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REGIONAL ENERGY SECURITY AND MARKET DEVELOPMENT – STRATEGIC PLANNING COMPONENT

INVESTMENT REQUIREMENTS AND BENEFITS ARISING FROM ENERGY EFFICIENCY AND RENEWABLE ENERGY POLICIES IN SELECTED ENERGY COMMUNITY OBSERVER COUNTRIES:

ARMENIA POLICY BRIEF

July 2012
This report was produced for review by the United States Agency for International Development (USAID).
It was prepared by the Energy Strategy Center (ESC) and International Resources Group (IRG).

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TABLE OF CONTENTS

List of Figures

List of Tables

ACRONYMS

AEO	Annual Energy Outlook
BAU	Business as Usual
CC	Combined cycle
CNG	Compressed Natural Gas
CRES	Centre for Renewable Energy Sources
EC	Energy Community
ECS	Energy Community Secretariat
EE	Energy Efficiency
EIA	Energy Information Association (US)
ESC	Energy Strategy Center
ESD	Energy Services Directive
ESEC	Energy Strategy of the Energy Community
EU	European Union
GDP	Gross Domestic Product
GFEC	Gross Final Energy Consumption
GT	Gas turbines
HGVs	Heavy Goods Vehicles
HPPs	Hydro power plants
ICE	Internal combustion engine
IEA	International Energy Agency
IPA	International Policy Analysis
IRG	International Resources Group
LCVs	Light Commercial Vehicles
LDVs	Light Duty Vehicles
LPG	Liquid Petroleum Gas
LWR	Light Water Reactor
MARKAL	MARKetALlocation
MENR	Ministry of Energy and Natural Resources of Republic of Armenia
NEEAPs	National Energy Efficiency Action Plans
NEEDS	New Energy Externalities Developments for Sustainability
NPESRE	National Program on Energy Saving and Renewable Energy ()
NPP	Nuclear Power Plant (NPP)

NPV	Net Present Value
NREAPs	National Renewable Energy Action Plans
O&M	Operation and maintenance
PC	Pulverized coal
PET	Pan-European TIMES model
PV	photovoltaic
RA	Republic of Armenia
RE	Renewable Energy
REDP	Regional Energy Demand Planning
RESMD	Regional Energy Security and Market Development
RoR	Run-of-river
RPS	Renewable Portfolio Standards
SF	Steam fossil
SSP	SYNENERGY Strategic Planning
UK	United Kingdom
US	United States
USAID	US Agency for International Development

A. INTRODUCTION

Under the US Agency for International Development (USAID) Regional Energy Security and Market Development (RESMD) project and in conjunction with the joint SYNENERGY Strategic Planning (SSP) effort undertaken with Greece Hellenic Aid, a strategic planning activity was undertaken to develop a comprehensive national energy planning framework to support policy making and analysis of future energy investment options.

This initiative builds on the earlier ground breaking USAID Regional Energy Demand Planning (REDP) project that laid the foundation for integrated supply/demand energy systems analysis in Southeast Europe.

This Policy Brief provides an overview of the analysis undertaken by the Armenian Planning Team using their national MARKAL (MARKet ALlocation) integrated energy system model, MARKAL-Armenia, to examine the role of energy efficiency (EE) and renewable energy (RE) in meeting future requirements through 2030 to support sustained economic growth, while considering energy security and energy diversification challenges of Armenian energy system.

The analysis reflects the results of one and half years of model development and use, jointly undertaken by the Ministry of Energy and Natural Resources of Republic of Armenia (MENR) and the Energy Strategy Center (ESC) of Scientific-Research Institute of Energy, supported by International Resources Group (IRG). The MARKAL-Armenia analysis undertaken uses a cross-sectoral, cost optimization approach to identify the most economic efficient set of measures.

This Policy Brief focuses on assessing the energy sector costs and benefits for the entire energy system of meeting the demand on energy and fostering energy security and diversification. It also considers different energy efficiency and renewable targets in Armenia, which can be achieved through a different set of policies. Furthermore, what is important for decision-makers is that there is now a strategic planning platform available for Armenia, where model assumptions and policy scenarios may be readily changed and explored, that can provide analytic rigor and insights to underpin future national strategic planning and policy formulation.

The following supply and demand analyses have therefore been undertaken:

- Reference (development according to strategic plans) Scenario: The development of supply and investment requirements to support the evolution of the national energy system in the absence of policies and programs aimed at altering current trends. This Reference scenario is fully discussed in Section C.

- Energy Efficiency (EE) Promotion: This demand-side policy 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 different existing programs aimed at achieving the energy efficiency potential, such as the Energy Savings Program). The EE scenario is fully discussed in Section D.

- Renewable Energy (RE) Target: This supply-side policy examines the requirements to successfully achieve a renewable energy target of 16% by 2020 aimed at enhancing energy security (by reducing imports). The RE scenario is fully discussed in Section E.

- Combined EE & RE Policies: This combination of supply-side and demand-side approaches examines the resulting synergies of these policy goals. The combined RE/EE scenario is fully discussed in Section F.

In addition, country-specific issues, in this case, the critical question of building a new 1000 MW nuclear plant, are examined in Section G. A new nuclear power plant is assumed to be in place by 2021 in the Reference and other policy scenarios discussed first.

RESMD Policy Briefs have been prepared for eight other participating Contracting Parties and Observer Countries, as well as a Regional Overview that compiles the results from all nine countries to provide an aggregate perspective of the analyses undertaking by each.

B. KEY INSIGHTS FOR POLICY MAKERS

The analysis undertaken provides some important insights on how improving energy efficiency and promoting renewable energy impact three key policy areas: energy security and diversification, economic competitiveness, and climate mitigation. These insights are summarized in Table 1.

Table 1. Summary Overview of the Impact of RE / EE Objectives on Key Energy Policy Issues

Policy issue / Scenario	Reference Scenario Trends	Renewables	Energy Efficiency	EE&RE
Energy security and diversification	• Increasing gas imports and consumption, based on electricity-for-gas swap agreement • Primary energy consumption and imports nearly double by 2030	• Significant uptake of RE potential in the Reference scenario limits the potential for cost effective increase under an RE target • Increased use of domestic RE resources under a target reduces imports by 2.1%	• Reduces fossil fuel imports by 1,095Ktoe (3.6%) • Lowers direct energy and electricity consumption by 759Ktoe (4%)	• Increased use of domestic RE (although at lower level than under RE case) • Primary energy further reduced compared to EE, by 3.9% • Cumulative total imports reduced by over 4.3%
Enhanced competitive-ness[1]	• Significant electricity system expansion at a total cost of 5,984 €M • Greater access to gas	• Stimulates investment in renewable market • Results in 282 MW of new wind capacity	• Lower fuel costs, saving 11.2% in fuel expenditure (735€M)	• Lower fuel costs, saving 11.7% in fuel expenditure (767€M) • Import and consumption decreases result in a *net savings* of 4.7%
CO_2 mitigation	• Emissions increase by more than 57% by 2030	• Cumulative reduction of 3.4% due to less fossil energy use (especially gas) and lower total energy consumption	• Cumulative reduction of 6.2% due to lower total energy consumption	• Cumulative reduction of 7.6% due to greater efficiency and more RE

[1] The analysis does not provide full insights into the real macroeconomic impacts of changes to the energy system, as it does not account for allocation of resources across other economic sectors, as a general equilibrium model does. However, by looking to minimize the costs of a sustainable energy system it is inherently fostering competiveness.

ENERGY SECURITY AND DIVERSIFICATION

Under both RE and EE scenarios, import levels will be reduced by around 2.1% and 3.6% respectively, or a 4.3% reduction under the combined scenario case. This is due to increased use of indigenous renewable energy under an RE target, and lower energy demand resulting from increased energy efficiency. Under the EE scenario, imported gas is reduced by over 4.8% cumulatively, while in the RE scenario, the reduction is 3.8%. (In the combined scenario, gas imports are reduced by 6.5%).

ENHANCED COMPETITIVENESS

An energy efficiency target with the right policies and programs has strong benefits for competitiveness by reducing payments for imports, reducing CO_2 emissions, and cutting industry production costs and lowering fuel bills for households. Total fuel expenditure savings (compared to the Reference case) amount to a reduction of more than 12% (in the combined scenario case), or cumulative saving of 0.32€ billion, nearly the half of 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 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 282 MW of RE capacity will be required by 2030. Energy system costs are 0.3% higher (0.07€ billion Net Present Value (NPV)[2]). If the RE target is implemented in parallel with policies to promote energy efficient technologies, the combined cost of meeting renewable targets and energy efficiency targets are reduced. It is important to note that electricity prices also increase, so understanding the distribution of impacts and, where necessary, reducing competitiveness or social impacts will be important.

