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# MODELING THE RELATIONSHIP AMONG ENERGY DEMAND, $CO_2$ EMISSIONS AND ECONOMIC DEVELOPMENT: A SURVEY FOR THE CASE OF GREECE

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**ABSTRACT**
The purpose of this paper is to offer an initial presentation and classification of the methodological approaches used to analyzing energy demand, related $CO_2$ emissions and economic development for countries, regions and subsequently to provide for an extended survey of related articles for the case-study of Greece that identified 48 scientific publications. It was found that all three main existent methodological analytical schemes, namely 'Top-down' models, Econometric methods and Decomposition Analysis methods, have been applied to model energy, environmental and macro-economic variables for Greece. Specific application areas included sectoral (industrial, transport, tourism, manufacturing, residential and electricity) energy demand and related $CO_2$ emissions, energy prices and energy taxation. The paper culminates to a comprehensive comparison of employed methods and obtained results for Greece and conclusions.

**KEYWORDS**: Energy demand, $CO_2$ emissions, Economic development, Survey, Greece.

## INTRODUCTION

As a fundamentally empirical activity, the practice of modeling of the relationship among energy use, $CO_2$ emissions and economic development is necessarily a synthesis of data and methods (Greening *et al.*, 2007). To this end, particular quantitative methodological tools and models appeared in the scientific literature in the late 70s, early 80s.
The objective of this article is to provide for an initiatory overview and categorization of the methodologies used in this area, and a survey and a first round comparison of relevant studies for the case of Greece. There is a multi-dimensional need for this review paper:

- There emerges an urgent need for current economic recession to be analyzed and accordingly tackled in order for Greece to be back on track towards a sustainable state form an economic, energy and environmental point of view.
- Greece has ratified the Kyoto Protocol and is in the process of assessing its course regarding greenhouse gas emissions under the post-Kyoto procedures.
- According to the Ministry of Development of Greece, at the end of 2020 $CO_2$ emissions will surpass the 1990 level by 68% leading the country to an unsustainable state form an environmental point of view (YPAN, 2004). Nevertheless, recent severe economic recession has significantly affected energy consumption and it would be expected that new scenarios for $CO_2$ emissions will be set at lower levels.
- Energy intensity has been decreased by 13% for 1980-2005, indicating improvements in energy efficiency and a shift from industry towards services, which are typically less energy intensive (YPAN, 2004).
- Under the 1980–2009 period, structural changes in the Greek energy sector (e.g. the penetration of natural gas in the electricity generation and the building sector) and economic reforms programmes (e.g. Community Support Framework I, II and III) have occurred, whereas the National Strategic Reference Framework is currently under progress.

- Greece could play a strategic role as a gas transit country (Doukas *et al*., 2010).

The paper is organized as follows. Section 2 provides for an overview of the basic methodological approaches; Section 3 presents the surveyed studies in a classified form, a description of their main features and a comparison of methods and results. Finally, in Section 4, the conclusions of the review are summarized.

## BASIC METHODOLOGICAL APPROACHES

Figure 1 presents the most common methodologies for investigating the relationship among Energy demand, $CO_2$ emissions and Economic development.

