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Abstract
This paper by using the Long range Energy Alternatives Planning System (LEAP) evaluates the progress towards sustainability with long-term scenarios for the energy map of Southeast Balkans, particularly the three countries of Bulgaria, Greece and Romania. The main objective of this work is to examine and compare scenarios based on organizations reports, so that countries achieve the objectives of the European Commission (abating 40% of greenhouse gas emissions by 2030 and 80-95% by 2050) and finally to observe the contribution of each country to reducing greenhouse gas (GHG) emissions. The results reveal that the main challenge for the Southeast Balkans policy makers will be the energy policies associated with the renewable energy usage. It appears that under the seven different energy policy scenarios the higher the participation of renewable energy the higher the reduction of GHG emissions.

Keywords: LEAP software; Renewable energy sources; Scenario analysis; Bulgaria; Greece; Romania.

JEL codes: Q20; Q40; Q41; Q42; Q50; Q54; Q58.

1. Introduction

The increasing movement in energy system[1] worldwide, together with the predicted exhaustion of the energy reserves of the planet in conventional energy sources and the associated environmental problems caused, leads to the necessity of much higher use of Renewable Energy Sources (hereafter RES). Most countries worldwide and primarily the developed ones are investing heavily in infrastructure, development and production of energy from clean sources like wind and sunlight. The European Union sets and updates the targets, forwards EU directives and at the same time manages the progress of each member-country on the evolution and future directions in the use of RES.

In parliamentary law to cope with climate change, the European Commission (EC) reconfirmed in February 2011, the EU's long-term target of abating greenhouse gas emissions (hereafter GHG) till 2050 by 80-95% (25% by 2020, 40% by 2030 and 60% by 2040) compared to 1990 emission levels. Hypothesized scenarios for the percentage of RES participation in the energy system may vary and they are a function of the inspirations and predictions of the different organizations. For example, some reports show 77% fossil fuels, 15% renewable, and 8% nuclear by 2040 (ExxonMobil 2012). Other cases show 46% fossil fuels, 41% renewable, and 12% nuclear by 2050 (IEA 2012). Many more ambitious show 18% fossil fuels, 82% renewable, no nuclear by 2050 (Eurelectric 2009) and the most ambitious show a 95% share of RES (Greenpeace/EREC 2012; WWF 2011).

Halkos and Tzeremes (2013) showed that different renewable energy policies among countries are subject to geographical variations reflecting their long-run environmental policies. They find support of the growth hypothesis where for lower

[1] An energy system may be considered as an interconnected set of relations between sources and stores of energy, associated by transmission and distribution of this energy to wherever it is necessary. For more information see http://environ.andrew.cmu.edu/m3/s3/energy_sys.pdf

consumption levels the effect is positive, for medium the effect becomes negative and for higher renewable energy consumption levels the effect on economic efficiency turns from neutral to positive. It is worth mentioning that especially for eastern and western European countries evidences for the feedback and neutrality hypothesis is fount showing a negative and a neutral effect of renewable energy consumption on their economic efficiency levels. Therefore, it seems that there are different renewable energy strategies among countries and these are determined by geographical variations reflecting their long term environmental policies.

In this paper, our goal is to show the progress towards sustainability with long-term scenarios for the energy map of Southeast Balkans, particularly for the three countries of Bulgaria, Greece and Romania. Within this framework, our paper constructs seven scenarios for the period 1990-2050, in order to evaluate Bulgaria's, Greece's and Romania's (Southeast Balkans) energy demand and supply using the Long range Energy Alternatives Planning System (LEAP). Our main objective is to examine and compare scenarios based on organizations reports, so that countries achieve the objectives of the European Commission (abating 40% of GHG emissions by 2030 and 80-95% by 2050) and finally to show the contribution of each country in reducing GHG emissions.

The structure of the paper is the following. Section 2 presents a brief literature review concerning the relevant studies for the three countries under consideration and for studies relying on LEAP in similar applications and research activities, whereas section 3 presents the steps in coping with climate change and the proposed seven scenarios and the structures of LEAP. Section 4 presents the empirical results derived while the last section concludes the paper.

2. Literature review

2.1 Relevant studies

There are no studies on long-term scenarios related to the energy system in the Southeast Balkans. However there are various studies on individual country level. In the case of Greece, Roinioti et al. (2012) model the Greek energy system until 2030 using LEAP. Halkos et al. (2014a) mention the dominant role of lignite in the generation of electricity claiming that the reduction of lignite stations in Greece will provide environmental benefits contributing to climate change mitigation.

Agoris et al. (2004) used a combination of two models, R-MARKAL and WASP IV, for the Greek energy system in order to meet the Kyoto Protocol targets. Dagoumas et al. (2007) used the ENPEP/BALANCE platform for the development of the energy related sectors and the WASP IV model for the electric power system expansion. Moreover, Dagoumas et al. (2008) used the WASP IV model to examine the Greek interconnected electric system until the time period of 2025. Ioakimidis et al. (2012) used The Integrated MARKAL/EFOM System (TIMES) to model and evaluate the Greek energy system towards the time horizon of 2040.

Kalampalikas and Pilavachi (2010a, b) using software package WASP IV investigated the electricity production system of the Greek Interconnected Electric Production System. Similarly, Rampidis et al. (2010) used the platform ENPEP/BALANCE to consider the Greek electric system with different energy scenarios. Furthermore, Voumvoulakis et al. (2012) using the WASP IV model examined the participation of RES in the Greek electric power sector to meet the European target by 2020. Georgiou (2015) presents a deterministic bottom-up Mixed Integer Linear Programming model for the long-term energy planning of the Greek power supply sector.

In Bulgaria, Christov et al. (1997) using the platform ENPEP/BALANCE assessed the mitigation options for the Energy System in Bulgaria until 2020. In Romania, Gota et al. (2011) using the EnergyPLAN tool examined the Romanian energy system and their findings indicate that the incorporation of more renewable energy in the system will increase the overall amount of produced power.

Apart from various studies, many organizations started to release their reports on policies to reduce GHG emissions. Specifically, many reports have been written based on various long-term scenarios for reducing GHG emissions. It is common from all reports that using RES may achieve effective reductions in GHG emissions with the bigger the ratio of RES the higher the reduction in GHG emissions (REN21, 2013).

2.2 Studies using LEAP

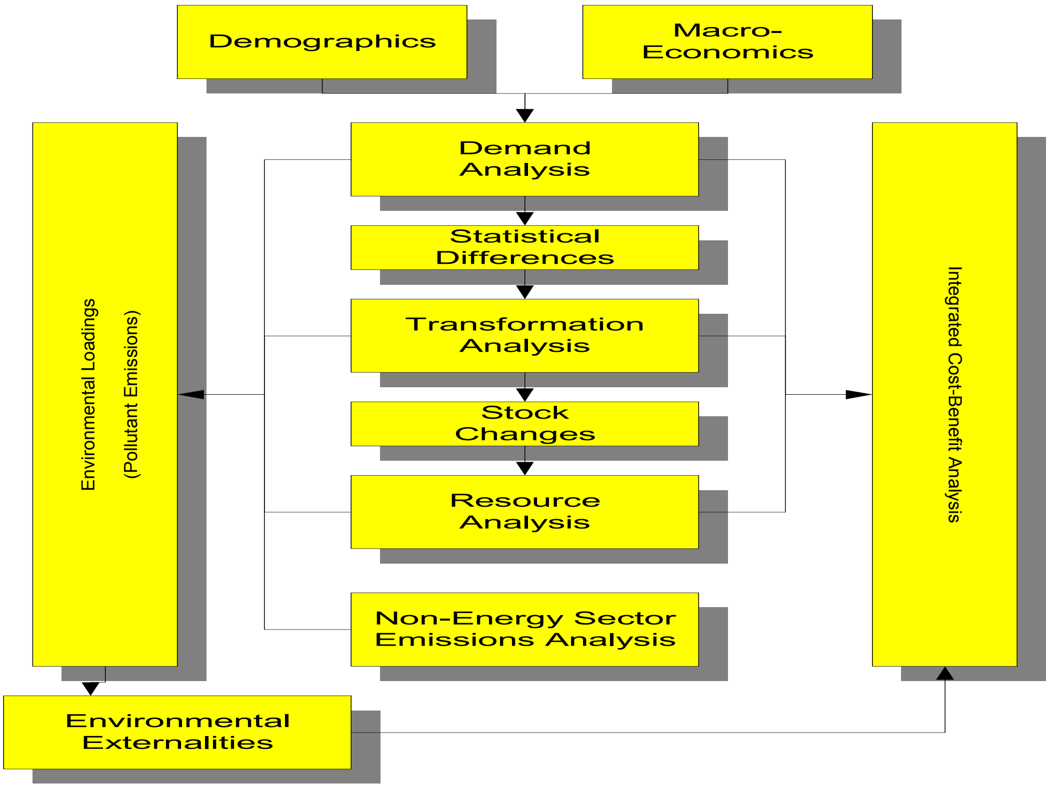
LEAP is an integrated modelling tool allowing evaluation of the effects of different energy policies on energy generation and consumption, including their associated emissions.[2] Figure 1 describes this framework in which the LEAP is based on.

