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Assessment of the impact of renewable energy and energy efficiency policies on the Macedonian energy sector development

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The main goal of this paper is to examine and quantify how the development of the energy system in Macedonia could be influenced by policies and programs that promote energy efficiency and renewable energy, in terms of energy security and diversification, economic competitiveness, and CO_2 mitigation. For this purpose, the MARKAL-Macedonia national energy planning model was used. These policies are explored by comparing a reference (business-as-usual) development of energy system with three alternative policy scenarios: (1) Renewable Energy (RE) Scenario—introducing a renewable energy target by 2020 in line with that proposed by the Energy Community; (2) Energy Efficiency (EE) Scenario—exploring the range of energy efficiency measures that are the most cost-effective means to meet national targets aimed at reducing final energy consumption; and (3) Combined RE and EE Scenario—a combination of supply-side and demand-side approaches that examine the resulting synergies of these policy goals. For each scenario, the implications of least-cost investment options for new capacity builds, investment spending requirements, electricity prices, fuel expenditures, and carbon dioxide emissions were assessed. The analyses have shown that even under the Reference scenario, the reliance on electricity import will be reduced, as a result of increased gas import. The RE scenario further reduces the overall import by 3% while the EE scenario by 12%. Total discounted costs of the energy system in the Reference scenario is estimated to nearly €36 billion, with investment of €3.773 billion for 2.803 GW of new electricity generation capacity needed to meet the increased demand by 2030. The proposed RE target increases the cost of the energy system only by 0.13%, due to the availability of additional renewables, particularly hydro, biomass, and biofuels. The combination of the policies that promote increased energy efficiency will decrease the discounted energy system costs of 0.24% (€87 million net present value). The baseline evolution of the energy system results in 59% increase of CO_2 emissions over the planning horizon. The analyzed RE and EE policies show strong synergies with a move to a lower carbon economy, resulting in cumulative CO_2 emissions reduction of 3.7% triggered by an overall drop in consumption and less use of fossil fuels. *© 2013 AIP Publishing LLC*. [http://dx.doi.org/10.1063/1.4813401]

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I. INTRODUCTION

The energy security and diversification, climate mitigation, and economic competitiveness have been identified in many countries as key policy drivers towards sustainable development, particularly in the energy sector. This has triggered a wide area of policies, such as programmes and support schemes for wider deployment of the renewable energy sources (RESs) for electricity production and promotion energy efficiency (EE) measures to encourage energy savings, especially in the European Union (EU).[1–6] The analyses of the interactions between renewable energy promotion and energy efficiency support schemes[4,5,7–10] have shown that with increased energy savings, it is easier to increase the share of renewable energy in energy supply and also both policy measures can contribute to greenhouse (GHG) emissions reduction.

The main goal of this paper is to analyse, from a perspective of an EU candidate country, the role of energy efficiency and renewable energy in meeting future requirements out through 2030 to support sustained economic growth while considering Energy Community (EC) commitments and EU accession directives. For this purpose, MARKAL/TIMES integrated energy system model was applied on the case of Macedonia. The model has demonstrated a substantial capacity to provide answers to some of the most pressing policy issues facing decision-makers, such as stemming the tide of increasing electricity imports and diversify supplies, as well as possibilities, costs, and viable options to move towards indicative EC/EU targets for energy efficiency and renewables.

II. METHODOLOGY

MARKAL (MARKet ALlocation) is a bottom-up, linear programming energy systems analysis modeling framework that is well suited to examine interlocking uncertainties through a systematic approach. The MARKAL/TIMES models produce robust, scenario-based projections of a country's energy balance, fuel mix, and energy system expenditures over time. The models relate economic growth to the necessary energy system resources, trades, and investments, while satisfying national environmental standards (or goals), to identify the least-cost energy future for the country that satisfies all the requirements (Software documentation[11]). Thus, the models provide a comparative framework for examining the impact of variations in key assumptions (e.g., fuel price, use of nuclear, availability of natural gas), policies (e.g., RE targets, climate change mitigation goals), and programs (e.g., National Energy Efficiency Action Plan, National Renewable Energy Action Plan) to advise informed decision-making and policy formulation.

The MARKAL objective is to minimize the total cost of the system, adequately discounted over the planning horizon. The objective function (Eq. (1)) is the sum over all regions of the discounted present value of the stream of annual costs incurred in each year of the horizon. Therefore,

$$NPV = \sum_{t=1}^{R} \sum_{t=1}^{NPER} (1+d)^{NYRS \cdot (1-t)} \cdot ANNCOST(r,t) \cdot \left(1+(1+d)^{-1}+(1+d)^{-2}+\ldots+(1+d)^{1-NYRS}\right), \tag{1}$$

where *NPV* is the net present value of the total cost for all regions, *ANNCOST(r,t)* is the annual cost in region *r* for period *t*, discussed below, *d* is the general discount rate, *NPER* is the number of periods in the planning horizon, *NYRS* is the number of years in each period *t*, and *R* is the number or regions.