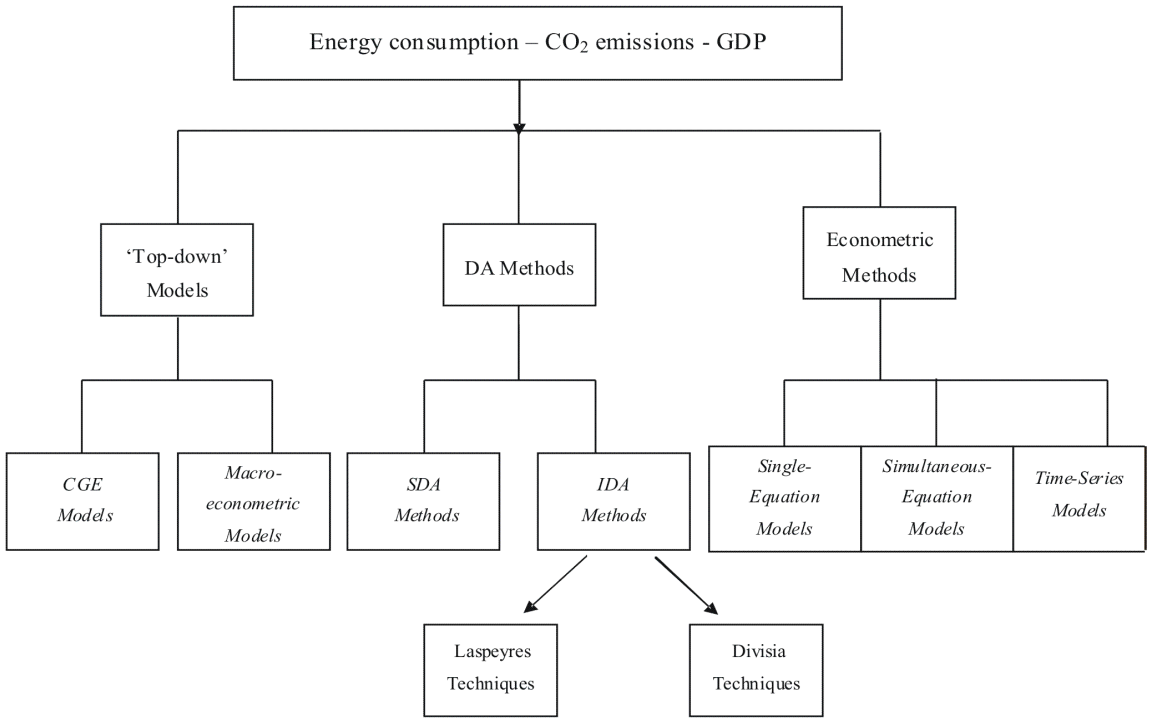


*Figure 1.* Methodologies for modeling energy demand, $CO_2$ emissions and GDP

'*Top-down' models*

This category of models/methodologies comprises of Computable General Equilibrium (CGE) models and macro-economic models that utilize econometrically estimated parameters as input data. The main advantage of this approach is the depiction of economy-wide interactions including impacts on sector and total output, employment, consumption, investment, trade, prices and wages (Allan *et al.*, 2007).

*Decomposition Analysis (DA) methods*

Decomposition Analysis (DA) methods constitute a widely accepted analytical tool for policymaking in energy and environmental issues; characteristically the paper by Liu and Ang, 2007 lists a total of 336 related publications up to 2006. Nevertheless, although widely used by a variety of researchers and organizations, no single or standard DA method for has emerged (Tol and Weyant, 2006). DA methods include Index Decomposition Analysis (IDA) and Structural Decomposition Analysis (SDA) and have a long history of independent development, leading to different approaches and techniques. IDA methods can be further divided into two groups: techniques based on the Divisia Index and techniques linked to the Laspeyres Index. For a review of IDA methods one may refer to Ang and Zhang, 2000 and Ang, 2004; an overview of SDA methods is provided by Rose and Casler, 1996.

*Econometric methods*

Econometric methods include single-equation models, simultaneous-equation models and time series models. They can range in complexity from very simple to relatively sophisticated, and can be

applied to data of varying temporal, spatial, and sectoral detail. Since the seminal work of Kraft and Kraft, 1978 different time series techniques such as correlation analysis, simple regressions, bivariate causality, unit root testing, multivariate cointegration, panel cointegration, and Vector Error Correction Modeling (VECM) have been carried out in order to determine the causal relationship between energy use and economic growth. A comprehensive review of this type of literature is presented in Ghali and El-Sakka, 2004. Particularly, the causal relationship between energy use and economic output has been the topic of considerable research in the energy economics literature; characteristically the paper by Chontanawat *et al.*, 2008 provides causality tests between energy consumption and Gross Domestic Product (GDP) for over 100 countries.

It should be noted that other types of models that study energy consumption and related $CO_2$ emissions also exist, however they fail to account for macro-economic variables in their analysis. Examples of such models are the so called 'bottom-up' detailed technological models that are based on disaggregation and the inclusion of a large number of technical parameters. These parameters represent the different end-sectors of an economy or the different end-use energy demand (Jacobsen, 1998). Models based on the bottom-up approach can be either optimization/programming (Mavrotas *et al.*, 2007) or simulation models (Gilen and Taylor, 2007; Oda *et al.*, 2007).

It is evident that there exists a variety of methodological approaches for modeling the relationship among energy consumption, $CO_2$ emissions and economic output (for an ex post evaluation of European energy models, one may refer to Pilavachi *et al.*, 2008) and that no compendium existed that surveyed the methods used in this area for the case of a particular country or region. We therefore hereinafter gather, present and categorize papers on a range of topics that deal within the general area of energy-economy-environment interactions analysis for the case of Greece.

## CLASSIFICATION – MAIN FEATURES OF PAST STUDIES

### *Presentation of reviewed studies*

We have reviewed 48 papers that deal with the modeling of macroeconomic, energy and environmental variables and their linkages for the case of Greece (Table 1).