This software has been applied widely for energy analyses and elaboration of energy scenarios in more than 150 countries (Gómez et al., 2014; Yophy et al., 2011). LEAP results have been published for many regions and cities. Many studies have been published in areas of Asia. For instance, in the case of China He et al. (2010) examined the co-benefits of reducing carbon dioxide emissions and improving air quality using different policies; Cai et al. (2008) examined CO_2 emission scenarios and mitigation opportunities in five sectors; Zhang et al. (2010) considered fuel

[2] LEAP was developed by the Stockholm Environment Institute in Boston (Stockholm Environment Institute, 2011; Heaps, 2002).

consumption of vehicles while Cai et al. (2007) examined CO_2 emissions reduction potential in the electricity sector and Lin et al. (2010) examined the GHG emissions in Xiamen city.

Figure 1: LEAP Calculation Flows



Source: Heaps (2002)

Similarly, Park et al. (2013) examined the electricity sector of Korea, Takase and Suzuki (2011) the energy sector of Japan, Mulugetta et al. (2007) and Mondal et al. (2010) the power sector scenarios for Thailand and Bangladesh, Kale and Pohekar (2014) forecast the electricity demand for the state of Maharashtra (India), and finally, Pagnarith and Limmeechokchai (2015a, b) examined the electricity supply of GMS countries (Cambodia, Laos, Thailand, and Vietnam) and how it could mitigate CO_2 emissions under alternative scenarios.

In America, among others, we have energy scenarios to explore alternative energy pathways in California of USA (Ghanadan and Koomey, 2005) and the electric-power sector of Mexico, Panama and Venezuelan (Islas and Grande, 2008; McPherson and Karney, 2014; Bautista, 2012). For Africa, Amoo and Fagbenle (2014) and Amous et al. (1994) examined the future energy carrier in Nigeria's transportation, energy and power sectors, and GHG emissions abatement in Senegal. For Europe, the Greek energy system (Roinioti et al., 2013), the power planning for the island of Crete-Greece (Giatrakos et al., 2009), the electric sector in Turkey (Özer et al., 2013), and the GHG emission reduction of Croatia (Gomez et al. 2014) are studied. Finally, Pukšec et al. (2014) examined the energy system of Kazakhstan.

Similarly, Halkos et al. (2014b) using DEA methodology on the results derived by using LEAP evaluated the efficiency of renewable energy commitments on reducing GHG emissions. Their results show that efficiency of renewable energy commitments as imposed by the Greek government under the Law 3851/2010 will not be enough to reduce systematically the generated GHG emissions over the time period under consideration. They show that Greece should increase energy consumption from renewable resources at least up to 27% by 2020 decreasing significantly more the GHG emissions compared to policies based on the commitments by Law 3851/2010.

3. Scenario generation

3.1 Steps in coping with climate change

In 1988 the Inter-governmental Panel on Climate Change (IPCC) by the World Meteorological Organization (WMO) took into consideration technical and socioeconomic research concerning climate change. The efforts to deal with climate change started by the "Earth Summit" in 1992 at Rio de Janeiro and this went ahead with the United Nations Framework Convention on Climate Change (hereafter UNFCCC) established in 1994 for the stabilization of greenhouse gas concentrations in the atmosphere and limiting average global temperature and coping with climate change. Since then there were 19 *Conferences Of the Parties* (**COP**s) and in COP3 in the Kyoto Conference in 1997 the states agreed to reduce the six GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6) leading to the Kyoto Protocol agreement (Halkos, 2014).

According to this Protocol industrial states are committed to reduce total GHG emissions in the first period of commitment (2008 to 2012) by at least 5% lower levels of their 1990 levels.[3] Specifically, it stated that "Annex B" (industrialized "Annex I" in the convention) countries should decrease GHG emissions in the first commitment period within 2008-2012 and in the second period within 2013-2020. Industrial nations agreed to limit emissions of GHGs to 5.2% below 1990 levels. This would be 30% below the levels projected for 2010. Now we have 195 participating countries in the Convention and 192 in the Kyoto Protocol.[4]

Greece, Romania and Bulgaria signed the UNFCCC in Rio de Janeiro in 1992. The first two countries ratified it in 1994 while Bulgaria ratified it in 1995. As an Annex I Party Bulgaria adopted year 1988 as base year for the implementation of the Convention instead of 1990 and set as target the stabilization of GHG emissions by 2000 at levels not greater than in 1988. Romania was included as Annex I country

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[3] In the framework of Kyoto Protocol, there are three mechanisms to be used by Annex I Parties to fulfil their emission targets at the lowest costs: the Clean Development Mechanism (CDM); the Joint Implementation (JI); and the International Emissions Trading (IET). For details see Halkos (2014).

[4] **List of Annex I Parties to the Convention** (Source: http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php) Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Cyprus, Czech Republic, Denmark, Estonia, European Union, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Liechtenstein, Lithuania, Luxembourg, Malta, Monaco, Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russian Federation, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, Ukraine, United Kingdom of Great Britain and Northern Ireland, United States of America.

with economy in transition. It signed the Kyoto Protocol in 1999 targeting an 8% in the first period of commitment.

Greece ratified the Kyoto Protocol in 2002 and recently various targets were set known as the "20-20-20" targets, including a 20% reduction in EU GHG emissions from 1990 levels; an increase in the share of EU energy consumption produced from renewable resources to 20%; and a 20% improvement in the EU's energy efficiency (Halkos et al., 2014a).

Table 1 presents the emissions per capita by sector for the year 2011 for the World, Greece, Bulgaria, Romania, OECD, Non-OECD, Annex I Kyoto Parties and Non Annex I Parties

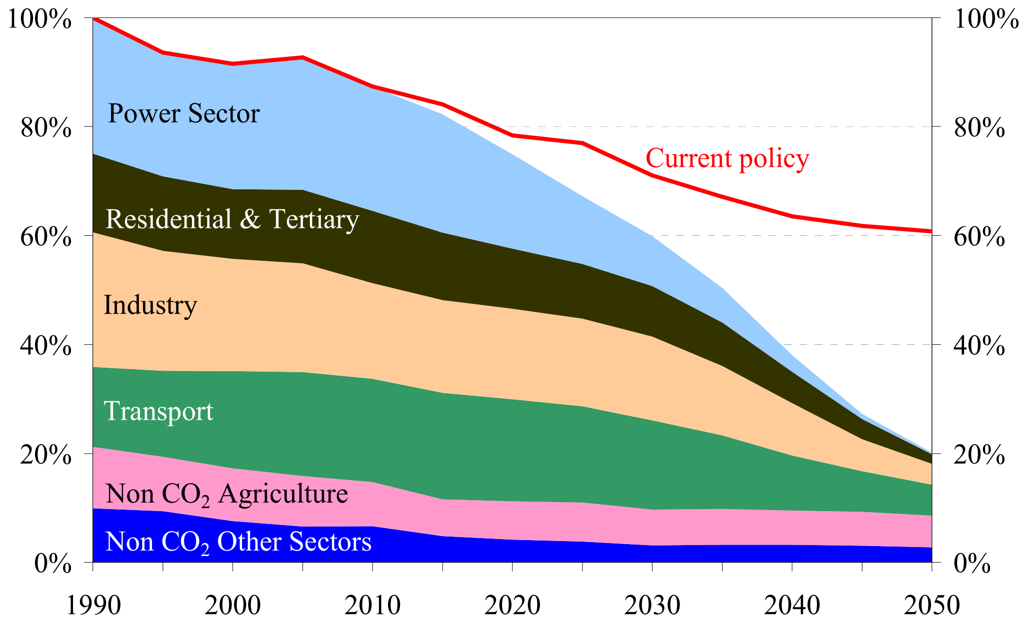
Table 1: Emissions per capita by sector in 2011 (in kg CO_2/c)

	Total CO_2 emissions	Electricity and Heat Production	Manufacturing Industries & Construction	Transport	Other sectors
World	4504	1878	935	1006	463
Greece	7395	3790	640	1723	1006
Bulgaria	6584	4553	578	1055	262
Romania	3823	1813	684	659	457
OECD	9948	3960	1425	2685	1326
Non-OECD	3129	1426	829	447	276
Annex I Kyoto Parties	8601	3606	1439	1886	1241
Non Annex I Parties	2978	1320	803	441	259

Source: Highlights © OECD/IEA (2013).