In addition, as already mentioned, a combined EE&RE policy can substantially reduce imports, saving valuable foreign exchange funds, amounting to 317€ million cumulatively that can offset some of the more expensive generation and efficient device upfront costs and be rechanneled for other domestic priorities.

CO_2 MITIGATION

The policies examined show strong synergies with a goal of moving to a lower carbon footprint for the Armenian energy economy. The combined EE and RE policy leads to cumulative reductions of 7.6% in CO_2 emissions.

POLICY IMPLICATIONS

The Energy Community region faces daunting investment challenges to replace aging infrastructure and keep pace with energy demand growth. As the Energy Strategy of the Energy Community (ESEC)[3] notes, the Western Balkans region will require an additional 13 GW of investment in new power plants just through 2020, at a cost of nearly 30€ billion, a figure that dwarfs actual investment in new capacity over the past two decades. As an Observer Country, Armenia is watching developments within the EC. The MARKAL-Armenia Reference scenario shows that rapid electricity demand growth requires an almost doubling of electricity generation

[2] All references to total system costs over the entire planning horizon are discounted at 7.5% and reported according to a 2006 base year as Net Present Values.

[3] Energy Community, 2012. 10thMC/18/10/2012 - Annex 19/27.07.2012

capacity by 2030 to 4,140 MW at a cost of nearly 5,980€ million. At the same time, policy priorities to ensure secure, diverse supplies increase the challenges.

Investment in energy efficiency can serve a key strategy to meet these priorities. The MARKAL-Armenia analysis shows that a 2.7% reduction in final energy consumption can be achieved at a net savings of 385€ million (or 1.0%), while achieving the more ambitious target of 8% (against 2006-2009 average consumption) requires only a modest cost increment over this value, with a 1.56% (358€ million) cost reduction compared to the baseline and 11.2% (739€ million) savings in fuel expenditures, 3.55% (1,095€ million) savings in imports and 6.15% reduction of carbon emissions. Achieving these goals requires a 8.62% (799€ million) increased investment in more efficient demand devices. The most cost-effective areas for energy efficiency investment identified in this analysis include residential and commercial space heating, lighting, and industrial process heat. The MARKAL-Armenia model is a readily available framework that, along with market analysis, can be used to identify key technology and building opportunities and develop targeted measures to achieve this potential.

Meeting RE targets, on the other hand, increases energy system costs by only 0.3%. (71€ million) While this is a relatively modest increase, it is important to highlight additional power sector investment is needed out to 2030 increasing by 5.7% (340€ million), or 282 MW. The modest increase is due to the fact that renewable energy is already playing a significant part in meeting future demand in the Reference Scenario without an established renewable energy target. Achieving the target, however, yields some substantial additional benefits: a more than 2% (658€ million) decrease in imports, an 4.15% (272€ million) decrease in fuel expenditures, and 3.38% decrease in carbon emissions.

Although the investment challenges are significant, pursuing the EE and RE strategies simultaneously leads to important synergies. The total system cost is decreased by 1.38% (317€ million). The savings are significant: a 11.7% (767€ million) decrease in fuel costs, 7.6% decrease in carbon emissions, and 4.3% (1,315€ million) decrease in imports. The benefits of these investments extend beyond 2030, creating a lasting shift of the economy onto a lower energy intensity, more sustainable, and secure trajectory.

Sensitivity analysis was also performed to examine under what conditions the construction of a new nuclear power plant is warranted. It shows that such a large investment is only feasible if a robust export market is identified and sustained, and that from the perspective of meeting domestic demand there are other alternatives worth considering.

The analyses described herein also make it clear that Armenia now has an integrated energy system planning model that can be used to examine in more detail the best policies to achieve these and other policy goals. Key areas for future analysis include assessing tradeoffs regarding power sector expansion and possibilities of electricity export/import in the region, and developing targeted EE policies, including standards and appliance and retrofit subsidies.

C. ARMENIA ENERGY SYSTEM REFERENCE PATHWAY

To assess the impact of different policies and programs on the evolution of the energy system in Armenia, a Reference scenario was developed, taking into account specific characteristics of the national energy system, such as existing technology stock, domestic resource availability and import options, and planned policy interventions. The Reference scenario is aligned with the National Strategy and other strategic documents and existing contracts. In addition, all other available national data sources (State Statistical Office, national energy balances, etc.) as well as some international databases (e.g., International Energy Agency or IEA) were utilized. The full list of information sources is provided in Appendix I.

A key assumption underpinning the Reference scenario is that by 2021 a new 1000 MW nuclear plant will come into operation. Another key assumption is the export of up to 6.9 billion kWh electricity in exchange for natural gas import with exchange rate of 3kWh = 1cub.meter.

Under the Reference scenario, energy consumption is projected to grow by 70.6% in terms of final energy by 2030, driven by Gross Domestic Product (GDP) growth and increasing per capita consumption. This will require nearly doubling electricity generation capacity from 2,345 MW to 4,140 MW and results in higher import levels, as well as growth in CO_2 emissions. Key indicators from the Reference scenario are shown in Table 2 and summarized subsequently.

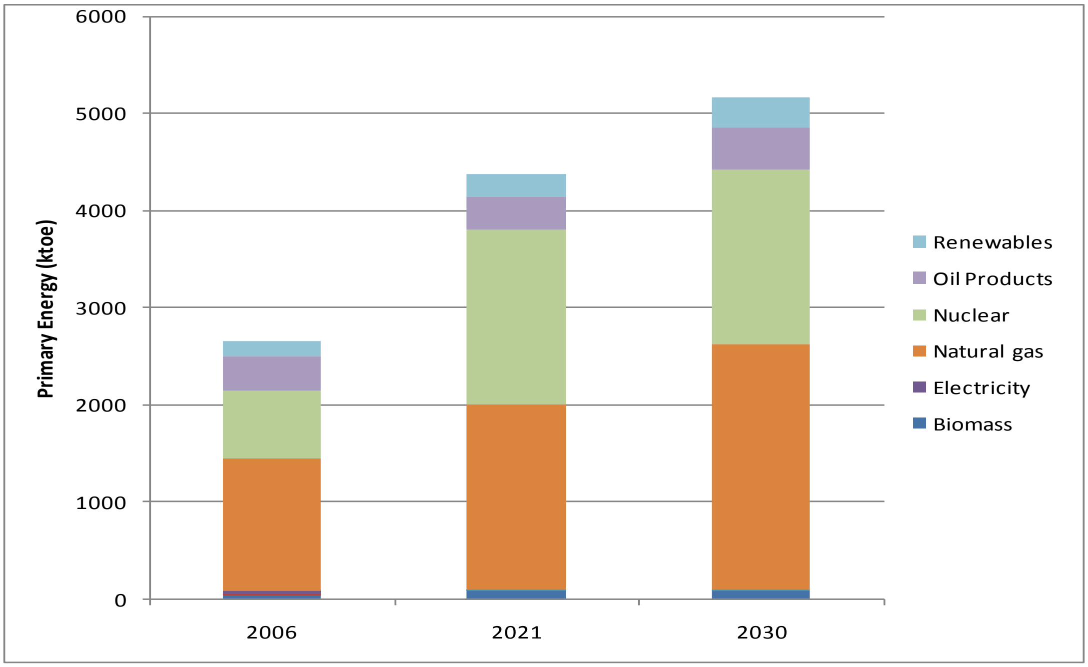
Table 2. Key Indicators for the Reference Scenario

Indicator	2006	2030	Annual Growth Rate (%)	Overall Growth (%)
Primary Energy (Ktoe)	2,646	5,163	2.82%	95.11%
Final Energy (Ktoe)	1,660	2,831	2.25%	70.57%
Power plant capacity (MW)	2,345	4,140	2.40%	76.51%
Imports (Ktoe)	2,445	4,756	2.81%	94.49%
CO_2 emissions (Kt)	3,816	6,007	1.91%	57.40%
GDP (€ million)	4,825	12,044	3.89%	149.62%
Population (000s)	3,223	3,411	0.24%	5.84%
Final Energy intensity (toe/€000 GDP)	0.34	0.24	-1.57%	-31.67%
Final Energy intensity (toe/Capita)	0.51	0.83	2.01%	61.16%

Primary energy consumption in 2030 is projected to be 5,163Ktoe, increasing from 2006 levels by 95%. Whilst growing GDP and increasing household energy intensity are driving up energy demand, it is also important to note that energy intensity per unit of economic output is lower than observed in 2006 – estimated to be 0.24 toe/1000€, a reduction of around 32%. This is a result of the continuation of current structural changes in the Armenian economy and natural technological progress underway throughout the world.