*Table 1.* Studies based on 'Top-down' models, DA methods and Econometric methods, for the Greek energy system (presented alphabetically)

| No | Publication | Methodological Approach | Application Area |
|---|---|---|---|
| 1 | Agoris *et al.*, 2004 | Econometric methods | Sectoral Energy Demand |
| 2 | Caloghirou *et al.*, 1997 | Econometric methods | Industrial Energy Demand |
| 3 | Capros *et al.*, 2001 | 'Top-down' models | Sectoral $CO_2$ Emissions |
| 4 | Capros and Vouyoukas, 2000 | 'Top-down' models | Energy Demand |
| 5 | Capros and Mantzos, 2000a | 'Top-down' models | $CO_2$ Emissions |
| 6 | Capros and Mantzos, 2000b | 'Top-down' models | Energy Demand |
| 7 | Capros and Mantzos, 2000c | 'Top-down' models | Industrial $CO_2$ Emissions |
| 8 | Capros and Mantzos, 1999 | 'Top-down' models | Sectoral $CO_2$ Emissions |
| 9 | Capros *et al.*, 1999a | 'Top-down' models | Energy Demand |
| 10 | Capros *et al.*, 1999b | 'Top-down' models | $CO_2$ Emissions |
| 11 | Capros *et al.*, 1999c | 'Top-down' models | Energy Demand |
| 12 | Capros *et al.*, 1999d | 'Top-down' models | $CO_2$ Emissions |
| 13 | Capros *et al.*, 1997 | 'Top-down' models | $CO_2$ Emissions |
| 14 | Capros and Kokkolakis, 1996 | 'Top-down' models | Energy Efficiency |
| 15 | Christodoulakis *et al.*, 2000 | Top-down' models | Energy Consumption |

*Table 1 (continued).* Studies based on 'Top-down' models, DA methods and Econometric methods, for the Greek energy system (presented alphabetically)

| No | Publication | Methodological Approach | Application Area |
|---|---|---|---|
| 16 | Christodoulakis and Kalyvitis, 1997 | 'Top-down' models | Energy Demand |
| 17 | Diakoulaki and Mandaraka, 2007 | DA methods | Industrial $CO_2$ Emissions |
| 18 | Diakoulaki *et al.*, 2006 | DA methods | $CO_2$ Emissions |
| 19 | Diakoulaki *et al.*, 2000 | DA methods | Manufacturing $CO_2$ Emissions |
| 20 | Donatos and Mergos, 1991 | Econometric methods | Residential Electricity Demand |
| 21 | Donatos and Mergos, 1989 | Econometric methods | Energy Demand |
| 22 | Floros and Vlachou, 2005 | Econometric methods | Manufacturing $CO_2$ Emissions |
| 23 | Hatzigeorgiou *et al.*, 2011 | Econometric methods | $CO_2$ Emissions |
| 24 | Hatzigeorgiou *et al.*, 2010 | DA methods | $CO_2$ Emissions |
| 25 | Hatzigeorgiou *et al.*, 2008a | DA methods | $CO_2$ Emissions |
| 26 | Hatzigeorgiou *et al.*, 2008b | DA methods | $CO_2$ Emissions |
| 27 | Hondroyiannis, 2004 | Econometric methods | Residential Electricity Demand |
| 28 | Hondroyiannis *et al.*, 2002 | Econometric methods | Energy Consumption |
| 29 | Hristu-Varsakelis *et al.*, 2010 | DA methods | $CO_2$ Emissions |
| 30 | Kouvaritakis *et al.*, 2000 | 'Top-down' models | $CO_2$ Emissions Scenarios |
| 31 | Maleviti *et al.*, 2009 | DA methods | $CO_2$ Emissions in the tourist sector |
| 32 | Mitropoulos *et al.*, 1982 | Econometric methods | Forecasting Energy Demand |
| 33 | Papadopoulos and Haralambopoulos, 2006 | Econometric methods | $CO_2$ Emissions & Energy Prices |
| 34 | Papagiannaki and Diakoulaki, 2009 | DA methods | $CO_2$ Emissions in the transport sector |
| 35 | Papapetrou, 2001 | Econometric methods | Energy Prices & Economic activity |
| 36 | Paravantis and Georgakellos, 2007 | Econometric methods | $CO_2$ Emissions in the transport sector |
| 37 | Patsouratis and Souflias, 1995 | Econometric methods | Manufacturing $CO_2$ Emissions |
| 38 | Polemis, 2007 | Econometric methods | Industrial Energy Demand |
| 39 | Polemis, 2006 | Econometric methods | Energy Demand in the transport sector |
| 40 | Rapanos and Polemis, 2006 | Econometric methods | Residential Energy Demand |
| 41 | Rapanos and Polemis, 2005 | Econometric methods | Energy Demand & Taxation |
| 42 | Rapanos, 1995 | Econometric methods | Environmental Taxes |
| 43 | Salta *et al.*, 2009 | DA methods | Manufacturing Energy Use |
| 44 | Samouilidis and Mitropoulos, 1984 | Econometric methods | Energy Demand |
| 45 | Vassos and Vlachou, 1996 | Econometric methods | Electricity Supply & Taxation |
| 46 | Vehmas, 2009 | DA methods | $CO_2$ Emissions |
| 47 | Vlachou *et al.*, 1996 | Econometric methods | $CO_2$ Emissions |
| 48 | Zonzilos and Lolos, 1996 | Econometric methods | Residential Energy Demand |