As mentioned the European Commission (EC) in 2011 reconfirmed EU's long-term target of abating GHG emissions till 2050 by 80-95% compared to 1990 levels. This is presented in Figure 2. In addition, on 22 January 2014 the European Commission presented a framework of actions for the climate and energy by 2030.

Figure 2: EU GHG emissions towards an 80% domestic reduction (100% =1990)



Source: European Commission (2011a, p.5).

This framework towards 2030 is designed to help the EU member countries to address topics such as:

- Next steps to achieve the goal of reducing GHG emissions by 80-95% below 1990 levels by 2050
- High energy costs and the vulnerability of the EU economy in the case of future gains in monetary terms, especially for oil and gasoline
- EU dependence on energy imports, often from regions threatened by insecurity
- The demand for the replacement and upgrading of energy infrastructure and the preparation of a stable regulatory framework for potential investors
- The necessity for the EU to meet GHG emissions reduction targets by 2030 as part of its contribution in the upcoming negotiations on a new worldwide accord on climate change (European Commission, 2011a; 2014)

3.2. Scenario Development

Seven different scenarios are generated in LEAP under different sets of options. Namely,

- *Business As Usual scenario (BAU)*, based on historical trends of each country.
- *EC 2030 scenario,* based on the assumptions of the "*Energy Trends 2030"* report by the European Commission (2009).[5]
- *IEA 2030 scenario*, based on the assumptions of the *"Energy Technology Perspectives"* and *"450 Scenario"* report by the International Energy Agency (IEA, 2012).[6]
- *Greenpeace 2030 scenario*, based on the assumptions of the "*Energy [R]evolution European Union"* report by the Greenpeace/European Renewable Energy Council (Greenpeace/EREC, 2012).[7]
- *EC 2050 scenario*, based on the assumptions of the *"Energy Roadmap 2050"* report by the European Commission (European Commission, 2011b).[8]
- *EREC 2050 scenario*, based on the assumptions of the *"RE-thinking 2050: 100% Renewable Energy Vision for the European Union"* report by the European Renewable Energy Council (EREC, 2010).[9]
- *SEI 2050 scenario*, based on the assumptions of the *"Europe's Share of the Climate Change"* report by the Stockholm Environment Institute/Friends of the Earth (SEI, 2009).[10]

[5] http://ec.europa.eu/clima/policies/package/docs/trends_to_2030_update_2009_en.pdf
[6] https://www.iea.org/publications/freepublications/publication/ETP2012_free.pdf
[7] http://www.greenpeace.org/eu-unit/Global/eu-unit/reports-briefings/2012%20pubs/Pubs%203%20Jul-Sep/E%5BR%5D%202012%20lr.pdf
[8] http://www.roadmap2050.eu/attachments/files/Volume1_ExecutiveSummary.pdf
[9] http://www.erec.org/fileadmin/erec_docs/Documents/Publications/ReThinking2050_full%20version_final.pdf
[10] http://sei-us.org/Publications_PDF/SEI-EuropeShareOfClimateChallenge-09.pdf

Except from the BAU scenario all other scenarios are based on organizations' reports. There are three scenarios for the target 2030 of the European Commission (EC 2030, IEA 2030 and Greenpeace 2030) and three other scenarios for the target 2050 (EC 2050, EREC 2050 and SEI 2050). All policy options and main assumptions are given in Table 2. [11]

Table 2: Policy options and assumptions for scenario generation

Scenarios	Policy options	Main assumptions
Business as usual		- The historical trends will continue
EC 2030	"Energy Trends 2030" report by the European Commission (EC, 2009)	- RES in Electricity is 36% - RES in Transport is 12.5% - RES in H&C is 21.3% - RES in Final Demand is 22.2%
IEA 2030	"Energy Technology Perspectives" report by the International Energy Agency (IEA, 2012)	- RES in Electricity is 48% - RES in Transport is 14% - RES in H&C is 19% - RES in Final Demand is 27%
Greenpeace 2030	"Energy [R]evolution European Union" report by the Greenpeace/European Renewable Energy Council (Greenpeace/EREC, 2012)	- RES in Electricity is 61% - RES in Transport is 17% (electricity will provide 12%) - RES in H&C is 51% - RES in Industry is 18.5% - RES in Final Demand is 42.6%
EC 2050	"Energy Roadmap 2050" report by the European Commission (EC, 2011)	- RES in Electricity is 97% - Electricity in Transport is 65% - Electricity in final energy demand to 36–39 % - RES in Final Demand is 55%
EREC 2050	"RE-thinking 2050: 100% Renewable Energy Vision for the European Union" report by the European Renewable Energy Council (EREC, 2010)	- RES in Electricity is 100% - Biofuels in Transport is 10% - RES-Electricity in final energy demand to 41% - RES-H&C is 45% - RES in Final Demand is 90-95%
SEI 2050	"Europe's Share of the Climate Change" report by the Stockholm Environment Institute/Friends of the Earth (SEI, 2009)	- RES in Electricity is 75% - RES, Electricity and H&C in Households and Services is 100% - RES, Electricity and Heat in Industry is 60% - Electricity in Transport is 50%

[11] As the assumptions of integrated scenarios are many, they may be found in details in the reports of each organization.

3.2 Structure of LEAP dataset

3.2.1. Demand Sectors

The LEAP "tree" in the case of Southeast Balkans (Bulgaria, Greece and Romania) includes a demand dataset describing the energy use in each branch "tree''. It also includes various demographic and economic indicators. The sources used for energy demand data include the National Institute of Statistics /Romanian Statistical Yearbook (NIS/Romania Statistical Yearbook)[12], the National Statistical Institute/Republic of Bulgaria (NSI)[13], the Hellenic Statistical Authority (El. Stat)[14], Eurostat[15], Bank of Greece, World Bank[16] and OECD[17].

Table 3 presents the energy demand structure with activities–such as number of households, economic output, fuel shares and energy intensities. Specifically it includes sectors, sub-sectors and fuel categories together with the sources of data. The demand includes six sectors: Households, Agriculture and Fishing, Services, Industry, Transport and the Non-Energy Fuel Use.[18]

LEAP allows each technology within the six sectors of demand and supply by the various sectors to be directly linked to emission factors in the Technology and Environmental Database (hereafter TED). Thus, the model calculates the resulting emissions from energy demand based on emission factors and other technical characteristics taken from the TED (Stockholm Environment Institute, SEI 2011).

[12] http://www.insse.ro/cms/en
[13] http://www.nsi.bg/en
[14] http://www.statistics.gr/
[15] http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/
[16] http://www.bankofgreece.gr/Pages/default.aspx
[17] http://www.oecd.org/
[18] This is accompanied by various demographic and economic indicators not presented here.

Table 3: Energy Demand Structure

Sectors/ Indicators	**Sub-sectors**	**Fuel categories**	**Sources**
Households		Oil, Natural gas, solar, wind, biomass, heat, electricity, coal	El.Stat, Eurostat, NSI, World Bank, OECD, NIS /Romanian Statistical Yearbook
Agriculture and Fishing		Coal, Oil, Heat, Natural gas, geothermal, electricity, biomass	El.Stat, Eurostat, NSI, World Bank, OECD, NIS /Romanian Statistical Yearbook
Services		Coal, Oil, Heat, solar, wind, electricity, biomass, natural gas	El.Stat, Eurostat, NSI, World Bank, OECD, NIS /Romanian Statistical Yearbook
Industry	Iron and Steel, Chemical and Petrochemical, Non Ferrous Metals, Non Metallic Minerals, Transport equipment, Paper Pulp and Printing, Wood and Wood Products, Textile and Leather, Construction, Mining and Quarrying, Other Industry	Lignite, coal, electricity, natural gas, biomass, Heat	El.Stat, Eurostat, NSI, World Bank, OECD, NIS /Romanian Statistical Yearbook
Transport	Road, Rail, Domestic Aviation, Domestic Shipping, Pipelines, Other Transport	Oil, electricity, natural gas, biofuel	El.stat, Eurostat, NSI, World Bank, OECD, NIS /Romanian Statistical Yearbook
Non Energy Fuel Use		Oil,Coal, natural gas	NSI, El.Stat, Eurostat, World Bank, OECD, NIS /Romanian Statistical Yearbook

3.2.2. Transformation modules

The fuel supply portion or transformation module of the dataset is divided into five transformation modules: Distribution Losses, Own Use, Combined Heat and Power (CHP) Production, Electricity Generation and Oil Refining (see Table 4). The most important sub-sector of transformation is the “Electricity generation” which has many functions and features such as capacities, efficiencies, availabilities and merit orders.

