	0.137	0.207
2015	0.001	1.988	0.144	0.278
2020	0.001	2.604	0.152	0.353
2025	0.001	3.439	0.162	0.433
2030	0.001	4.439	0.194	0.531
2035	0.001	5.454	0.229	0.633

Table F.11. Renewable Energy Consumption Results of Scenario IP3 (TWh)

Year	Solar	Wind	Bioenergy	Geothermal
2000	0.001	0.033	0.127	0.076
2005	0.001	0.060	0.131	0.139
2010	0.001	0.090	0.779	0.207
2015	0.001	0.121	0.975	0.278
2020	0.001	0.153	1.243	0.353
2025	0.001	0.188	1.611	0.433
2030	0.001	0.231	2.106	0.531
2035	0.001	0.275	2.802	0.633

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