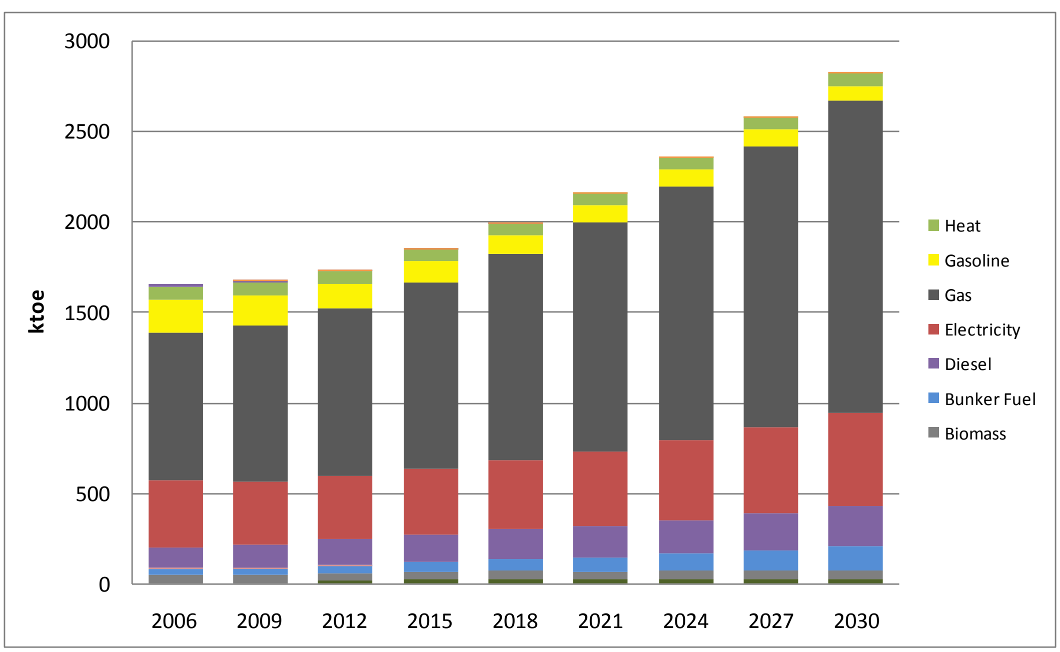
The most significant component of primary energy growth is the growth in nuclear energy, which increases from one-quarter to more than one-third of total primary energy. Much of this energy is designated for export, and the exchange for a new source of natural gas allows gas to remain approximately one half of total primary supply. The growth in transport demand is reflected in the increase in imported oil products, although the share in primary energy is similar.

Figure 1.Primary Energy Supply – 2006 / 2021 / 2030



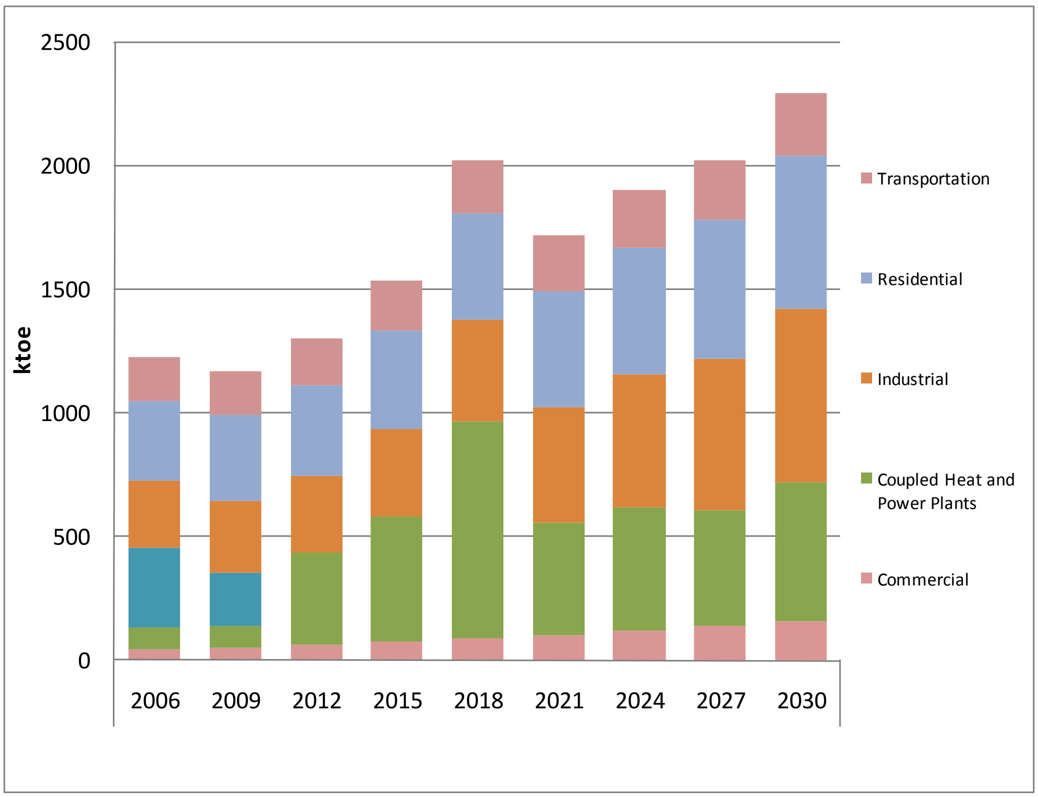
Total final energy consumption grows by more than 70% over the planning horizon. Imports of natural gas allow its share in final energy to rise from one-half to more than 60% by 2030, as shown in Figure 2.

Figure 2. Final Energy Consumption by Energy Type



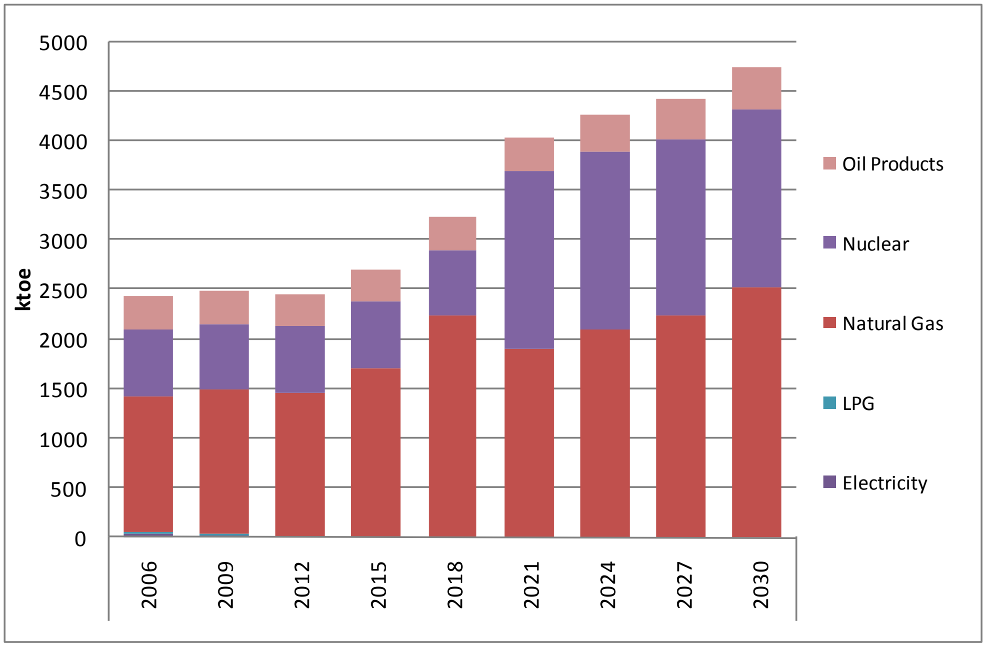
A more detailed view of gas consumption by sector is shown in Figure 3. It shows that the majority of gas is used in the residential, commercial, and industry sectors but with significant take-up for power generation until a new Nuclear Power Plant (NPP) comes into force in 2021. In the residential sector, gas is used primarily for cooking and space/water heating, while in the commercial sector the main uses are for cooking and space heating. The continued high use of compressed natural gas (CNG) for transport keeps consumption of imported gasoline low. Gas is used across most industry sectors for the production of high temperature heat for a number of different processes.