Table 4: Fuel supply dataset of Southeast Balkans LEAP software

Module	Process types	Fuels	Sources
Distribution Losses	Process	Electricity, natural gas	El. Stat, Eurostat, PPC[19],NSI, NIS
Own Use	Process	Electricity, natural gas, Lignite, Oil	El. Stat, Eurostat, PPC, NSI, NIS
CHP Production	Output Fuels	Electricity	El. Stat, Eurostat, PPC, NSI NIS
	Process	Natural gas, Lignite, Oil, Biomass	El. Stat, Eurostat, PPC, NSI NIS
Electricity Generation	Output Fuels	Electricity	El. Stat, Eurostat, PPC, NSI, NIS
	Process	Wave and Tidal, Natural gas, Natural gas CHP, Coal, Hydro storage, Oil, Biomass, Wind Onshore with storage, Wind Onshore, Wind Offshore, Solar PV, Solar Thermal, Large Hydro, Small Hydro, Geothermal, Nuclear, Peat,	El. Stat, PPC, CRES[20], RAE[21], H.T.S.O.S.A[22], NSI, NIS
Oil Refining	Process	Crude oil	El. Stat, Eurostat, PPC, NSI, NIS

4. Empirical Results

4.1. Results for Bulgaria

Figure 3 illustrates the reduction of GHG of Bulgaria's energy system by each scenario. Moreover, figure 4 represents the energy demand (sub-figure 4a) and supply (sub-figure 4b) in the seven scenarios. The best choice for the target 2030 and the only which achieves its objective is Greenpeace 2030 scenario with a 39.8% reduction of GHG emissions (from 96,3 $MtCO_2e$ in 1990 to 57,9 $MtCO_2e$ in 2030). The IEA 2030 and EC 2030 scenarios will not achieve the target. The reductions are 33.6% (from 96,3 $MtCO_2e$ in 1990 to 63,9 $MtCO_2e$ in 2030) and 32.8% (from 96,3 $MtCO_2e$ in 1990 to 64,7 $MtCO_2e$ in 2030) respectively. For 2050, the best scenarios are EREC 2050 and EC 2050 with 88.4% (from 96,3 $MtCO_2e$ in 1990 to 11,2 $MtCO_2e$ in 2050)

[19] http://www.dei.gr/
[20] http://www.cres.gr/kape/index.htm
[21] http://www.rae.gr/site/portal.csp
[22] http://www.desmie.gr/nc/en/home/

and 84.2% (from 96,3 $MtCO_2e$ in 1990 to 15,2 $MtCO_2e$ in 2050) respectively. The SEI 2050 scenario will not achieve the target. The reduction is 69.5% (from 96,3 $MtCO_2e$ in 1990 to 29,3 $MtCO_2e$ in 2050) (see Table 5).

Figure 3: GHG emissions for Bulgaria's energy system by scenario ($MtCO_2e$)[23]

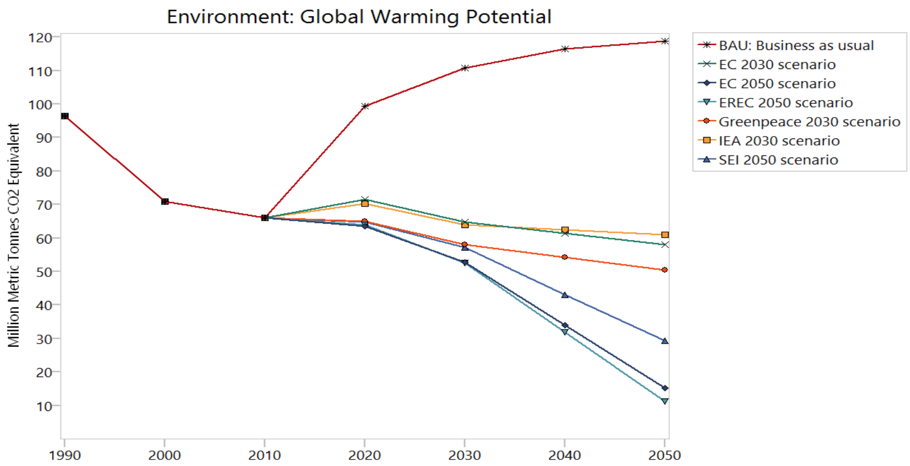
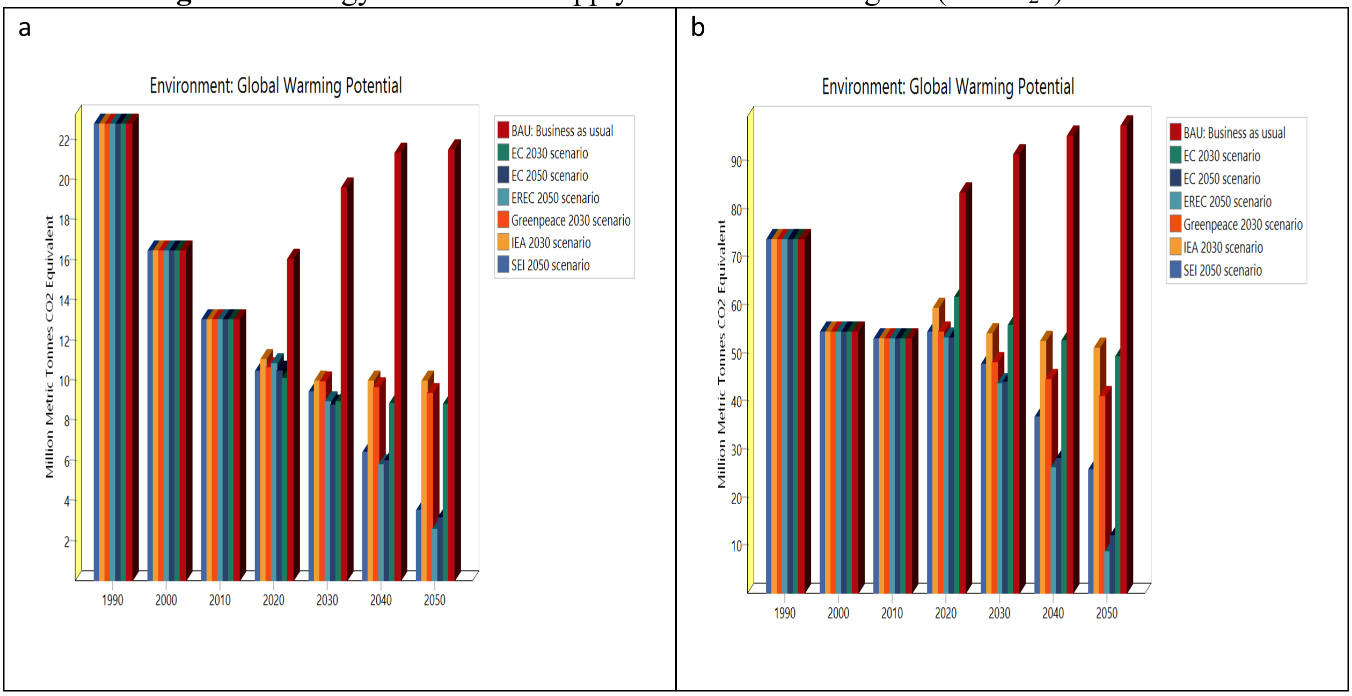


Figure 4: Energy demand and supply emissions for Bulgaria ($MtCO_2e$)



[23] Global Warming Potential (GWP) is an index measuring different GHGs emissions with different atmospheric lifetimes and different radiative properties. In order to maintain the climate impact constant, the measures of GWP permit comparison and substitution among different gases to achieve the target. CO_2 has a GWP equal to 1, CH_4 has a GWP equal to 25 and N_2O has GWP equal to 298. At the same time the atmospheric lifetimes of perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are very long ranging, from 3,200 years for SF_6 to 50,000 years for perfluoromethane (CF_4). Often GHGs emissions estimates are presented in millions of metric tons of CO_2 equivalents (mmt of CO_2e) weighting each pollutant by the value of its GWP (Halkos, 2014, p. 13).