The total annual cost *ANNCOST(r,t)* (Eq. (1a)) is the sum over all technologies *k*, all demand segments *d*, all pollutants *p*, and all input fuels *f* of the various costs incurred, namely, annualized investments, annual operating costs (including fixed and variable technology costs, fuel delivery costs, costs of extracting and importing energy carriers), minus revenue from exported energy carriers, plus taxes on emissions, plus cost of demand losses

$$
\begin{aligned}
ANNCOST(r,t) = \sum\nolimits_k \{ & Annualized\_Inv\cos t(r,t,k) \cdot INV(r,t,k) \\
& + Fixom(r,t,k) \cdot CAP(r,t,k) \\
& + Varom(r,t,k) \cdot \sum\nolimits_{s,s} ACT(r,t,k,s) \\
& + \sum\nolimits_c [Deliv\cos t(r,t,k,c) \cdot Input(r,t,k,c) \cdot \sum\nolimits_s ACT(r,t,k,s)]\} \\
& + \sum\nolimits_{c,s} \{Mining\cos t(r,t,c,l) \cdot Mining(r,t,c,t) \\
& + Trade\cos t(r,t,c) \cdot TRADE(r,t,c,s,i/e) \\
& + Importprice(r,t,c,l) \cdot Import(r,t,c,l) \\
& - Exportprice(r,t,c,l) \cdot Export(r,t,c,l)\} \\
& + \sum\nolimits_c \{Tax(r,t,p) \cdot ENV(r,t,p)\} \\
& + \sum\nolimits_d \{DemandLoss(r,t,d)\},
\end{aligned} \tag{1a}
$$

where *Annualized_Inv cos t(r,t,k)* is the annual equivalent of the lump sum unit investment cost, obtained by replacing this lump sum by a stream of equal annual payments over the life of the equipment, in such a way that the present value of the stream is exactly equal to the lump sum unit investment cost, for technology *k*, in period *t*. Note carefully that by stopping the summation over *t* at the end of the horizon, the objective function automatically accounts for the salvage value of all assets stranded at the end of the horizon.

Fixom(k,t,r), Varom(r,t,k) are unit costs of fixed and operational maintenance of technology *k*, in region *r* and period *t*;
Delivcost(r,t,k,c) is the delivery cost per unit of commodity *c* to technology *k,* in region *r* and period *t*;
Input(r,t,k,c) is the amount of commodity *c* required to operate one unit of technology *k,* in region *r* and period *t*;
Miningcost(r,t,c,l) is the cost of mining commodity *c* at price level *l,* in region *r* and period *t*;
Tradecost(r,t,c) is the unit transport or transaction cost for commodity *c* exported or imported by region *r* in period *t*;
Importprice(r,t,c,l) is the (exogenous) import price of commodity *c,* in region *r* and period *t*; this price is used only for exogenous trade, see below; *Exportprice(r,t,c,l)* is the (exogenous) export price of commodity *c,* in region *r* and period *t*; this price is used only for exogenous trade, see below;
Tax(r,t,p) is the tax on emission *p,* in region *r* and period *t*; and
DemandLoss(r,t,d) represents the welfare loss (in non reference scenarios) incurred by consumers when a service demand *d,* in region *r* and period *t,* is less than its value in the reference case.

While minimizing total discounted cost, the MARKAL model must obey a large number of constraints which express the physical and logical relationships that must be satisfied in order to properly depict the associated energy system.

MARKAL analyses not only show what is to be constructed (and also what is not) but also when and for how much (Software documentation[11]). Based on the engineering and economic representations of energy supply, conversion plants, and end-use devices in each country—mines, power plants, heat and power facilities, air conditioners, furnaces, light bulbs, etc.—the least cost energy supply and demand balance that can satisfy the physical and policy requirements can be explored by national experts.

The MARKAL/TIMES modeling framework is currently in use for several major international and global applications and in developed and developing countries for national strategic planning (see, e.g., Refs. 12–14), including analysis of changes in fuel consumption,[15] energy saving potential,[16] and renewable energy policies.[7,17–19]

III. CASE STUDY: POLICY ANALYSIS FOR MACEDONIA

The Republic of Macedonia as a candidate country for membership in the European Union and a signatory of the Energy Community Treaty has committed to the formation of a regional electricity market and implementation of EU Energy Policy, pursuing three fundamental objectives: competitiveness, security of supply, and sustainability.[20,21] Specifically, the national legislation should be harmonized with the existing legislation of the European Union (acquis communautaire) on energy, environment, competition, renewable energy sources, energy efficiency, and oil reserves, which was clearly stipulated in the Strategy for Energy Development of the Republic of Macedonia[22] and incorporated in the Law on Energy.[23] A recent review has reported that Macedonia has achieved a high degree of convergence with EU law in the field oil reserves[24] and some progress has been identified in the energy sector[25,26] and certain areas of the environment sector.[27] Furthermore, the EU RES and EE targets[1,2] have been also analyzed for Macedonia using the same methodology which was applied for the EU member countries, and the estimated indicative national targets were incorporated in all strategic documents.[28,29]

Recent analysis made for the energy sector in the country[30] has also drawn the attention to the efficient use of energy and the importance of utilization of the RES as key factors for sector development, particularly for reduction of GHG emissions[31–34] and diversification of energy mix in the system where fossil fuels are dominating.

The focus of this analysis is to examine and quantify how the identified issues could be influenced by policies and programs that promote energy efficiency and renewable energy. These policy issues were addressed by examining a Reference and three alternative policy scenarios for the Macedonian energy system. The alternative policy scenarios are

1. RE Scenario, which examines the implementation of a renewable energy target by 2020 in line with that proposed by the Energy Community [IPA Study[35]] (based on the approach used for setting the EU member state targets under the Renewable Directive.[1]
2. EE Scenario, which explores the range of energy efficiency measures (e.g., conservation measures, improved appliances, building shell improvements across all sectors) that are the most cost-effective means to meet national targets aimed at reducing final energy consumption (in line with National Energy Efficiency Action Plans or NEEAPs).
3. Combined RE and EE Scenario, a combination of supply-side and demand-side approaches that examines the resulting synergies of these policy goals.

The analysis was undertaken using the national MARKAL integrated energy system model, MARKAL-Macedonia. This national modelling framework for energy planning was developed under the USAID Regional Energy Security and Market Development (RESMD) Project.

The planning horizon is from 2006 till 2030, i.e., 25 years.

IV. RESULTS

A. Reference scenario

To assess the impact of different energy strategies or policies in Macedonia, a Reference scenario was developed, providing an outlook for the energy system based on current policies. The Reference scenario takes into account specific characteristics of the national energy system, such as existing technology stock, domestic resource availability and import options, and near term policy interventions.