Figure 3. Gas Consumption by Sector



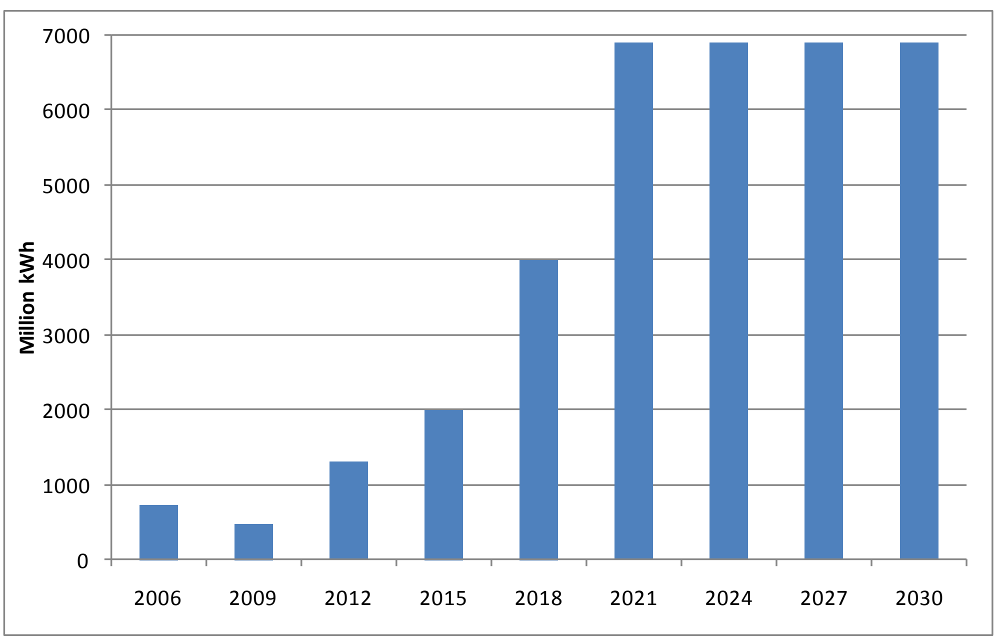
All of Armenia's fossil and nuclear energy requirements are imported. Imports nearly double over the planning horizon, in proportion with the growth in primary energy. Liquid Petroleum Gas (LPG) imports decrease to none by 2021. Nuclear fuel imports remain constant, owing to the power plant operating at its nominal rate (all the time), and changes only in 2021 as the new nuclear plant comes online.

Figure 4. Imports by Type



Electricity exports reach over 7 billion kWh in 2030, as called for as part of an intergovernmental "swap" agreement regarding electricity/gas exchange. Armenia exports electricity as part of the agreement starting in earnest from 2012 (1.3 billion kWh) and continues until the past of planning period, as shown in Figure 5.

Figure 5. Electricity exports



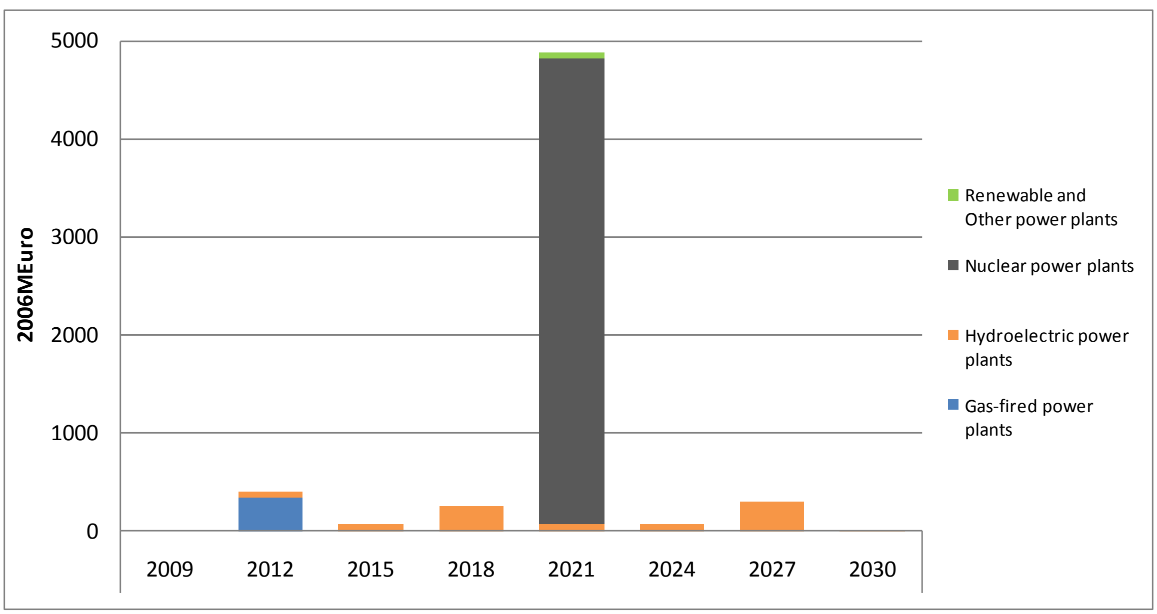
New power generation capacity additions needed are shown in Table 3, starting from a 2009 total installed capacity of 2,223 MW. Continued expansion of hydropower is the most prevalent, with a cumulative additional capacity of 650 MW by 2030 including small hydro power plants (HPPs). Although the model includes renewable potentials for wind, solar, and other renewables, only 25MW of new geothermal capacity is cost effective in the Reference scenario. 687 MW of thermal capacity in 2012 includes two thermal power plants running on natural gas (Yerevan CC - 242 MW, Hrazdan 5 – 445 MW), which are already built. Table 3 shows the new capacity additions in each three-year period.

Table 3. Additional Power Plant Capacity by Fuel Type (MW)

Plant Type	Total Installed 2009	2012	2015	2018	2021	2024	2027	2030	Total Additional Capacity
Gas	750	687	0	0	0	0	0	0	687
Hydro	1,075	60	60	195	60	60	200	15	650
Nuclear	395	0	0	0	1,000	0	0	0	1,000
Renewable	2.6	0	0	0	25	0	0	0	25
Total New Capacity		747	60	195	1,085	60	200	15	2,362
% of Total Installed Capacity		25.6%	2.0%	6.1%	28.1%	1.5%	4.8%	0.4%	57.1%

The full (lump-sum) cost of the new nuclear power plant in 2021 is reflected in the figure below. However, as shown in Table 4, the annualized investment payments are spread over the long lifetime period of nuclear plant (over 60 years). In 2018 and 2027, investment payments are for the medium-sized hydro power plants constructed in those years. All other investments are for small hydro and other renewables, along with the 2012 gas-fired power plants being completed now. construction delay costs are considered for all power plants.

Figure 6. Total Investment Cost of New Power Plants



* *Investment levels are not annual but cumulative for a three-year period

Growth in the energy system will require significant levels of new investment and increased payments for fuel. However, 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, as shown in Table 2. A breakdown of the energy system cost components is presented in Table 4, showing the growth in expenditure for fuel (extraction, import, and sector differential charges), operating and maintenance (O&M) costs (fixed and variable), 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.

Table 4. Annual Energy System Expenditure (€ Million)[4]

Expenditure Type	2009	2012	2015	2018	2021	2024	2027	2030
Fuel Costs	658	659	779	846	562	685	789	961
O&M Costs (Demand)	101	117	137	158	170	181	193	205
O&M Costs (Power)	325	304	313	338	335	344	364	379
Annualized Investment (Demand)	168	355	536	726	857	914	972	1033
Annualized Investment (Power)	0	33	38	63	451	456	478	479
Total	1,252	1,464	1,795	2,119	2,363	2,568	2,782	3,043

Under the Reference scenario assumptions, to add the 2,362 MW of new generation capacity required by 2030, a total investment of 5.984€ billion is required. At the same time, by 2030 over 1.0€ billion annually will be required to cover the cost of new demand devices, with the majority of this investment made by the private sector, including households. Fuel costs will increase slightly, driven by growing demand and increasing prices, from 658€ million per year to 961€ million per year.