Table 5: GHG emissions for Bulgaria's energy system, demand and supply by scenario ($MtCO_2e$)

	1990 Total	1990 Demand	1990 Supply	**2030 Total**	2030 Demand	2030 Supply	**2050 Total**	2050 Demand	2050 Supply
BAU	96,3	22,7	73,6	110,6	19,5	91,1	118,6	21,4	97,2
EC 2030	96,3	22,7	73,6	64,7	8,9	55,8	58	8,8	49,2
EC 2050	96,3	22,7	73,6	52,5	8,7	43,8	15,1	3,1	12
EREC 2050	96,3	22,7	73,6	52,5	8,9	43,6	11,1	2,5	8,6
Greenpeace 2030	96,3	22,7	73,6	57,9	9,9	48	50,3	9,3	41
IEA 2030	96,3	22,7	73,6	63,8	9,9	53,9	61	9,9	51,1
SEI 2050	96,3	22,7	73,6	57	9,4	47,6	29,2	3,5	25,7

4.2. Results for Greece

Figure 5 illustrates the reduction of GHG of Greece's energy system by scenario while figure 6 represents the energy demand (sub-figure 6a) and supply (sub-figure 6b) in the seven scenarios. The best choice for the target 2030 and the only one achieving its objective is Greenpeace 2030 scenario with a 42% reduction of GHG emissions (from 116,3 $MtCO_2e$ in 1990 to 67,4 $MtCO_2e$ in 2030). Again the IEA 2030 and EC 2030 scenarios will not achieve the target with reductions of 37.2% (from 116,3 $MtCO_2e$ in 1990 to 73 $MtCO_2e$ in 2030) and 32.6% (from 116,3 $MtCO_2e$ in 1990 to 78,4 $MtCO_2eq$ in 2030) respectively. For 2050 the best scenarios are EREC 2050 and EC 2050 with 90% (from 116,3 $MtCO_2e$ in 1990 to 11,6 $MtCO_2e$ in 2050) and 80.5% (from 116,3 $MtCO_2e$ in 1990 to 22,6 $MtCO_2e$ in 2050) respectively. Similarly to the case of Bulgaria the SEI 2050 scenario will not achieve the target with a reduction of 49.9% (from 116,3 $MtCO_2e$ in 1990 to 58,3 $MtCO_2e$ in 2050) (see Table 6).

Figure 5: GHG emissions for Greece's energy system by scenario ($MtCO_2e$)

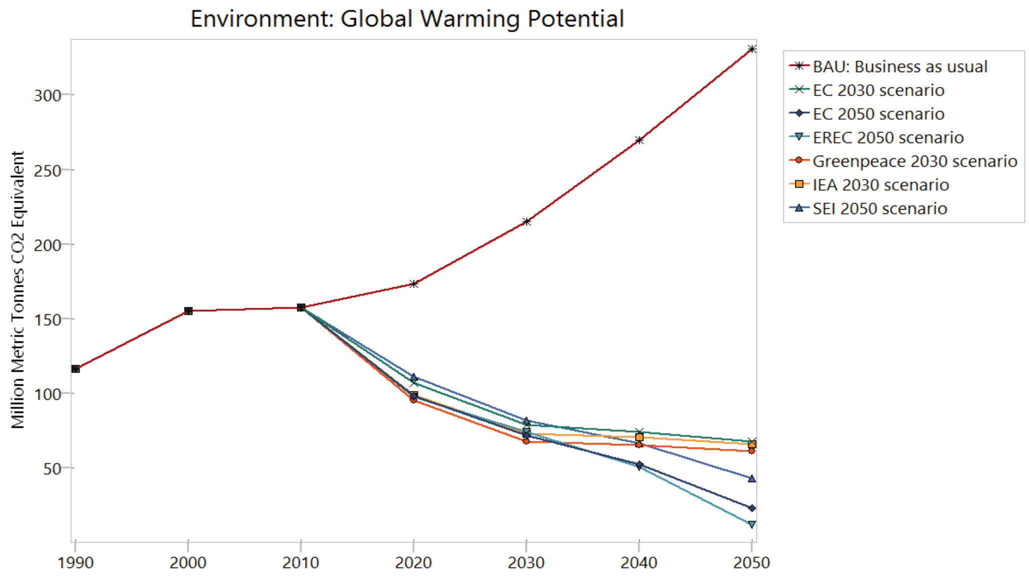


Figure 6: Energy demand and supply emissions for Greece ($MtCO_2e$)

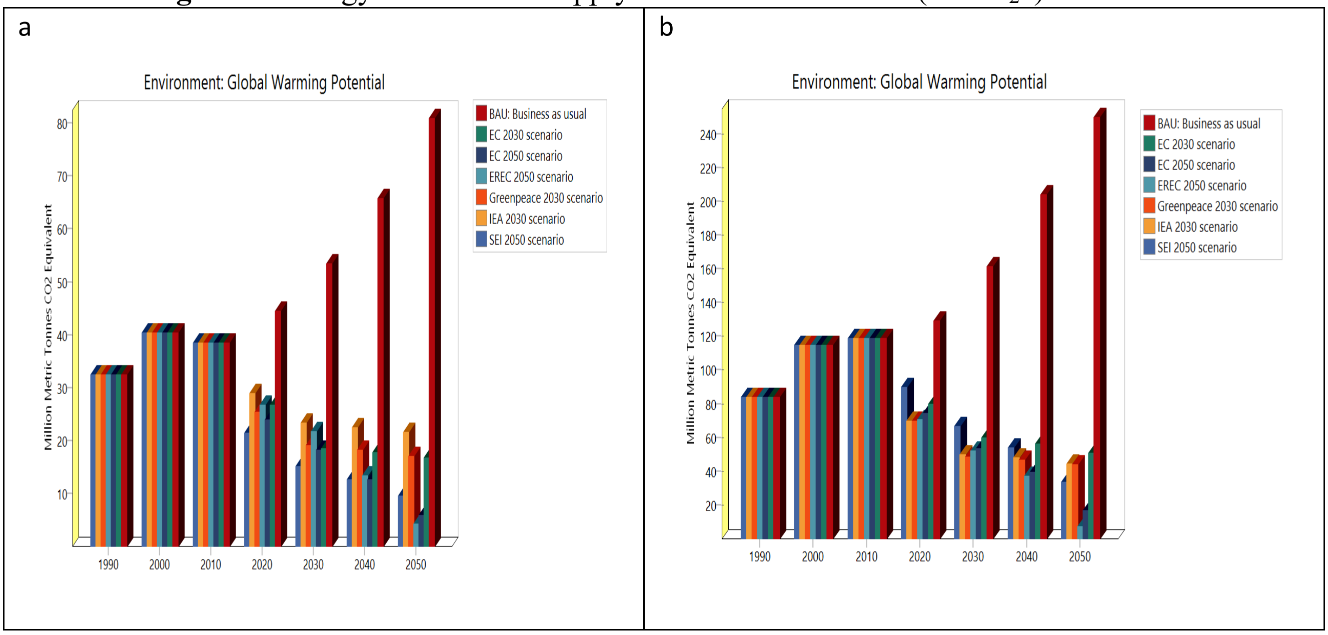


Table 6: GHG emissions for Greece's energy system, demand and supply by scenario ($MtCO_2e$)

	1990 Total	1990 Demand	1990 Supply	**2030 Total**	2030 Demand	2030 Supply	**2050 Total**	2050 Demand	2050 Supply
BAU	116,3	32,4	83,8	214,7	53,4	161,3	330,6	80,9	249,7
EC 2030	116,3	32,4	83,8	78,4	18,4	60	67,7	16,8	50,9
EC 2050	116,3	32,4	83,8	71,6	18,2	53,4	22,5	5,8	16,7
EREC 2050	116,3	32,4	83,8	74	21,7	52,3	11,6	4,2	7,4
Greenpeace 2030	116,3	32,4	83,8	67,3	19	48,3	61,1	17	44,1
IEA (2012)	116,3	32,4	83,8	73	23,3	49,7	65,8	21,5	44,3
SEI (2009)	116,3	32,4	83,8	81,5	15	66,5	58	9,5	33,5