***Methodological Approach***

To study possible changes over time, we classified the studies into three time periods: 1980–1990, 1990–2000, and 2000–2011. The total numbers of publications in these three periods are respectively 3, 14, and 31. Figure 2 presents the number of studies during the selected sub-periods, according to the applied methodological approach.

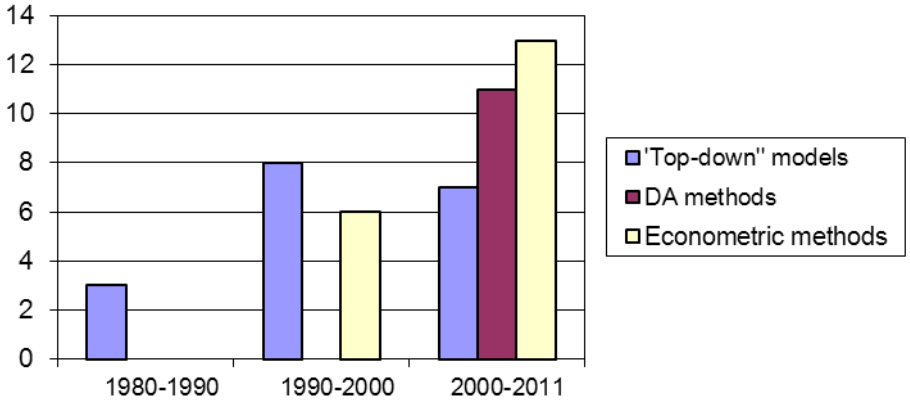


*Figure 2.* Number of studies according to the applied methodology

From Figure 2 the following remarks can be given:

- For the first sub-period we have identified only 3 studies (Donatos and Mergos, 1989; Mitropoulos *et al.*, 1982; Samouilidis and Mitropoulos, 1984) which have investigated energy demand and its association to output and prices, using conventional econometric techniques. The paper by Samouilidis and Mitropoulos, 1984 is probably the first publication in a recognized scientific journal, in this line.
- Most studies dealing with the application of 'Top-down' models to the Greek economy have appeared in the literature at the beginning of 2000s. The majority of these articles analyzed the impact of certain economic activities or governmental policies on energy consumption and related $CO_2$ emissions using macroeconomic models (e.g. Christodoulakis *et al.*, 2000). It can also be observed that 43% of the selected papers in the 1990-2000 time period adopted econometrics methods. Characteristically, the publication by Donatos and Mergos, 1991 examined the residential electricity consumption over the period 1961-1986, using a single equation model.
- During the last sub-period, IDA has been an area in which extensive research has been conducted; the share taken up by IDA applications is 35%. Examples of such studies include Diakoulaki and Mandaraka, 2007, Diakoulaki *et al.*, 2006, Diakoulaki *et al.*, 2000. In addition, Hatzigeorgiou *et al.*, 2008, investigated the factors that explain the increase of energy-related $CO_2$ emissions in Greece from 1990 to 2002 by means of the Arithmetic Mean Divisia Index (AMDI) and the Logarithmic Mean Divisia Index (LMDI) techniques on a period-wise and on a time-series basis. Recently, Hristou-Varsakelis *et al.*, 2011 have used a SDA analysis to optimize production with $CO_2$ emission constraints in Greece.
- Considering the studies dealing with the econometric methods, in the 2000-2011 time period we have collated 13 published papers which have investigated the relationship between energy demand and economic growth on the basis of modern econometric approaches. An illustrative example of such studies is the article by Hondroyiannis *et al.*, 2002 which has examined the empirical relationship between energy consumption and economic growth (1960-1996) by means of cointegration and Granger causality tests. In addition, Hatzigeorgiou *et al.*, 2011 investigated the causality among GDP, energy intensity and $CO_2$ emissions from 1977 to 2007, in Greece, using, modern techniques of time series analysis.

### *Application Area*

In the third column of Table 1 papers are presented by application area. Application area consists of two (2) basic categories: (1) energy-related $CO_2$ emissions analysis and (2) energy demand analysis.