To develop the Reference scenario, the available National Strategies[28,29] were used, from which the energy resource potential of the country was developed. Also, all other available national data sources (State Statistical Office, National energy balances, etc.) as well as some International databases (IEA Databases[36]) were utilized. A detailed list with the key data sources is given in Appendix, Table IX. The key assumptions and constraints for the Reference scenario are given in Table I.

Under the Reference scenario, energy consumption is projected to grow significantly, by 105% in terms of final energy by 2030. This will require expansion of the electricity generation

TABLE I. Key assumptions and constraints for the reference scenario.

Category	Assumption
GDP growth rate	e.g., 6.73% (2006–2020), 5.87% (2020–2030)
Population growth rate	−0.16%
Sector/issue	Constraint
Resource supply	
Domestic resources	
Coal (lignite)	• Production price vary between 1 and 2.25 €/GJ • Relatively high price for imported coal, running from 4.13 to 7.25 €/GJ
RES potential	
Hydro	Limited potential for small hydro power plants (up to 200 MW by 2020)
Wind	Limited potential for wind power plants (up to 360 MW by 2030)
Solar	Limited potential for PV installation (up to 40 MW)
Imports/Exports	• No limit • Prices for imported electricity running from 4.5 to 11.8 €cents/kWh
Electricity generation	Feed-in Tariffs (FIT) for small hydro (100 €/MWh), wind (97 €/MWh), and PV (420 €/MWh), with associated potential
Technology availability	• Nuclear generation is not available • The location and the capacities of the large hydro power plants are limited (based on the available National Studies of the hydro potential in the country)

system, from 1.470 to 3.252 GW and results in higher import levels, as well as growth in CO_2 emissions. Key indicators from the Reference scenario are shown in Table II.

Reference scenario energy growth is driven by the rather optimistic assumption regarding economic growth, averaging to 6.4% per annum, so the resulting requirements for the energy system may be on the high side of what will actually be needed. Although GDP growth averaged 5.9% in 2007 and 4.8% in 2008, it of course dropped significantly in 2009 and 2010 but is expected to recover to pre-economic-crisis levels.

Primary energy consumption in 2030 is projected to be 4656 ktoe. The energy intensity per unit of economic output is significantly lower than observed in 2006—estimated to be 0.15 toe/€1000, a reduction of around 54%. This is a result of the continuation of current structural changes in the Macedonian economy and natural technological progress underway internationally. As shown in Figure 1, primary energy supply becomes more diverse and increases by 79% in 2030 with imported natural gas accounting for 17% of total supply. The growth in transport demand is reflected in the increase in oil products (imported) and crude oil. The contribution of renewable energy sources (excluding biomass) to total primary energy during this period grows from 5% to over 8% and in absolute terms grows by 175%. This is primarily due to additional wind capacity in the power sector. The biomass contribution is almost the same at around 6%, although in absolute terms grows by 70%.

TABLE II. Key indicators for the reference scenario.

Indicator	2006	2030	Annual growth rate (%)	Overall growth (%)
Primary energy (ktoe)	2616	4656	2.4%	79%
Final energy (ktoe)	1646	3371	3.0%	105%
Power plant capacity (GW)	1470	3252	3.4%	121%
Imports (ktoe)	1184	2584	3.3%	118.3%
CO_2 emissions (kt)	8359	13 253	1.9%	59%
Final energy intensity (toe/€000 GDP)	0.324	0.150	−3.2%	−54%
Final energy intensity (toe/Capita)	0.808	1.722	3.2%	113%

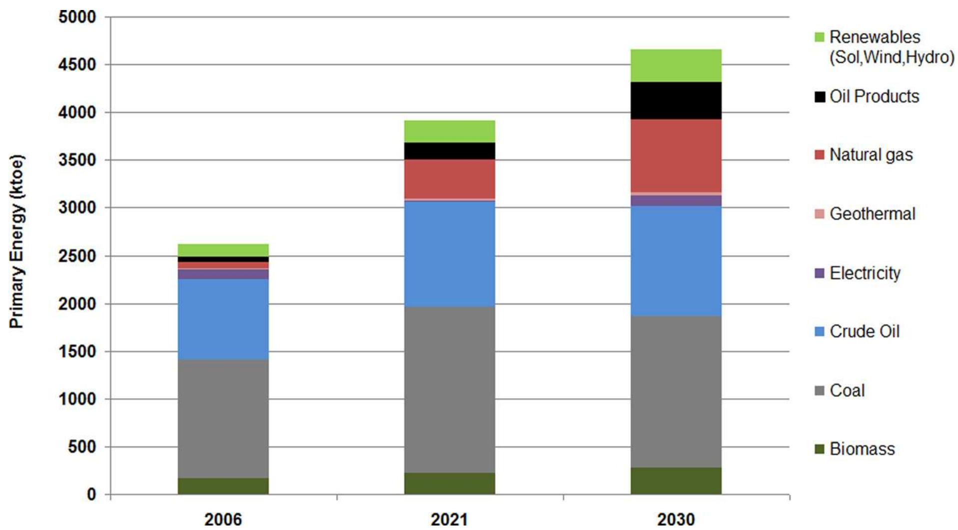

FIG. 1. Primary energy supply – 2006/2021/2030.

Total final energy consumption grows by 105% over the planning horizon, with the most significant increase from diesel and electricity use, and a greater share of natural gas, available through import, as shown in Figure 2.

The overall increase in natural gas use is driven by the construction of new gas-fired Combined Heat and Power (CHP) facilities totaling about 600 MW of additional capacity by 2030, along with increased direct consumption in the main demand sectors. The drop in gas use for electric only generating plants in 2021 is due to the addition of a coal-fired power plant, whereas the increase in gas-fired generation rises in 2030 results as the existing coal-fired power plant is retired. In terms of end use sector consumption, the main end use consuming sectors are industry and transport. Concerning transport, there are potentially a range of costs not explicitly incorporated into the modeling relating to CNG infrastructure; therefore, more analysis is need to more fully assess this switch in transport fuel consumption. There is limited penetration in commercial and residential sectors, due to large investment requirements in distribution infrastructure.