4.3. Results for Romania

Figure 7 illustrates the reduction of GHG of Romania's energy system by scenario while figure 8 the energy demand (sub-figure 8a) and supply (sub-figure 8b) in the seven scenarios. As in the case of Bulgaria and Greece, the best choice for the target 2030 and the only achieving its objective is Greenpeace 2030 scenario with a 42.3% reduction of GHG emissions (from 121,1 $MtCO_2e$ in 1990 to 69,9 $MtCO_2e$ in 2030). Once more IEA 2030 and EC 2030 scenarios will not achieve the target with reductions of 35.4% (from 121,1 $MtCO_2e$ in 1990 to 78,2 $MtCO_2e$ in 2030) and 32.8% (from 121,1 $MtCO_2e$ in 1990 to 81,3 $MtCO_2e$ in 2030) respectively. For 2050, the best scenario is EREC 2050 achieving an 80% reduction (from 121,1 $MtCO_2e$ in 1990 to 25,1 $MtCO_2e$ in 2050). As before, EC 2050 and SEI 2050 scenarios will not achieve the target with reductions 71.2% (from 121,1 $MtCO_2e$ in 1990 to 34,9 $MtCO_2e$ in 2050) and 62.7% (from 121,1 $MtCO_2e$ in 1990 to 45,1 $MtCO_2e$ in 2050) respectively (see Table 7).

Figure 7: GHG emissions for Romania energy system by scenario ($MtCO_2e$)

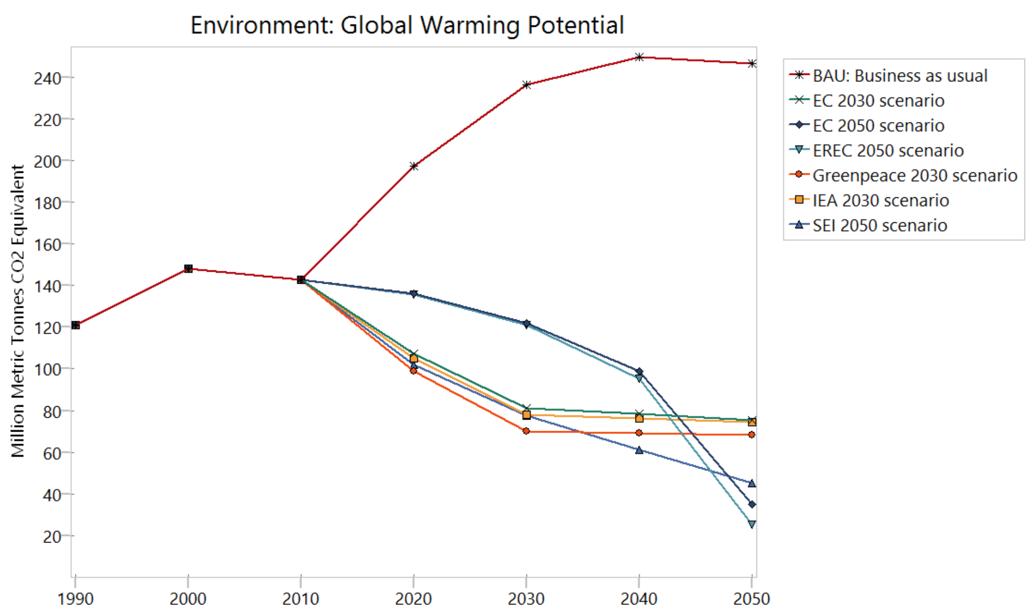


Figure 8: Energy demand and supply emissions for Romania ($MtCO_2e$)

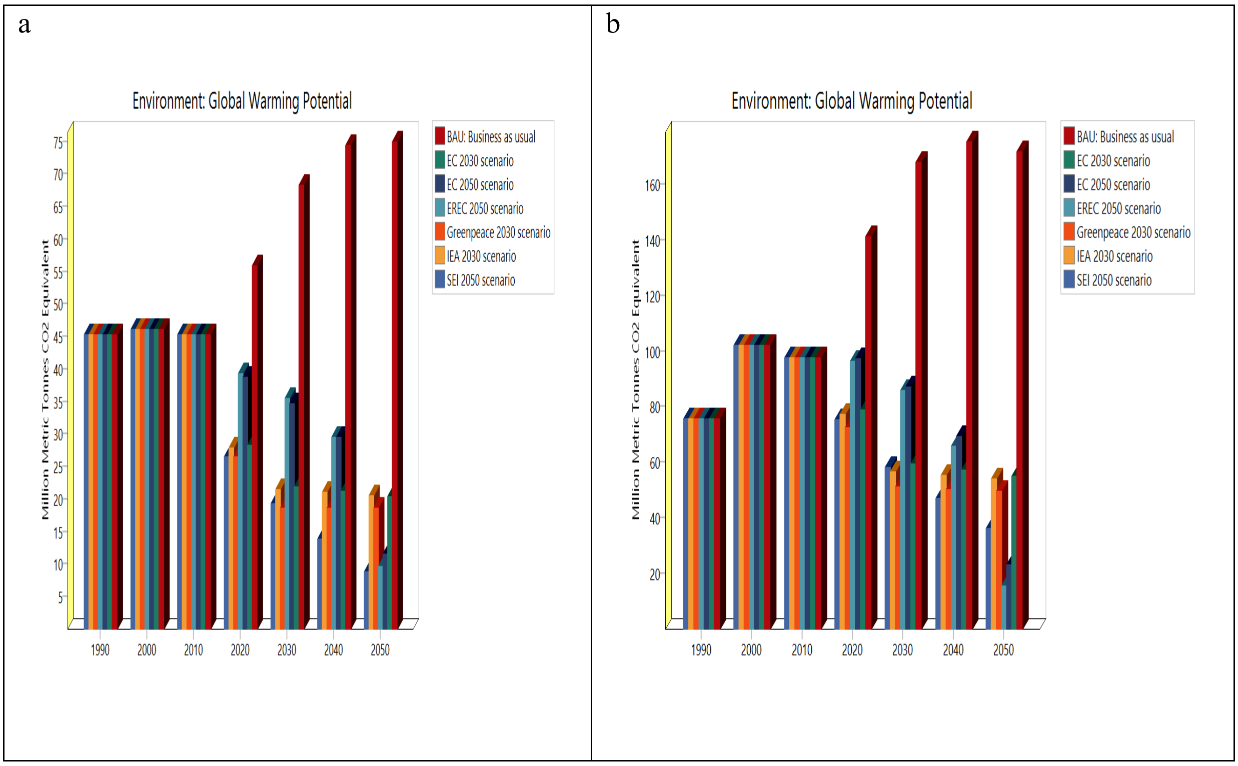


Table 7: GHG emissions for Romania energy system, demand and supply by scenario ($MtCO_2e$)

	1990 Total	1990 Demand	1990 Supply	**2030 Total**	2030 Demand	2030 Supply	**2050 Total**	2050 Demand	2050 Supply
BAU	121,1	45,3	75,7	236,1	68,2	167,9	246,6	74,9	171,7
EC 2030	121,1	45,3	75,7	81,3	21,9	59,4	75,3	20,4	54,9
EC 2050	121,1	45,3	75,7	121,9	34,7	87,2	34,8	11,5	23,3
EREC 2050	121,1	45,3	75,7	121,2	35,5	85,7	25,1	9,7	15,4
Greenpeace 2030	121,1	45,3	75,7	69,8	18,5	51,3	68	18,6	49,4
IEA 2030	121,1	45,3	75,7	78,1	21,5	56,6	74,5	20,5	54
SEI 2050	121,1	45,3	75,7	77,3	19,2	58,1	45	8,7	36,3

4.4 Southeast Balkans results

Let us now move to Figure 9, which illustrates the reduction of GHG emissions of the Southeast Balkans energy system by scenario. Moreover, figure 10 represents the energy demand (sub-figure 10a) and supply (sub-figure 10b) in the seven scenarios. The largest abatement for the target 2030 is achieved by Greenpeace 2030 scenario with a 41.5% reduction of GHG emissions (from 333,7 $MtCO_2e$ in 1990 to 195,2 $MtCO_2e$ in 2030), and it is followed by IEA 2030 and EC 2030 with reductions of 35.5% (from 333,7 $MtCO_2e$ in 1990 to 215,1 $MtCO_2e$ in 2030) and 32.7% (from 333,7 $MtCO_2e$ in 1990 to 224,5 $MtCO_2e$ in 2030) respectively. For 2050, the largest abatement is achieved by EREC 2050 scenario with 85.6% (from 333,7 $MtCO_2e$ in 1990 to 48 $MtCO_2e$ in 2050) and it is followed by EC 2050 and SEI 2050 scenarios with reductions of 78.2% (from 333,7 $MtCO_2e$ in 1990 to 72,7 $MtCO_2e$ in 2050) and 64.8% (from 333,7 $MtCO_2e$ in 1990 to 117,5 $MtCO_2e$ in 2050) respectively (see Table 8).