Particulalry, it is found that 50% of the selected studies deal with the analysis of overall (e.g Hatzigeorgiou *et al.*, 2008; Papadopoulos and Haralambopoulos, 2006) or sectoral energy related $CO_2$ emissions (e.g Diakoulaki *et al.*, 2007; Hondroyiannis, 2002; Salta *et al.*, 2009). Further breakdown shows substantial increase in the number of energy related $CO_2$ emissions studies whose share in total studies raised from nil in 1980-1990 to 58% in 2000–2011. This might be the result of the world-wide concern on global environmental issues and sustainable development. Most of these studies are concerned with historical analysis. However, the study by Hatzigeorgiou *et al.*, 2010 decomposed changes of future energy-related $CO_2$ emissions, by means of IDA, while Capros and Mantzos, 2000 use the macroeconomic model PRIMES to project $CO_2$ emissions up to 2030.

Energy demand and energy consumption analysis is another popular application area for energy researchers in Greece. Of the 48 selected studies, 19 deal with this area. Until the earlier 2000s most of the publications, focused on energy demand projections, were based on 'Top-down' models. In other papers, sectoral energy demand is estimated using econometric methods; see, for example, Hondroyiannis 2004, Polemis, 2006 and Rapanos and Polemis, 2005.

Lastly, and in addition to the two application areas discussed, econometric methods have also been applied to study the impact of the environmental taxation on energy demand (Rapanos and Polemis, 2005; Rapanos, 1995; Vassos and Vlachou, 2005).

### *Comparison of methods and results*

Several exercises of modeling energy-economy-environment mechanisms have been made for the case of Greece that started form primitive single equation models in the early 80' until more cohesive multivariate time series analysis models lately. More particularly and following the classification of Figure 1 we may address the following. 'Top-down' models have been employed to estimate and project demand functions by sector of economic activity and type of energy. The work of Christodoulakis *et al.*, 2000 is a representative example of such an approach. The authors found that energy demand follows closely economic output and that the annual growth of $CO_2$ emissions for the period 1990-2012 would be around 2%. Decomposition Analysis methods disentangle distinct components behind historical energy and/or emissions data in order to identify the factors that might have caused the observed changes. In a characteristically example Diakoulaki *et al.*, 2006 have applied DA methods for Greece and for the time period of 1990-2002 and concluded that economic growth is strongly coupled with energy consumption and related emissions. In particular, they culminated to the fact that the economic activity is responsible for a +150% of total change of $CO_2$ emissions, while energy intensity is responsible for a -35% of total change. Finally, econometric methods investigate whether economic growth takes precedence over energy consumption or if energy consumption can boost economic growth. Modern econometric techniques focus on exploring the association mechanisms among energy, economic and environmental time series data. Hondroyiannis *et al.*, 2002 uncover that there is a long-run relationship between energy consumption, real GPD and price developments for the studied 1960-1996 time period. More recently Hatzigeorgiou *et al.*, 2011 also concluded that $CO_2$ emissions and GPD are causally interrelated.

Even though all these methodologies investigate the generic relationship among energy, economic and environmental parameters from different points of view and for different purposes, one may say that for the case-study of Greece most scholars have evidenced that there exists a quite strong bi-directional relationship between energy consumption/$CO_2$ emissions and economic output. This main common finding might aid potential policy makers to identify, design and promote adequate relevant fiscal measures tailor-made for Greece to boost social welfare.

## CONCLUSIONS

In contemporary energy planning studies, a broad set of empirical tools has been used to investigate the relationship among energy demand, $CO_2$ emissions and economic development. The comparison of different methodological approaches and results has significant policy implications for the countries, regions studied. This paper offers an initial presentation and classification of

methodologies for analyzing potential links among energy demand, related $CO_2$ emissions and economic development for countries, regions. An extended survey for the case-study of Greece is subsequently presented that identified 48 relevant publications. Next, these studies have been categorized according to the methodological approach adopted, the application area and time-period. A comprehensive comparison of employed methods and results obtained is also unfolded to aid to the identification of the main features of these studies. It was found that all three main existent methodologies, 'Top-down' models, Econometric methods and Decomposition Analysis methods, widely used in current literature, have been applied to model energy, environmental and macro-economic variables for Greece. Specific application areas included sectoral, i.e. industrial, transport, tourism, manufacturing, residential, electricity energy demand and related $CO_2$ emissions, energy prices and energy taxation. Further research could be directed towards the additional analysis of the results for Greece, and subsequently the integration of current methodological approaches to more advanced platforms that would better model current energy, economic and environmental systems.