The majority of Macedonia's fossil energy requirements are imported. This demand for natural gas increases import dependency, resulting in a doubling of imports by 2030 (relative to current levels), shown in Figure 3.

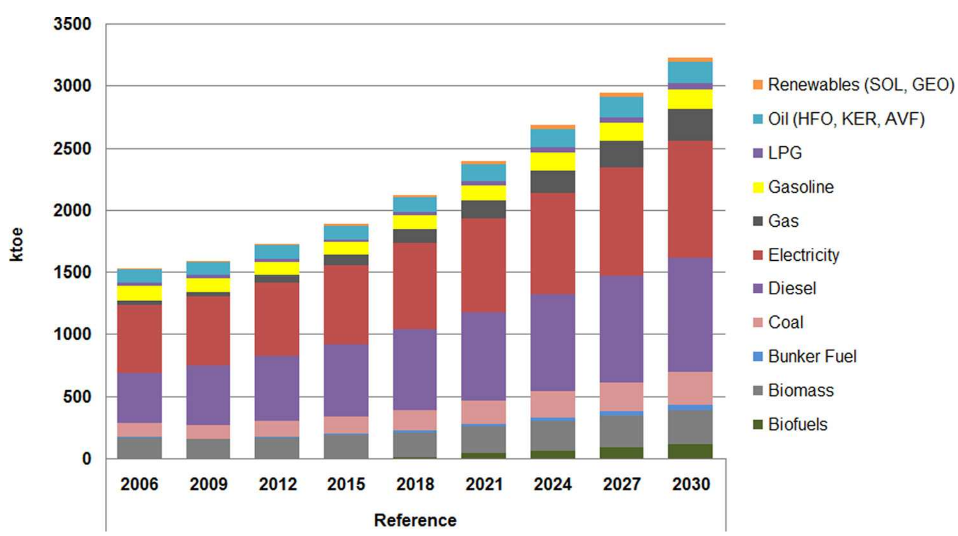

FIG. 2. Final energy consumption by fuel type.

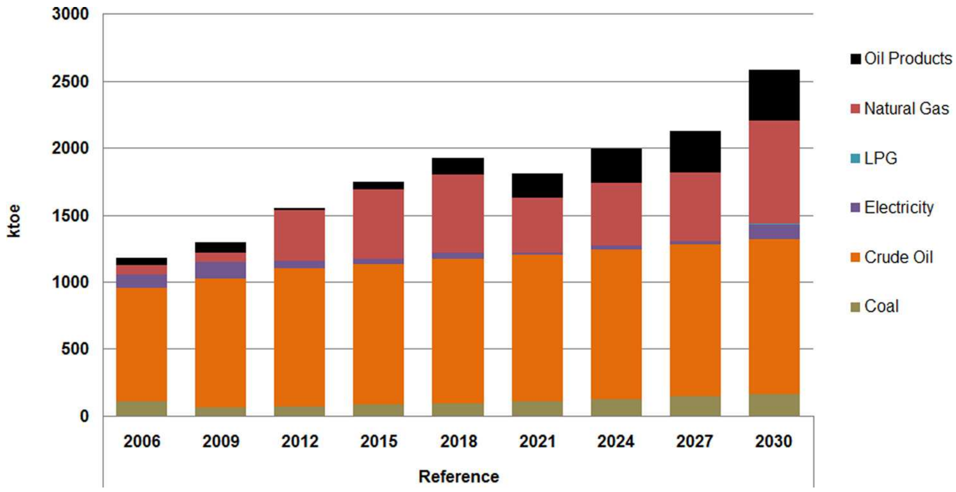

FIG. 3. Imports by type.

Growth in the energy system will require significant levels of new investment and expanded payments for fuels. However, in macro-economic terms, energy system expenditures are generally expected to absorb a smaller percentage of GDP in 2030 due to the reduced energy intensity per unit of economic output, shown in Table II. A breakdown of the energy system cost components is presented in Table III, showing the growth in expenditure for fuel, operating and maintenance costs, investments in new power plants, and the purchase of new end-use devices. The investment expenditures for new power plants and devices are incurred as demand rises and existing power plants and devices reach the end of their operational lifetimes.

Under the Reference scenario, to add the 2.803 GW of new generation capacity by 2030, a total investment of €3773 billion is required, which translates to average annual payments of the order of €190 million. At the same time, by 2030, over €540 million annually will be required to cover the cost of new demand devices (including vehicles), with the majority of this investment made by the private sector, including households. Fuel supply costs will also increase significantly, driven by growing demand and increasing prices, from €450 million per year to €1.7 billion per year. The annualized investment costs associated with existing power plants and demand devices are not included.

Currently, electricity supply is provided primarily by lignite-based plants (56%), hydro power (18%), and imports (23%). New power generation capacity additions between 2012 and 2030 are shown in Table IV. Coal power plants remain the main producers of electricity with new installed capacity of 900 MW between 2021 and 2027. The highest level of investment is in hydropower, with cumulative additional capacity of 944 MW by 2030, while new gas power plants have a cumulative installed capacity of 619 MW. Wind, solar, and biomass (under Renewable and Other category) also make an important contribution, (340 MW) where wind is primarily incentivized by a feed-in tariff. Figure 4 shows the capital investment requirements associated with the new capacity added in each three year period.

TABLE III. Annual energy system expenditure (€ million).