[4] For power plants and end-use devices, the upfront capital cost is amortized over the lifetime of the unit with annualized payments calculated according to the lifetime and cost of capital. These annualized payments, along with associated operating and maintenance costs and fuel expenditures constitute the overall energy system cost. The annualized investment costs associated with existing power plants and demand devices are not included.

D. EXAMINATION OF THE PROMOTION OF ENERGY EFFICIENCY IN ARMENIA

The Ministerial Council of the Energy Community adopted Decision D/2009/05/MC-EnC in December 2009 concerning the implementation of certain Directives on Energy Efficiency, including Directive 2006/32/EC on energy end-use efficiency and energy services (ESD). This required Contracting Parties (under Article 14(2)) to submit their first National Energy Efficiency Action Plan by June 2010.

As a non-Party country, Armenia does not have any obligations concerning this Directive. But there is a National Program on Energy Saving and Renewable Energy (NPESRE), under which the Government plans various energy efficiency measures in all sectors of the economy. According to this program three scenarios are planned: pessimistic, average, and optimistic with 30%, 65% and 100% realization of EE measures respectively, or reduction of final energy consumption by 8%, 17.4%, and 26.7%. The analysis in this section focuses on the modest efficiency improvement scenario, implemented as a reduction of 8% of 2006-2009 average final energy consumption from Reference case values by 2021, as this was considered the most realistically achievable.

In implementing policies and measures to increase energy efficiency, the focus is frequently on overcoming barriers to the take-up of different technologies, such as long payback periods, lack of familiarity with more efficient technology options, inconvenience, and high transaction costs. The costs of overcoming these barriers can be significant, and require strong policies and programs (e.g., appliance and building standards, information campaigns, low interest (subsidized) loans, "giveaway" programs for the poor). Such barriers and policy options are highlighted in the World Bank (2010) report *Status of Energy Efficiency in the Western Balkans*.[5]

The costs attributed with these barriers are accounted for in this analysis by the inclusion of so-called hurdle rates,[6] which simulate the customer behavior in responding to these barriers, as discussed in Appendix II. As a result, such options are not invested in under the Reference case. However, it is assumed that when energy efficiency policies are pursued, programs aimed at reducing these impediments (or "hurdles") are also put in place, reducing those inherent added costs.

Thus, this section considers two EE scenarios, one in which the hurdle rates are simply lowered by 20% from the rates in the Reference scenario (Energy Efficiency Promotion scenario), representing roughly a 20% decrease in the barriers to adoption of cost effective technologies, as well as a scenario in which the hurdle rates are lowered *and* an 8% final energy reduction target is imposed (Energy Efficiency + Target scenario.) The Energy Efficiency Promotion scenario can be interpreted as illustrating the economically efficient opportunities to increase efficiency when the barriers are successfully lowered. The Energy Efficiency + Target scenario goes further by forcing the model to find enough savings to meet a target in line with those being considered by the Energy Community.

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[5] Report can be found at ECS website - http://www.energy-community.org/pls/portal/docs/664179.PDF

[6] For example, UK studies include *The hidden costs and benefits of domestic energy efficiency and carbon saving measures* (Ecofys 2009) and *Review and development of carbon dioxide abatement curves for available technologies as part of the Energy Efficiency Innovation Review* (Enviros Consulting 2006).

Table 5 shows the reduction of final energy that is to be achieved in the Energy Efficiency + 8% EE Target scenario and Table 6 compares the key results from the two EE scenarios, expressed as changes from Reference scenario values.

Table 5. Energy Efficiency Reduction Level

	2012	2015	2018	2021	2024	2027	2030
Reduction totals (Ktoe)	11	49	82	130	158	172	151

Table 6. Cumulative Impacts of the EE on the Energy System (Change Compared to Reference Scenario)

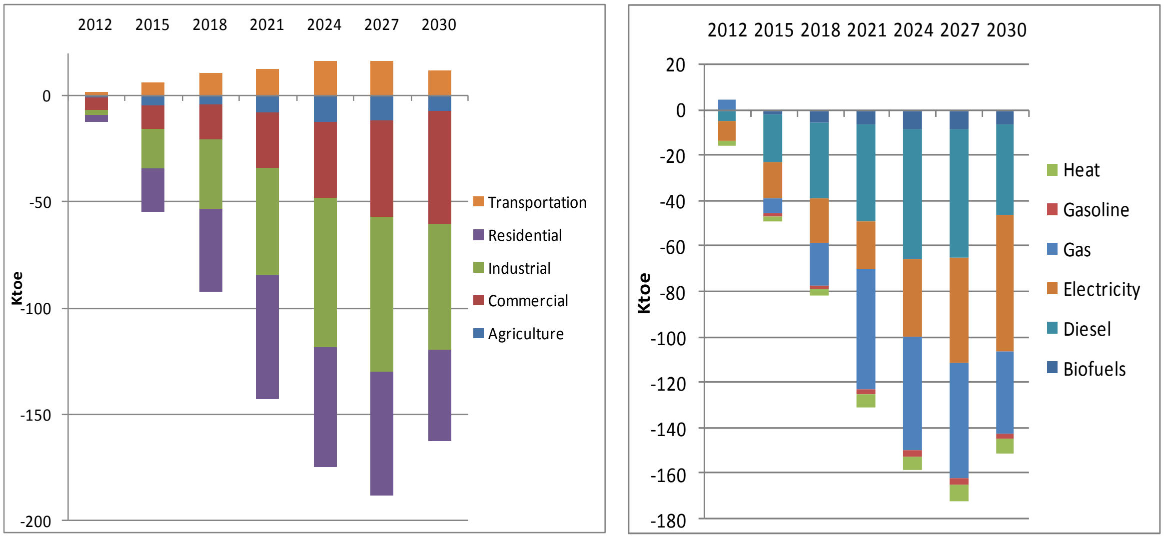
Indicator	Units	Reference	Energy Efficiency Promotion		Energy Efficiency 8% Target	
Total Discounted Energy System Cost	2006M€	23,004	-385	-1.68%	-358	-1.56%
Primary Energy Supply	Ktoe	33,549	-984	-2.93%	-1169	-3.49%
Imports	Ktoe	30,833	-916	-2.97%	-1095	-3.55%
Fuel Expenditure	2006M€	6564	-626	-9.54%	-735	-11.19%
Power Plant New Capacity	MW	2,362	0	0%	0	0%
Power Plant Investment Cost	2006M€	5,984	0	0%	0	0%
Demand Technology Investments	2006M€	5,561	340	6.12%	799	8.62%
Final Energy	Ktoe	18,874	-516	-2.73%	-756	-4.01%
CO_2 Emissions	Kt	42,111	-2,270	-5.39%	-2,589	-6.15%

As Table 6 shows, the economically efficient level of investment in EE when barriers to investment are lowered results in a cumulative final energy savings of 2.73% and a corresponding reduction in primary energy supply and fuel imports of nearly 3%, at a modest but noticeable savings of total system cost of 1.68%. Going farther to meet the target of the policy scenario results in larger energy savings – 3.49% of primary supply and imports and nearly 4.01% of final energy – while still saving 1.56% from the Reference scenario system cost. Because power plant investments are driven by the electricity-for-gas swap policy and the new nuclear build, the EE scenarios result in no change to power plant investments. Instead, they trade off higher costs for more efficient end use devices against the associated fuel savings.

The remainder of this section focuses *Energy Efficiency + 8% Target* case, as the NPESRE is the main policy action in this area. At the end of the section, variants of the EE analysis that simulate the average and optimistic scenarios outlined in the NPESRE are briefly discussed to look further at energy efficiency policy in Armenia.

The contribution of different sectors to meeting the 8% target is shown in Figure 7, indicating that energy saving potential is economy-wide, and that all sectors except transport provide a significant contribution. Under the energy efficiency target, industry provides the largest savings (37% of total savings), followed by the residential sector (34%), and commercial at 23%. A slight increase in consumption in the transport sector results from reducing the hurdle rate on CNG-powered light commercial vehicles. While slightly less efficient than the diesel vehicles they replace, the CNG vehicles take advantage of a much cheaper fuel.