**REFERENCES**

Agoris D., Tigas K., Giannakidis G., Siakkis F., Vassos S., Vassilakos N., Kilias V., and Damassiotis M. (2004) An analysis of the Greek energy system in view of the Kyoto commitments, *Energy Policy,* **32**, 2019–2033.

Allan G.J., Hanley N., McGregor P.G., Swales K., and Turner K.R.. (2007) The impact of increased efficiency on the industrial use of energy: a computable general equilibrium analysis for the United Kingdom, *Energy Economics,* **29**, 779–798.

Ang B.W. (2004) Decomposition analysis for policymaking in energy: which is the preferred method?, *Energy Policy,* **32**, 1131–1139.

Ang B.W., and Zhang F.Q. (2000) A survey of index decomposition analysis in energy and environmental studies, *Energy,* **25**, 1149–1176.

Caloghirou Y.D., Mourelatos G.A., and Thompson H. (1997) Industrial energy substitution during the 1980s in the Greek economy, *Energy Economics,* **19**, 476-491.

Capros P., Kouvaritakis N., and Mantzos L. (2001) Economic evaluation of sectoral emission reduction objectives for climate change: Top-down analysis of greenhouse gas emissions reduction possibilities in the EU, Contribution to a Study for DG Environment, European Commission by Ecofys Energy and Environment, AEA Technology Environment and National Technical University of Athens. Available at: http://ec.europa.eu/environment/enveco/climate_change/pdf/top_down_analysis.pdf (accessed 1 August 2012).

Capros P., and Vouyoukas E.L. (2000) Technology Evolution and Energy Modelling: overview of research and findings, *Int. J. Global Energy Issues,* **14**, 1-32.

Capros P., and Mantzos L. (2000a) Kyoto and technology at the European Union: costs of emission reduction under flexibility mechanisms and technology progress, *Int. J. Global Energy Issues,* **14**, 169-183.

Capros P., and Mantzos L. (2000b) The European energy outlook to 2010 and 2030, *Int. J. Global Energy Issues,* **14**, 137-154.

Capros P., and Mantzos L. (2000c) The economic effects of EU-wide industry-level emission trading to reduce greenhouse gases: results from PRIMES energy systems model, Institute of Communication and Computer Systems of National Technical University of Athens. Available at: http://ec.europa.eu/environment/enveco/climate_change/pdf/primes.pdf (accessed 1 August 2012).

Capros P. and Mantzos L. (1999) Energy system implications of reducing $CO_2$ emissions: analysis for EU sectors and member-states by using the PRIMES ver.2 energy system model, Institute of Communication and Computer Systems of National Technical University of Athens. Available at: http://ec.europa.eu/environment/enveco/climate_change/pdf/ecoeva.pdf (accessed 1 August 2012).

Capros P., Georgakopoulos P., van Regemorter D., Proost S., Schmidt T.F.N., Koschel H., Conrad K. and Vouyoukas E.L. (1999a) *Climate technology strategies 2: The macroeconomic cost and benefit of reducing greenhouse gas emissions in the European Union*, Springer-Verlag, Berlin.

Capros P., Mantzos L., Criqui P., Kouvaritakis N., Soria A., Schrattenholzer L. and Vouyoukas E.L. (1999b). *Climate technology strategies 1: Controlling greenhouse gases. Policy and technology options*, Springer-Verlag, Berlin.

Capros P., Mantzos L., Vouyoukas E.L. and Petrellis D. (1999c) European energy and $CO_2$ emission trends to 2020: PRIMES model v.2, *Bulletin of Science Technology and Society,* **19**, 474-492.

Capros P., Mantzos L., Petrellis D., Panos V., and Delkis K. (1999d) European Union, Energy Outlook to 2020. Special issue of "Energy in Europe", European Commission-Directorate General for Energy, Office for official publications of the European Communities, Luxembourg, ISBN 92-828-7533-4.

Capros P., Georgakopoulos T., Van Regemorter D., Proost S., Schmidt T., and Conrad K. (1997) The GEM-E3 model for the European Union, *Economic & Financial Modelling* **4**, 51-160.

Capros P., and Kokkolakis E. (1996) Energy Efficiency and Conversion Decentralization: Evidence from the PRIMES Model. In Instruments for Environmental Improvement with Structural and Technological Change in the Electricity Sector International Workshop jointly organised by the European Commission, the International Energy Agency and the OECD on 9-10 September, Brussels, Belgium.

Christodoulakis N., Kalyvitis S., Lalas D., and Pesmajoglou S. (2000) Forecasting energy consumption and energy related $CO_2$ emissions in Greece: An evaluation of the consequences of the Community Support Framework II and natural gas penetration, *Energy Economics,* **22**, 395-422.