	2009	2012	2015	2018	2021	2024	2027	2030
Fuel costs	660	912	1182	1463	1623	1930	2164	2597
Operation and maintenance (O&M) Costs	512	594	709	798	925	1023	1119	1204
Annualized investment (demand)	269	507	754	1158	1566	1933	2182	2441
Annualized investment (power)	3	30	47	66	152	245	306	314
Total	1445	2042	2693	3485	4267	5132	5771	6556

TABLE IV. New power plant capacity additions (MW).

	2012	2015	2018	2021	2024	2027	2030	Total
Coal (lignite)	0	0	0	300	300	300	0	900
Natural gas	260	300	0	0	0	0	59	619
Large hydro	61	23	96	360	359	23	23	944
Renewables (and other)	4	32	32	32	30	156	54	340
Total	325	355	128	692	689	479	136	2803

The Reference scenario evolution of the Macedonian energy system results in an increase in CO_2 emissions from 8359 kt to 13253 kt corresponding to a 59% increase over the planning horizon.

B. RE scenario

The Energy Community Secretariat (ECS) commissioned a study in 2009 examining illustrative RE targets for the contracting parties (IPA Study[35]), adopting the RE Directive[1] methodology for allocating targets, with biofuels assumed to contribute 10% of transportation sector energy requirements. This study has subsequently been updated with revised targets estimated. A 2020 renewables target of 29% of Gross Final Energy Consumption (the target is applied to the year 2021 owing to three year period interval used in the model) for Macedonia has been proposed by the ECS. However, this target value was based on a much higher biomass estimate in 2009 and has yet to be agreed. The target value of 21%, as adopted in the *Strategy on use of renewable energy sources in the Republic of Macedonia by 2020*[28] is therefore used in this analysis.

The Reference scenario envisions an increase in new hydro and wind power generation capacity of about 1284 MW out of a total for new capacity additions of 2803 MW. In other words, renewable electricity generation is playing a crucial part in meeting future demand without an established renewable energy target. However, to further enhance energy security and address climate change, pursuing an even more aggressive renewables strategy has merit, though at a cost. By comparison, the RE target scenario (see Table V) shows that a 47 MW increase in renewable energy generation can be achieved by 2020 at a relatively low (0.13%) increase in the energy system cost relative to the Reference scenario.

A summary of the change in renewable energy use sourced from centralized electricity and distributed technologies compared with the Reference scenario is provided in Figure 5. The

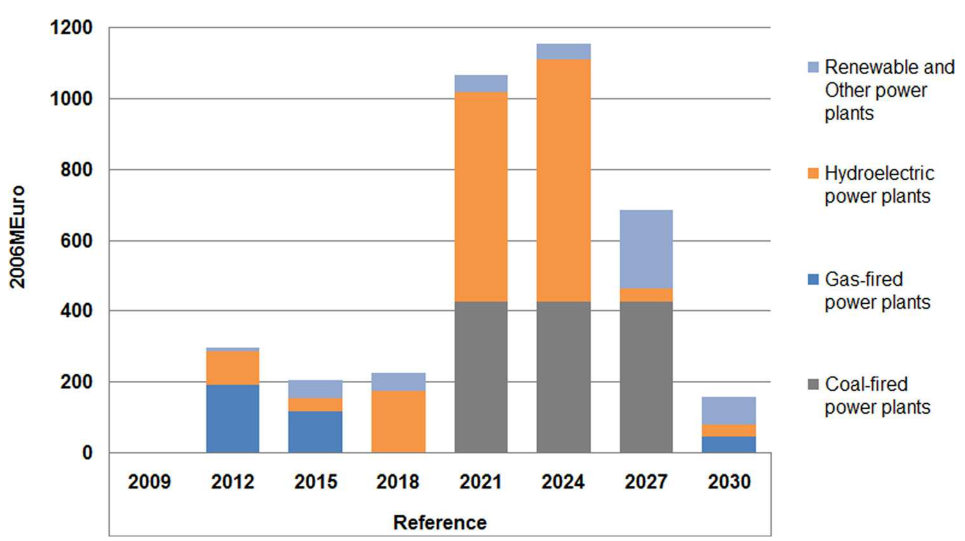

FIG. 4. Total investment cost of new power plants.

TABLE V. Cumulative impacts of the RE target (21%) on the energy system (compared to Reference scenario).

	Units	Reference	RE target change	
Total discounted energy system cost	M€2006	36 316	47	0.13%
Primary energy supply	ktoe	97 045	5	0.0%
Imports	ktoe	48 667	−734	−1.5%
Fuel expenditure	M€2006	25 807	−347	−1.3%
Power plant new capacity	MW	2 803	47	1.7%
Power plant investment cost	M€2006	3 773	98	2.6%
Final energy	ktoe	62 960	348	0.6%
CO_2 emissions	kt	293 805	−1648	−0.6%

main addition in RE is from biomass in residential sector, biofuels (prior to 2021), hydro, and wind. However, the size of the required additions is low, at just under 60 ktoe in 2021.

Further work is needed to develop the renewable options available to the model. The potential of many of the RE options is used due to the importance of such options in the Reference case, particularly given the high GDP growth assumptions.

C. EE scenario

The *First National Energy Efficiency Action Plan of the Republic of Macedonia by 2018* (NEEAP)[29] was published in 2011 and included a national adopted energy savings target of 12.2% (of current consumption levels) by 2018, with an interim target in 2012 of 4%. The target was based on the methodology outlined in Annex 1 of the Directive.[2]

This analysis provides insights into the cost-effective technologies that would be required to meet the NEEAP target. It is difficult to compare the outputs of this analysis with the measures listed in the NEEAP, as those measures tend to be related to policies and programs rather than technologies per se. It is also difficult to compare costs, as the NEEAP only cites implementation costs required in the public budget, not the costs of the actual technologies net of fuel savings (which MARKAL provides).

It is also clear that the costs of overcoming barriers to take-up of different technologies can be significant and require strong policies and programs. However, simply removing some of these barriers is not enough to meet the reduction levels required by the target in the NEEAP. So, finding the balance between policies, programs, and targets is important to ensure that goals are achieved without undue burden on the economy or individuals.