Figure 9: GHG emissions for Southeast Balkans energy system by scenario ($MtCO_2e$)

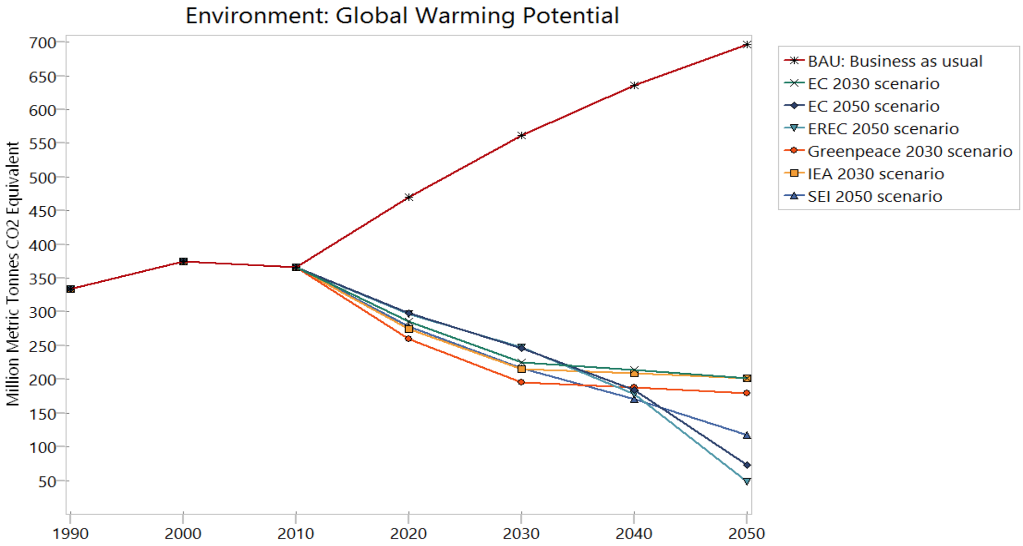


Figure 10: Energy demand and supply emissions for Southeast Balkans ($MtCO_2e$)

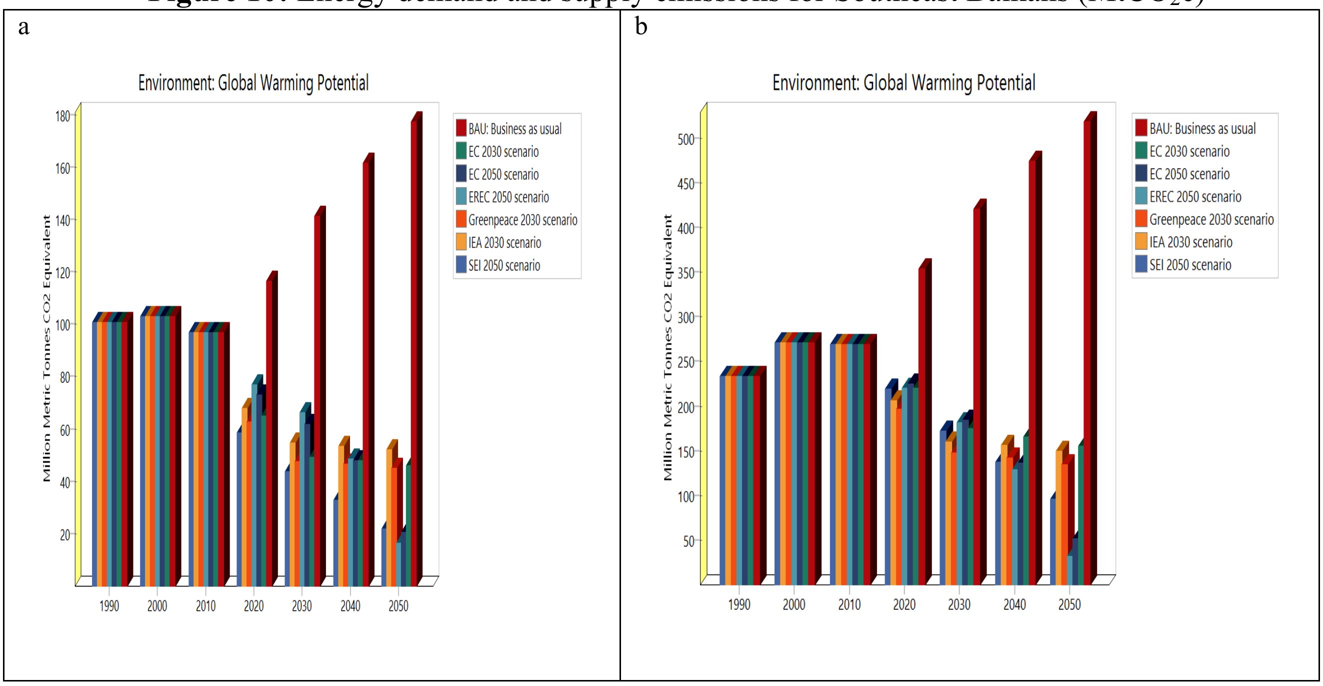


Table 8: GHG emissions for Southeast Balkans energy system, demand and supply by scenario ($MtCO_2e$)

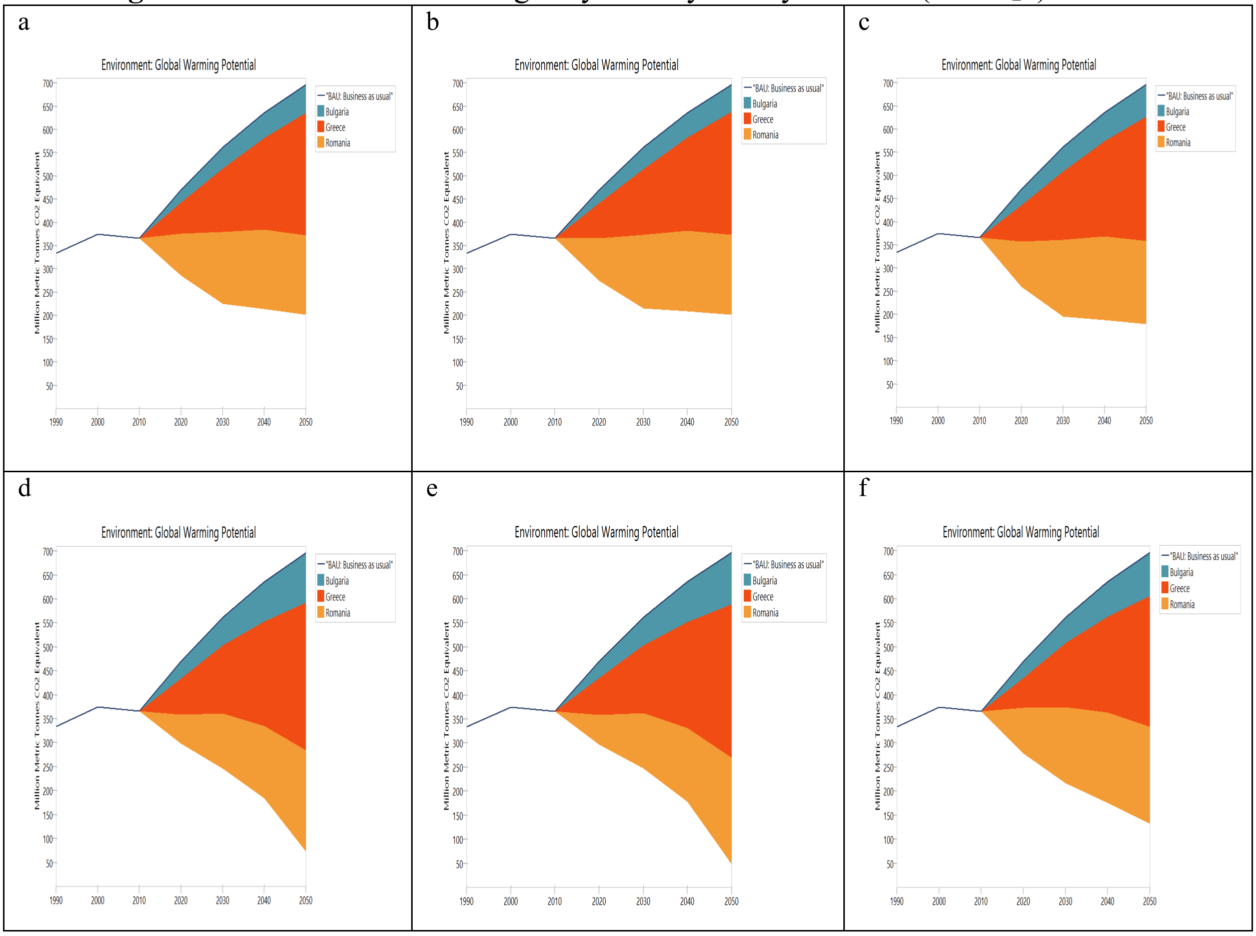
	1990 Total	1990 Demand	1990 Supply	**2030 Total**	2030 Demand	2030 Supply	**2050 Total**	2050 Demand	2050 Supply
BAU	333,7	100,5	233,1	561,7	141,3	420,4	696	177,3	518,7
EC 2030	333,7	100,5	233,1	224,4	49,2	175,2	201,1	46	155,1
EC 2050	333,7	100,5	233,1	246,3	61,7	184,6	72,6	20,5	52,1
EREC 2050	333,7	100,5	233,1	247,9	66,2	181,7	48	16,4	31,5
Greenpeace 2030	333,7	100,5	233,1	195,2	47,5	147,7	179,6	45	134,6
IEA (2012)	333,7	100,5	233,1	215,1	54,8	160,3	201,4	52	149,4
SEI (2009)	333,7	100,5	233,1	216,1	43,7	172,4	117,4	21,8	95,6