Chontanawat J., Hunt L.C, and Pierse R. (2008) Does energy consumption cause economic growth: Evidence from a systematic study of over 100 countries, *Journal of Policy Modeling,* **30**, 209–220.

Christodoulakis N., and Kalyvitis S. (1997) The demand for energy in Greece: assessing the effects of the Community Support Framework 1994-1999, *Energy Economics,* **19**, 393-416.

Diakoulaki D., and Mandaraka M. (2007) Decomposition analysis for assessing the progress in decoupling industrial growth from $CO_2$ emissions in the EU manufacturing sector, *Energy Economics,* **29**, 636-664.

Diakoulaki D., Mavrotas G., Orkopoulos D., and Papayannakis L. (2006) A bottom-up decomposition analysis of energy-related $CO_2$ emissions in Greece, *Energy,* **31**, 2638-2651.

Diakoulaki D., Hontou V., Pavlidou S., and Mavrotas G. (2000) Decomposition analysis of $CO_2$ emissions from the Greek manufacturing sector, *Global Nest*: *the Int. J.,***2**, 119-127.

Donatos G.S., and Mergos G.J. (1991) Residential demand for electricity: The case of Greece, *Energy Economics,* **13**, 41–47.

Donatos G.S, and Mergos G.J. (1989) Energy demand in Greece: The impact of the two energy crisis, *Energy Economics,* **11**, 147-152.

Doukas H., Flamos A., Karakosta Ch., Flouti M., and Psaras J. (2010) Web tool for the quantification of oil and gas corridors' socio-economic risks: the case of Greece, *International Journal of Energy Sector Management,* **4**, 213-235.

Floros N., and Vlachou A. (2005) Energy demand and energy-related $CO_2$ emissions in Greek manufacturing: Assessing the impact of a carbon tax, *Energy Economics,* **27**, 387– 413.

Ghali K.H., and El-Sakka M.I.T. (2004) Energy use and output growth in Canada: a multivariate cointegration analysis, *Energy Economics,* **26**, 225–238.

Gielen D., and Taylor M.S. (2007) Modelling industrial energy use: the IEAs Energy Technology Perspectives, *Energy Economics,* **29**, 889–912.

Greening L.A., Boyd G., and Roop M.J. (2007) Modeling of industrial energy consumption: An introduction and context, *Energy Economics,* **29**, 599–608.

Hatzigeorgiou E., Polatidis H., and Haralambopoulos D. (2011) $CO_2$ emissions, GDP and energy intensity: A multivariate cointegration and causality analysis for Greece, 1977–2007, *Applied Energy,* **88**, 1377-1385.

Hatzigeorgiou E., Polatidis H., and Haralambopoulos D. (2010) Energy $CO_2$ emissions for 1990–2020: a decomposition analysis for EU-25 and Greece, *Energy Sources Part A,* **32**, 1908–1917.

Hatzigeorgiou E., Polatidis H., and Haralambopoulos D. (2008a) $CO_2$ emissions in Greece for 1990-2002: A decomposition analysis and comparison of results using the AMDI and LMDI techniques, *Energy,* **33**, 492-499.

Hatzigeorgiou E., Polatidis H., and Haralambopoulos D. (2008b) Energy related $CO_2$ emissions for Greece: Decomposition Analysis for 1990-2002, In 4$^{th}$ International Congress for South Eastern Europe Energy Efficiency and Renewable Energy Sources, paper No.49, Sofia Bulgaria.

Hondroyiannis G. (2004) Estimating residential demand for electricity in Greece, *Energy Economics,* **26**, 319– 334.

Hondroyiannis G., Lolos S., and Papapetrou E. (2002) Energy consumption and economic growth: assessing the evidence from Greece, *Energy Economics,* **24**, 319-336.

Hristu-Varsakelis D., Karagianni S., Pempetzoglou M., and Sfetsos A. (2010) Optimizing production with energy and GHG emission constraints in Greece: An input–output analysis, *Energy Policy,* **38**, 1566–1577.

Jacobsen H.K. (1998) Integrating the bottom-up and top-down approach to energy-economy modeling: the case of Denmark, *Energy Economics,* **20**, 443-461.

Kouvaritakis N., Criqui P. and Thonet C. (2000) World post-Kyoto scenarios: benefits from accelerated technology progress, *Int. J. Global Energy Issues,* **14**, 184-203.

Kraft J., and Kraft A. (1978) On the relationship between energy and GDP, *Journal of Energy and Development,* **3**, 401–403.

Liu N., and Ang B.W. (2007) Factors shaping aggregate energy intensity trend for industry: Energy intensity versus product mix, *Energy Economics,* **29**, 609-635.