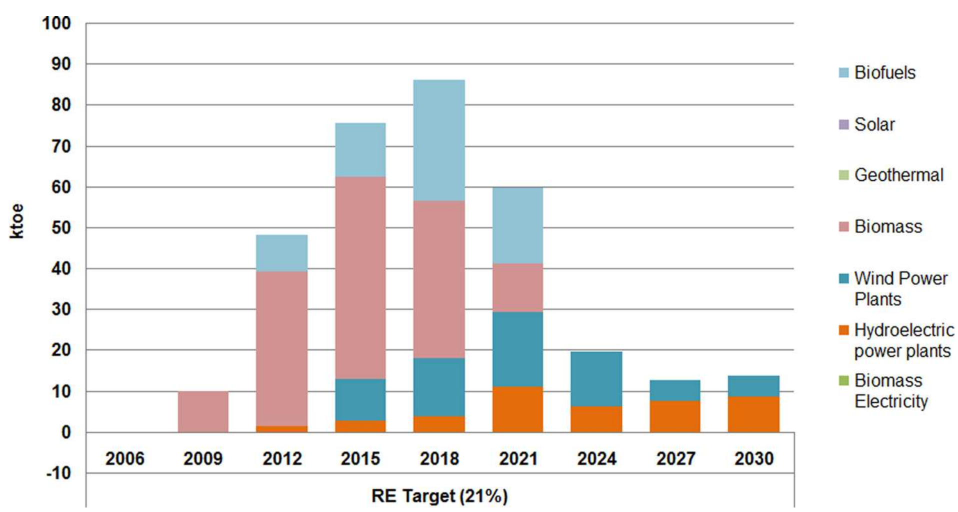

FIG. 5. Additional renewable energy under RE target, compared to the Reference scenario.

TABLE VI. Cumulative impacts of the EE target on the energy system (change compared to Reference scenario).

	Units	Reference	Energy efficiency target	
Total discounted energy system cost	M€2006	36 316	−87	−0.24%
Primary energy supply	ktoe	97 045	−3969	−4.1%
Imports	ktoe	48 667	−2869	−5.9%
Fuel expenditure	2006 M€	25 807	−1558	−6.0%
Power plant new capacity	MW	2803	−59	−2.1%
Power plant investment cost	2006 M€	3773	−43	−1.1%
Demand technology investments	2006 M€	10 811	940	8.7%
Final energy	ktoe	62 960	−3277	−5.2%
CO_2 emissions	kt	293 805	−8604	−2.9%

The basis for the energy efficiency target is the Macedonian NEEAP, which has a percentage reduction calculated from the 2006–2009 average final energy consumption levels. As the NEEAP only extends out to 2018, it is assumed that the reductions under NEEAP continue over the later years in the planning horizon, reflecting Government ambition to maintain improvements in energy efficiency over time.

The focus of this section is on the benefits of EE policies and measures that lower the barriers associated with the uptake of more efficient devices while the NEEAP consumption reduction target is required to be met. Table VI shows the key results as changes between the EE and the Reference scenario. As shown in the table, all of the key cumulative metrics (other than investment in new demand technologies) are reduced due to efficiency savings. For example, overall system cost reduces by 0.2%, power plant investment reduces by 1.1%, imports drop by 6%, and fuel expenditure goes down by 6% saving €87 million, €43 million, 2869 ktoe, €1.56 billion, respectively. Such savings enhance economic competitiveness and energy security.

The contribution of different sectors to the targets is shown in Figure 6, indicating that energy saving potential is economy wide and that all sectors provide a significant contribution. Under the energy efficiency target, the industry sector provides the largest cumulative savings (39% of total savings), followed by the residential sector (28%), and commercial (23%).

In terms of fuels, the largest near-term reductions come from electricity, diesel (transport), coal (industry), and biomass (residential). The use of distributed heat increases slightly because the fuel used for production of heat, like electricity, is not subject to the energy efficiency target.

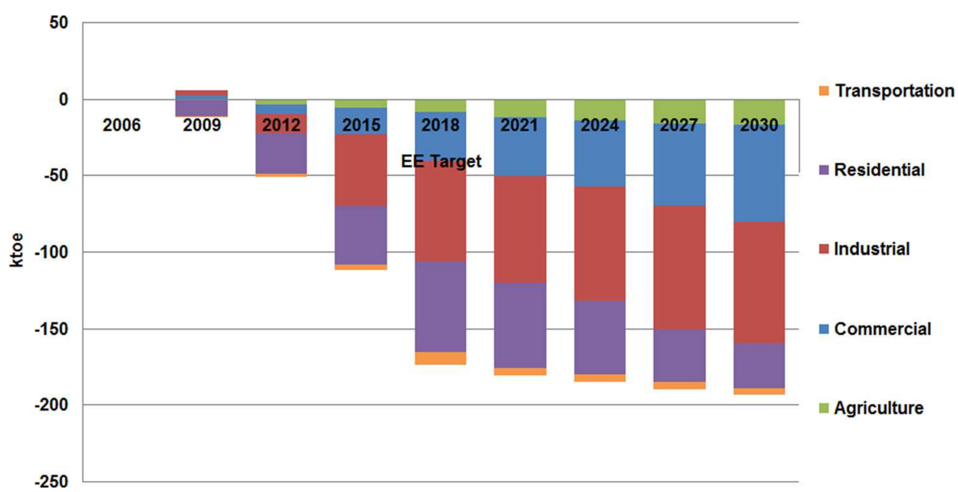

FIG. 6. Final energy reduction by sector energy efficiency target.