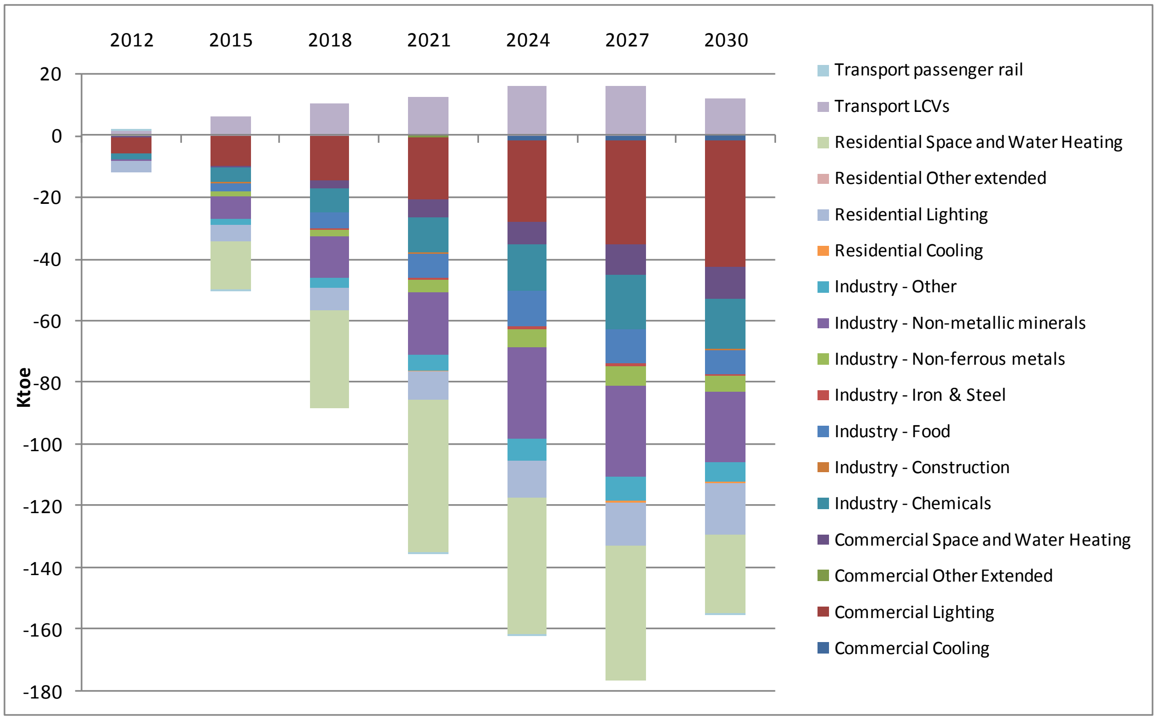
Figure 7. Final Energy Consumption Reduction by Sector and Fuel under Energy Efficiency + 8% Target



In terms of fuels, the largest near-term reductions in consumption come from diesel, gas, and electricity. The overall net reduction is lower than these reductions suggest due to an increase in oil and gas being used in more efficient technologies. Large reductions in gas for space heating in the residential sector are observed due to switching to more efficient appliances, as described below.

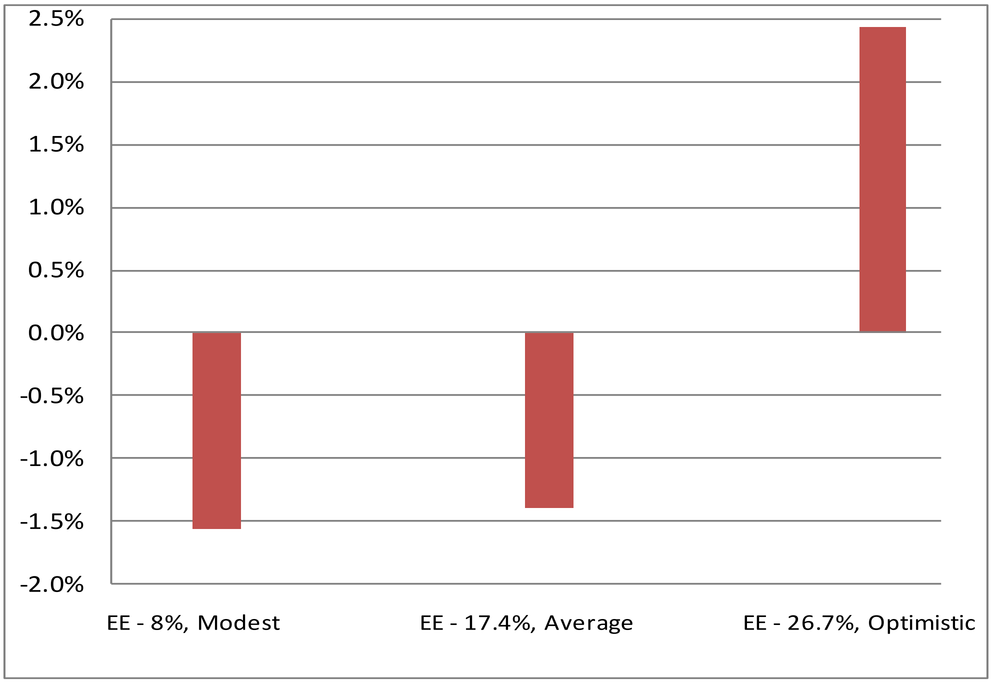
A more detailed overview of savings by energy service demands are shown in Figure 8. The most cost-effective reductions occur in the more efficient provision of space and water heating, with a strong uptake of heat pumps (using electricity) and more efficient use of appliances. This leads to a fairly strong reduction in gas consumption while electricity consumption levels increase by a small percentage. Additional reductions mainly come from lighting and some sub-sectors of industry (non-metallic, chemical, etc.).

Figure 8. Final Energy Consumption Reduction by Energy Service Type under Energy Efficiency + 8% Target



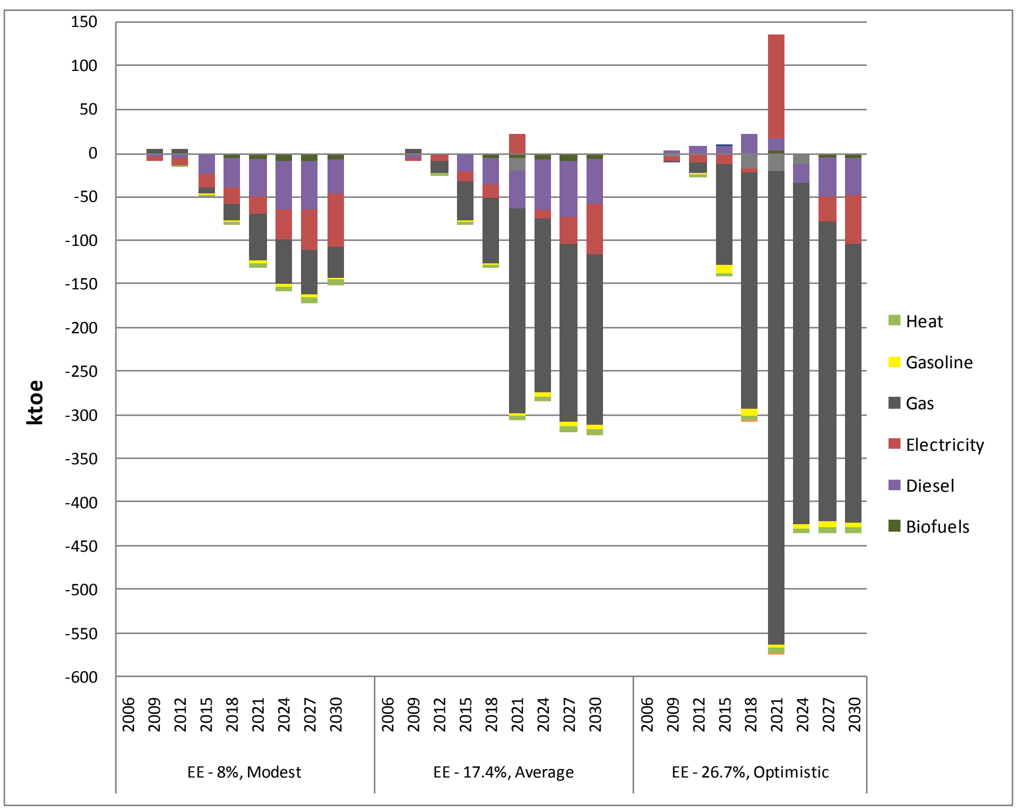
As mentioned above, the sensitivity of EE measures on the energy system was analyzed for 17.4% and 26.7% final energy reduction targets, corresponding to the average and optimistic scenarios in the NPESRE. In each case, the barriers to the uptake of energy efficiency are assumed to be reduced further, to represent more success promoting the adoption of cost-effective technologies. As shown in the figure below, in the case of a 17.4% target system, the cost is slightly higher than in a base 8% case, but still less than in the Reference case. In other words, this is a target that saves money overall. The 26.7% target is harder to reach. When we force a 26.7% reduction of final energy, the system cost increases by 2.4%.