Maleviti E., Yacob M., and Walter W. (2009) Energy Consumption in the Greek Hotel Sector: The Influence of Various Factors on Hotels' Carbon Footprints under the Implementation of the EU and Greek Legislative Framework, In Howlett R.J., Jain L.C., and S.H. Lee (Ed.) *Sustainability in Energy and Buildings*, Springer Berlin, Heidelberg, pp. 339-345.

Mavrotas G., Georgopoulou E., Mirasgedis S., Sarafidis Y., Lalas D., Hontou V., and Gakis N. (2007) An integrated approach for the selection of Best Available Technologies (BAT) for the industries in the greater Athens area using multiobject combinatorial optimization, *Energy Economics,* **29**, 953–973.

Ministry of Development (YPAN). (2004), National Allocation Plan 2005-2007. Available at: http://www.minenv.gr/sede/greeknap_draft_eng_v3.pdf (accessed 1 August 2011) (in Greek).

Mitropoulos C., Samouilidis J., and Protonotarios E. (1982) Forecasting Energy Demand in the Greek Economy, A Kalman Filter Approach. Working paper. National Technical University of Athens (in Greek).

Oda J., Akimotot K., Sanot F., and Tomoda T. (2007) Diffusion of energy efficient technologies and $CO_2$ emission reductions in iron and steel sector, *Energy Economics,* **29**, 868–888.

Papadopoulos E., and Haralambopoulos D.A. (2006) Carbon Emissions: Responses to Energy Intensity, Energy Conversion and Energy Prices. Cointegration analysis for Greece. In ECOS, American Society for Mechanical Engineers (ASME), 19th Int. Conf. on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems.

Papagiannaki K. and Diakoulaki D. (2009) Decomposition analysis of $CO_2$ emissions from passenger cars: The cases of Greece and Denmark, *Energy Policy,* **37**, 3259–3267.

Papapetrou E. (2001) Oil price shocks, stock market, economic activity and employment in Greece, *Energy Economics,* **23**, 511-532.

Paravantis J.A. and Georgakellos D.A. (2007) Trends in energy consumption and carbon dioxide emissions of passenger cars and buses, *Technological Forecasting & Social Change,* **74**, 682-707.

Patsouratis V., and Souflias J. (1995) The impact of an environmental tax on Greek manufacturing, Foundation for Economic and Industrial Research (IOBE), Athens.

Pilavachi P.A., Dalamanga Th., Rossetti di Valdalbero D., and Guilmot J-F. (2008) Ex-post evaluation of European energy models, *Energy Policy,* **36**, 1726-1735.

Polemis M.L. (2007) Modeling industrial energy demand in Greece using cointegration techniques, *Energy Policy,* **35**, 4039–4050.

Polemis M.L. (2006) Empirical assessment of the determinants of road energy demand in Greece, *Energy Economics,* **28**, 385–403.

Rapanos V.T., and Polemis M.L. (2006) The structure of residential energy demand in Greece, *Energy Policy,* **34**, 3137–3143.

Rapanos V.T., and Polemis M.L. (2005) Energy demand and environmental taxes: the case of Greece, *Energy Policy,* **33**, 1781–1788.

Rapanos V.T. (1995) The effects of environmental taxes on income distribution, *European Journal of Political Economy,* **11**, 487–501.

Rose A., and Casler S.D. (1996) Input–output structural decomposition analysis: a critical appraisal, *Economic Systems Research,* **8**, 33–62.

Salta M., Polatidis H., and Haralambopoulos D. (2009) Energy use in the Greek manufacturing sector: A methodological framework based on physical indicators with Aggregation and Decomposition Analysis, *Energy,* **34**, 90-111.

Samouilidis J. E. and Mitropoulos C.S. (1984) Energy and economic growth in industrializing countries: the case of Greece, *Energy Economics,* **6**, 191-201.

Tol R.S.J., and Weyant J.P. (2006) Energy economics' most influential papers, *Energy Economics,* **28**, 405–409.

Vassos S., and Vlachou A. (1996) Evaluating the impact of carbon taxes on the electricity supply industry, *The Journal of Energy and Development,* **21**, 189– 215.

Vehmas J. (2009) Decomposition analysis of $CO_2$ emissions from fuel combustion in selected countries, *International Journal of Environmental Technology and Management,* **11**, 47-67.

Vlachou A., Vassos S., and Andrikopoulos A. (1996) Energy and environment: reducing $CO_2$ emissions from the electric power utility, *Journal of Policy Modeling,* **18**, 343–376.

Zonzilos N., and Lolos S. (1996) Household Energy Demand in Greece, Working paper. National Technical University of Athens, (in Greek).