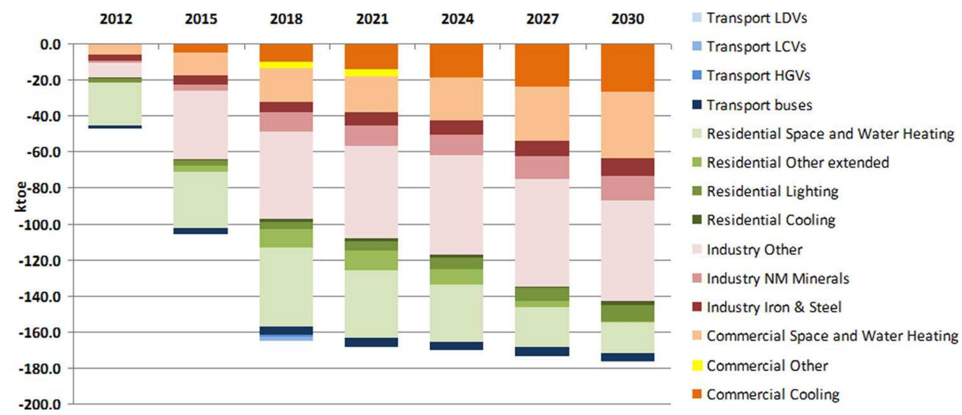

FIG. 7. Final energy reduction by energy service type under energy efficiency target.

A more detailed overview of savings by energy service demands is shown in Figure 7. The most cost-effective reductions occur in the industry iron and steel sector, particularly across gas and oil using technologies, with a reduction in the role of coal. In the commercial sector, more efficient provision of space and water heating and cooling technologies are introduced and as a result, significant savings of electricity and oil are observed. There is also provision of more efficient technologies in residential space and water heating sector and this leads to reduction of electricity and biomass.

It is important to highlight that there are significant uncertainties concerning the potential of opportunities for energy efficiency. Therefore, it is important to continually review the data in the model for use in future analyses, assessing new data available in Macedonia to further improve the robustness of the analysis.

D. Combined RE/EE scenario

Promoting both energy efficiency and renewable energy goals in parallel may have strong policy synergies. This analysis looked at assessing both objectives at the same time. In the case of Macedonia, the NEEAP and the Renewable Strategy will be implemented in parallel; therefore, this analysis is a better reflection of the policy reality. The analysis highlights that strong synergies do exist between these policies in terms of energy savings and CO_2 reductions. Table VII shows the key result changes between the combined RE and EE scenario and the Reference scenario.

Figure 8 shows the change in final energy consumption by fuel type for three policy scenarios relative to the Reference scenario. It shows the stronger energy reductions under the combined case, as efficiency measures reduce the required contribution from renewable energy.

TABLE VII. Cumulative impacts of combined RE/EE targets on the energy system (compared to Reference scenario).

	Units	Reference	EE + RE target change	
Total discounted energy system cost	2006 M€	36 316	27	0.07%
Primary energy supply	ktoe	97 045	−4033	−4.2%
Imports	ktoe	48 667	−3657	−7.5%
Fuel expenditure	2006 M€	25 807	−1931	−7.5%
Power plant new capacity	MW	2803	11	0.4%
Power plant investment cost	2006 M€	3773	71	1.9%
Demand technology investments	2006 M€	10 811	1028	9.5%
Final energy	ktoe	62 960	−3325	−5.3%
CO_2 emissions	kt	293 805	−10 995	−3.7%

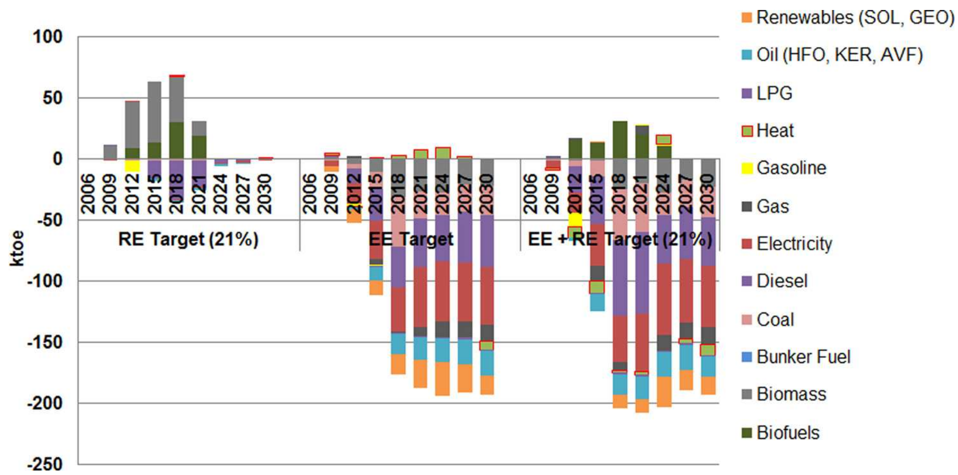

FIG. 8. Change in final energy consumption by fuel type.

In the combined EE and RE scenario, the energy system costs increase by €27 million or 0.07%. This cost is slightly higher than the aggregate cost observed under the individual RE and EE cases. This is primarily because biomass and biofuels use under the RE target means less lower cost efficiency gains can be made under the EE target.

Due to the lower fuel consumption and greater use of clean domestic options, additional benefits of the combined scenario include lower import dependency (a reduction over the entire planning horizon by 3657 ktoe or 7.5%) and reduced CO_2 emissions (by 10995 kt or 3.7%). Both are important in achieving a more sustainable energy system and enhancing energy security.

TABLE VIII. Summary of policy drivers for each scenario.