Figure 9. Total System Cost in Three EE Scenarios



As we can see, as the stringency of the target increases, the main reductions must come from natural gas (appliances on gas changes into electricity).

Figure 10. Final Energy Consumption Reduction in Three EE Scenarios



Again, the bulk of the reductions are spread across the residential, industrial, and commercial sectors. When a higher EE target is imposed, reductions also occur in the transportation sector with a shift to more efficient buses and light duty diesel vehicles.

Figure 11. Final energy consumption reduction by sectors

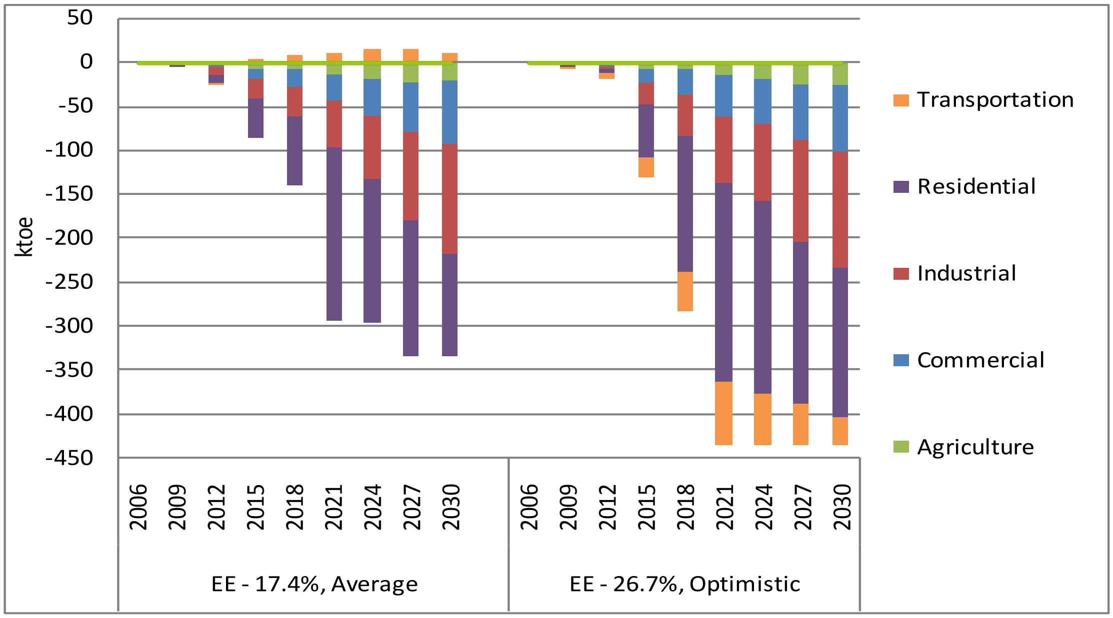
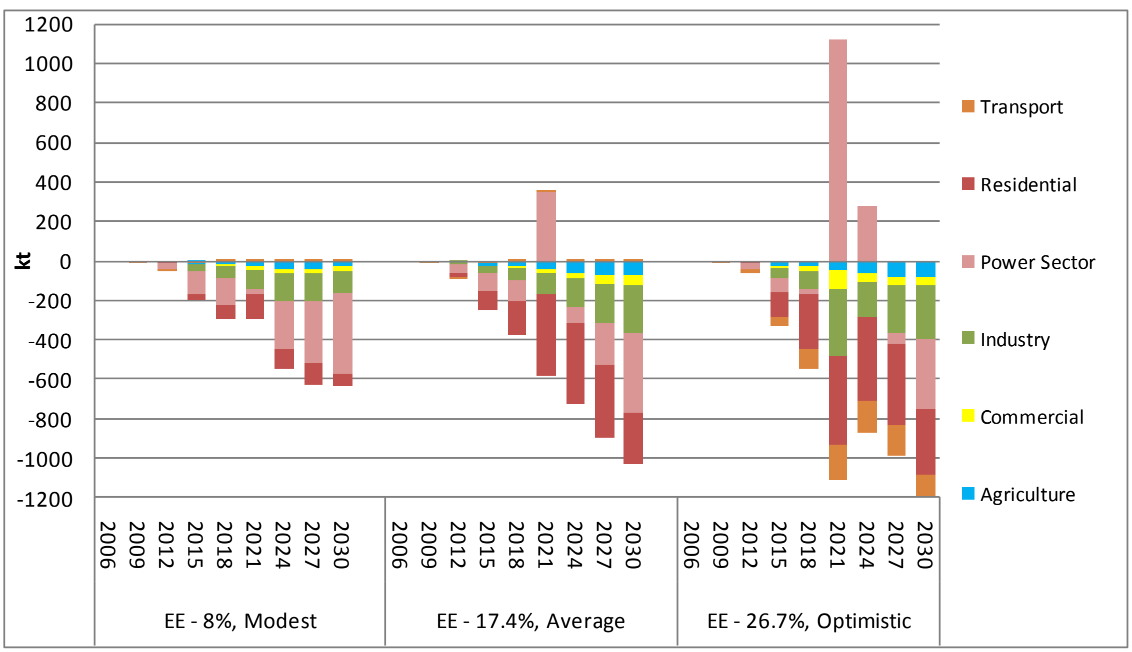


Figure 12. CO_2 Emissions Reduction by Sectors due to Energy Efficiency



As shown in the figure above, in all three EE scenarios we get reductions of emission more than in the Reference scenario. The majority of reductions on the demand side occur in residential, industry and power sectors.

E. ASSESSMENT OF A RENEWABLE ENERGY STRATEGY FOR ARMENIA

In 2011 Armenia, in cooperation with Danish Energy Management, developed the Renewable Energy Roadmap for Armenia. In this paper, the technically and economically available potential of renewable energy sources was assessed and projections of future RES development were made. The potentials for small hydro, wind, and geothermal documented in the Roadmap were included in the MARKAL model, and the Roadmap's target of 16% renewable energy (including traditional biomass and large hydro) by 2021 was imposed.

Table 7 summarizes the key results of the RE Target scenario. Cumulative energy system costs (to 2030) are only 0.3% % higher. While this is a relatively modest increase it is important to highlight that additional power sector investment is needed out to 2030 increasing by 5.7%, or 282 MW. This policy contributes towards moving to a lower emissions pathway, with cumulative CO_2 reduction reaching 3.4% (between 2009-2030).

Table 7. Cumulative Impacts of the RE Target on the Energy System (Compared to Reference Scenario)

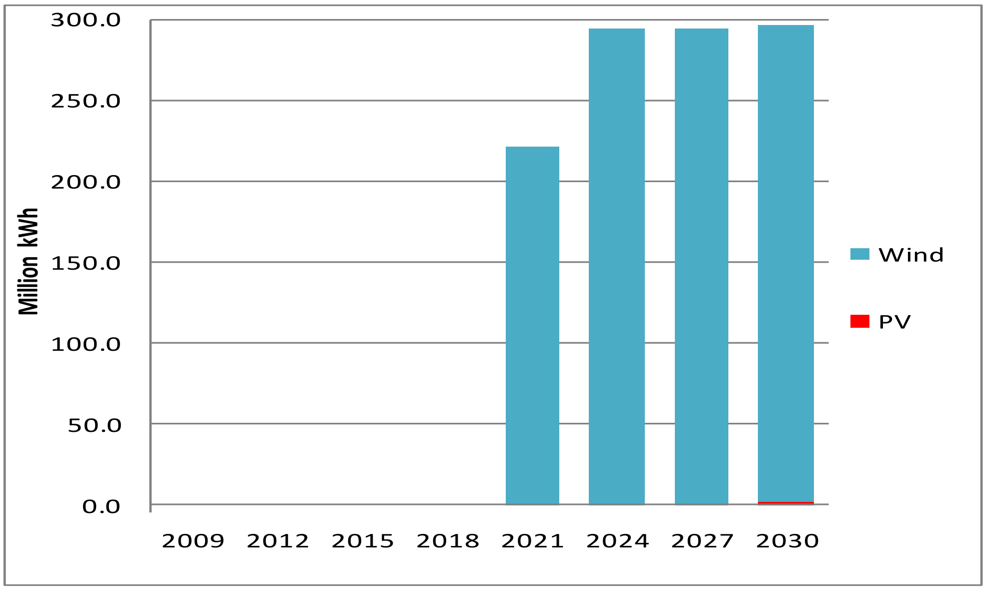
Indicator	Units	Reference	RE Target	Change
Total Discounted Energy System Cost	M€2006	23,004	71	0.31%
Primary Energy Supply	Ktoe	33,549	-556	-1.66%
Imports	Ktoe	30,833	-658	-2.14%
Fuel Expenditure	M€2006	6,564	-272	-4.15%
Power Plant New Capacity	MW	2,362	282	11.94%
Power Plant Investment Cost	M€2006	5,984	340	5.69%
Final Energy	Ktoe	18,874	-376	-1.99%
CO_2 Emissions	Kt	42,111	-1,422	-3.38%