4.5 Contribution of each country to reducing the GHG emissions

Figure 11 (and Table 9 as summary) illustrate the evolution of emissions in relation to the Business as usual scenario. The top line on this chart shows the BAU scenario for GHG emissions reduction. Below that, a series of "wedges" is displayed showing the contribution of each country to reducing the BAU emissions down to the final level seen in the EC 2030 scenario (sub-figure 11a).

Each country plays an important part in the reduction, but the largest reductions come from measures in Romania 154,8 $MtCO_2e$ reducing 27.5% in relation to the BAU scenario, in Greece 136,3 $MtCO_2e$ is reducing 24.2% and in Bulgaria 46 $MtCO_2e$ and an associated reduction of 8.2%. For IEA 2030 scenario (sub-figure 11b) the largest reductions come from measures in Romania 157,9 $MtCO_2e$ reducing 28.1% in relation to the BAU scenario, Greece 141,7 $MtCO_2e$ reducing 25.2% and Bulgaria 46,8 $MtCO_2e$ with a reduction of 8.3%. For the Greenpeace 2030 (sub-figure 11c) scenario the largest reductions come from measures in Romania 166,2 $MtCO_2e$ reducing 29.5% in relation to the BAU scenario, Greece 147,3 $MtCO_2e$ reducing 26.2% and Bulgaria 52,8 $MtCO_2e$ reducing 9.4%.

Figure 11: GHG emissions wedges by country and by scenario ($MtCO_2e$)



For the EC 2050 scenario (sub-figure 11d) the largest reductions come from measures in Greece with 308 $MtCO_2e$ reducing 44.2% in relation to the BAU scenario, Romania 211,7 $MtCO_2e$ reducing 30.4% and Bulgaria 103,5 $MtCO_2e$ with a reduction of 14.8%. For EREC 2050 (sub-figure 11e) scenario the largest reductions come from measures in Greece 319 $MtCO_2e$ reducing 45.8% in relation to the BAU scenario, Romania 221,4 $MtCO_2e$ reducing 31.8% and Bulgaria 107,5 $MtCO_2e$ with a reduction of 15.4%. Similarly, for the SEI 2050 (sub-figure 11f) scenario the largest reductions come from measures in Greece 272,3 $MtCO_2e$ reducing 39.1% in relation to the BAU scenario, Romania 201,5 $MtCO_2e$ reducing 28.9% and Bulgaria 89,4 $MtCO_2e$ reducing 12.8%.

Summarizing and according to the empirical findings (as summarized in Table 10) the most effective scenario for the three countries (Bulgaria, Greece and

Romania) and for the year 2030 is the Greenpeace 2030 with rates equal to 39.8%, 42% and 42.3% respectively, while for the year 2050 EREC 2050 scenario is the most effective with rates equal to 88.4%, 90% and 80% respectively.

Table 9: GHG emissions scenarios wedges by countries ($MtCO_2e$)

	1990	**EC 2030**	**IEA 2030**	**Greenpeace 2030**	**EC 2050**	**EREC 2050**	**SEI 2050**
BAU	333,7	561,7	561,7	561,7	696	696	696
Bulgaria	0	46	46,8	52,8	103,5	107,5	89,4
Greece	0	136,3	141,7	147,3	308	319	272,3
Romania	0	154,8	157,9	166,2	211,7	221,4	201,5

Moreover, we mention that in Bulgaria not only energy and transport sectors but also industry is polluting. The effectiveness of the scenarios in GHG emissions reduction applied in these sectors are 39.8%, 88.4% and 84.2% for Greenpeace 2030, EREC 2050 and EC 2050 respectively. In Greece, the transport sector is one of the most polluting while the effectiveness of the scenarios applied in all sectors is 42%, 90% and 80.5% for Greenpeace 2030, EREC 2050 and EC 2050 respectively. Finally, for Romania and the Southeast Balkans area the effective scenarios are Greenpeace 2030 and EREC 2050 with rates equal to 42.3% and 80% (for Romania) and 41.5% and 85.6% (Southeast Balkans).

Table 10: Rates GHG reduction by scenarios and by countries (%)

	Bulgaria	Greece	Romania	Southeast Balkans
EC 2030	32.8%	32.6%	32.8%	32.7%
EC 2050	**84.2%**	**80.5%**	71.2%	78.2%
EREC 2050	**88.4%**	**90%**	**80%**	**85.6%**
Greenpeace 2030	**39.8%**	**42%**	**42.3%**	**41.5%**
IEA 2030	33.6%	37.2%	35.4%	35.5%
SEI 2050	69.5%	49.9%	62.7%	64.8%

5. Concluding remarks

The purpose of this research was to provide a look to the 2030 and 2050 horizon in terms of GHG emissions abatement scenarios for Southeast Balkans (examining the cases of Bulgaria, Greece and Romania), in such a way as countries to achieve the objectives of the European Commission (abating 40% of GHG emissions by 2030 and 80-95% by 2050).

We have generated seven scenarios which are based on organizations reports. In all seven scenarios the role of RES emerges with the largest the rate of RES, the largest the rate of reduction of GHG emissions. In particular, the energy sector is the most polluting for the three countries while for Greece, as shown in Halkos et al. (2014c, d) transport is a very polluting sector. In Bulgaria not only the energy and transport sectors but also industry is polluting. In Romania, the household sector is among the most polluting ones. Halkos et al. (2014e) found that control methods in the industry sector cost significantly less compared with abatement methods in the energy sector, but there are substantially larger abatement potentials in the latter. They find that the energy sector in Greece is the largest emitter presenting however great opportunities for pollution control.

Each country should focus on those sectors with the largest pollution levels. To achieve a higher participation of RES in energy production, more construction of hydro power plants and increased use of biomass for heat and electricity production, a coordination of fiscal, regulatory and technical planning is required. Additional measures may be used like reductions in losses in the distribution and transmission networks in the energy sector; energy efficiency, increased use of natural gas, reductions in thermal losses and upgrading of the steam generation and energy consumption reduction for the industrial sector; and installation of solar collectors, energy efficiency and other RES heat water installations for the residential sector.

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