Policy driver / scenario	Reference	Renewables	Energy efficiency	EE + RE
Energy security and diversification	• Increasing gas imports • Lignite thermal-dominated generation system	• Increased use of domestic RE resources	• Reduces fossil fuel imports by 2869 ktoe (6%) • Lowers direct energy and electricity consumption by 3277 ktoe (5.2%)	• Increased use of domestic RE (although at lower level than under RE case) • Final energy further reduced compared to EE, by 5.3% • Cumulative total imports reduced by over 7.5%
Enhanced competitiveness	• Electricity system expansion	• Only modest cost increase (0.13%) for 21% target • Potential to stimulate investment in renewable market	• Lower fuel costs, saving 6% in fuel expenditure (€1558 million) • Power sector investment reduced by 1% (€43 million)	• Lower fuel costs, saving 7.5% in fuel expenditure (€1931 million)
CO_2 mitigation	• 58% higher emissions by 2030 due to increased use of coal and natural gas	• Cumulative reduction of 0.6% due to use of less fossil energy (partic. Gas)	• Cumulative reduction of 3% due to lower total energy consumption	• Cumulative reduction of 3.7% due to more RE and lower energy consumption

V. CONCLUSIONS

The relevance for the key policies areas of energy security and diversification, climate mitigation, and economic competitiveness arising under each scenario is summarized in Table VIII and elaborated upon subsequently.

Under both RE and EE scenarios, import levels are reduced by around 1.5% and 6%, respectively, or by 7.5% under the combined scenario case, thus enhancing the energy security. In the renewable case, the reduction of imports is lower because of the higher penetration of RE sources in the reference case. In the EE scenario, the reduction is due to lower energy demand resulting from increased energy efficiency. Gas imports are particularly affected. Under the RE scenario, the reduction of imported gas is 3%, while in the EE scenario, the reduction is 12% (or combining both goals, gas imports are reduced by 16%).

Furthermore, an energy efficiency target with the right policies and programs has strong benefits for competitiveness by reducing payments for imports, decreasing power sector capacity needs, cutting industry production costs, and lowering fuel bills for households. Total fuel expenditure savings (compared to the Reference case) amount to a reduction of 7.5% (in the combined scenario case), equivalent to cumulative saving of €1.9 billion, offsetting the cost of the more expensive efficient technologies. Once transformed, the energy system savings continue into the future.

The proposed 2020 RE target increases the cost of the energy system, albeit by a modest amount, due to the additional renewable generation investment required, particularly towards 2030, under the assumption that the RE share is to be sustained over time. To meet the target, an additional 181 MW of RE capacity will be required by 2020. The overall energy system costs are 0.13% higher (€47 million NPV). If the RE target is implemented in parallel with policies to promote energy efficient technologies, energy system costs only increase by €27 million or 0.07%, highlighting the synergies between renewable and energy efficiency policies.

From the environmental point of view, the policies analyzed show strong synergies with a move to a lower carbon economy. For example, the combined EE and RE policy leads to cumulative reductions of 3.7% in CO_2 emissions. This is accomplished by overall reduction in demand for energy owing to the more efficient energy system and a switch to lower carbon generation mix.

Finally, besides the valuable insights on the role of EE and RE in meeting the EC Targets, the use of model also has illustrated an enhanced analytical capacity in the country, enabling policy makers to explore the impacts and opportunities for low emissions development. This is particularly timely given the initiatives undertaken by the World Bank on green growth opportunities and USAID on low emission development strategies.

APPENDIX: DATA SOURCES

TABLE IX. Key data sources.

Data Requirement	Source
2006 energy balance	• IEA Online Database: Energy Balances of Non-OECD and Energy Statistics of Non-OECD [2008] • National Energy Balances (from the State Statistical Office and the Ministry of Economy)
Domestic energy prices	• Energy Regulatory Commission (Annual report for 2009) • Energy balances of the Ministry of Economy (for 2006 and 2007) • Oil refinery OKTA • "Domestic lignite price based upon feasibility study for underground exploitation of coal for the purposes of Bitola TPP from the Zhivojno mine," developed by the Mining Institute from Macedonia
Resource potential, including imports/exports	• Strategy on Sustainable Development of Forestry in the Republic of Macedonia, Ministry of Agriculture, Forestry, and Water Economy, 2007

TABLE IX. (*Continued*.)

Data Requirement	Source
	• Biomass Availability Study for Macedonia, van der Hem, SENTER project PSO99/MA/2/2, February 2001 • Energy from Biomass, Slave Armenski, Skopje, 2009 • Coal-Position in energetic concept of the Republic Macedonia, BorceAndreevski, Proceeding International Symposium ENERGETICS 2008, ZEMAK, 2008 • Strategy for Energy Development of the Republic of Macedonia until 2030
Installed capacity and characterization of existing electricity, heating and CHP plants	• Annual Report of ELEM for 2006—for the electricity generation capacities • Reports of Toplifikacija AD Skopje for heating and CHP
Electricity generation plants (adjustment to the SSP plant characterizations)	• Hydro: ELEM www.elem.com.mk, MEPSO - www.mepso.com.mk • CHP: TE-TO Skopje, www.te-to.com.mk/ • Coal: Report from UBS Investment Research: European Power Prices, P. Lekander, A. Gandolfi, S. Comper, and A. Wright, November 2007 • Wind: Wind Park Development Project Macedonia – Feasibility Study, A. Bogdanci , Infrastructure Project Facility for Western Balkans (EU's CARDS Programme, February 2010)
Timing of demands for energy services	No data available currently in Macedonia. Assumptions are consistent with the overall electricity load profile
Fuel consumption patterns by energy service	Data available at sector level but not at energy service level
Demand drivers	• UN Projections for the Population growth • Base year GDP—Ministry of Finance • GDP growth—same as the Strategy for Energy Development of the Republic of Macedonia until 2030 (based on projections made by national experts)
Known energy policies	• Strategy for Energy Development of the Republic of Macedonia until 2030, March 2010 • Strategy on Use of the Renewable Energy Sources in the Republic of Macedonia by 2020, September 2010 • Energy Efficiency Strategy of the Republic of Macedonia, USAID, June 2010

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