The target is somewhat challenging for the model to reach. Final energy consumption decreases by 2.0% as the model chooses to reduce fossil consumption as a means of meeting the percentage target. In large part, this occurs because the Reference scenario is already taking advantage of most of the cost-effective renewable potential identified, including an increase in new hydro generation capacity of about 650 MW and geothermal capacity of 25 MW (see Figure 14) out of a total for new capacity additions of 2,362 MW. In the transport sector, the high penetration of CNG vehicles reduces the potential for an increase in biofuels use, which is also at its maximum in the Reference scenario. In other words, renewable energy is already playing a significant part in meeting future demand without an established renewable energy target. Searching for biofuels utilization options in sectors outside transport may offer another possibility for increasing renewable energy use.

Under the RE target, cumulative additions in RE capacity (between 2009-2030) total 957 MW out of total new capacity of 2,644 MW. Comparing this to the Reference case, this means an additional 282 MW of RE capacity, coming mostly from wind-powered generation and in small part from photovoltaic (PV). This suggests that meeting the target and critically sustaining it beyond 2020 will require policies to stimulate investment and attract high levels of capital in the power generation sector. The additional capital required under the RE target in the power generation sector is estimated at 340€ million.

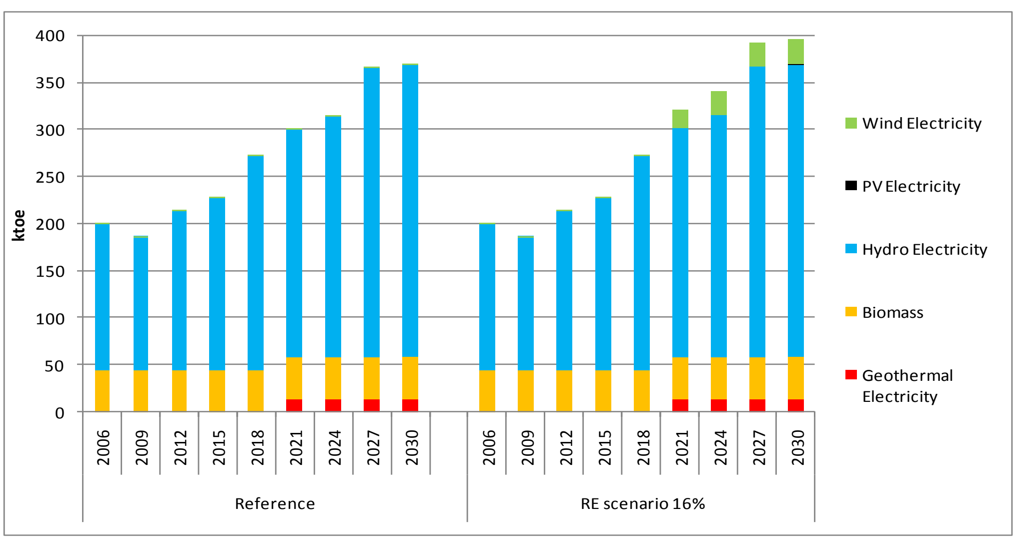
A summary of the change in renewable energy use compared with the Reference scenario is provided in Figure 13. The additional 282 MW of wind capacity produces over 300 million kWh electricity. Also, there is insignificant electric coming from solar PV in the later years.

Figure 13. Additional Renewable Electricity Generation under RE Target, Compared to the Reference Scenario



Total renewable energy under the Reference and RE target cases are compared below, in Figure 14. The main difference, as noted earlier, is the addition of wind electricity production.

Figure 14.Total Renewable Energy under Reference and RE Target Cases



F. COORDINATED RENEWABLES AND ENERGY EFFICIENCY POLICIES FOR ARMENIA

Promoting both energy efficiency and renewable energy goals in parallel may have strong policy synergies. The analysis discussed in this section looked at assessing both objectives at the same time. In the case of Armenia, the energy-saving program and RE Roadmap will be implemented in parallel; therefore, this analysis is a better reflection of the policy reality. What the analysis highlights is that this approach is more cost-effective due to the synergies between these policy areas.

Key insights include:

- Energy system costs decrease by 317€ million or 1.4%, making it only slightly more expensive than the Energy Efficiency target scenario and a net savings from the Reference scenario.
- The combined scenario has 1.7% lower energy system cost than the Renewable scenario, making the combined approach a significantly more cost effective way to achieve the renewables target. The efforts to reduce final energy through energy efficiency (reduced by 4.7%) means a lower level of renewable energy required, resulting in lower overall costs.
- CO_2 emissions and imports are reduced by 7.6% and 4.3% respectively, illustrating the important synergies and co-benefits arising from the implementing efficiency and renewable energy policies together.

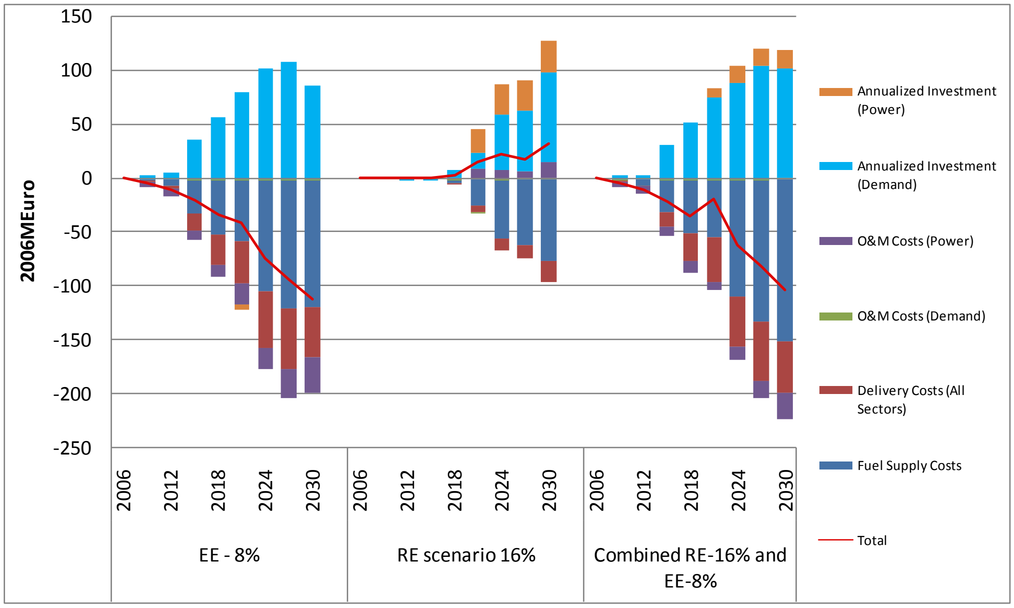
Table 8 shows the key result changes between the combined RE&EE scenario and the Reference scenario.

Table 8. Cumulative Impacts of Combined RE/EE Targets on the Energy System

Indicator	Units	Reference	EE&RE Targets	Change
Total Discounted Energy System Cost	2006M€	23,004	-317	1.38%
Primary Energy Supply	Ktoe	33,549	-1310	-3.90%
Imports	Ktoe	30,833	-1315	-4.26%
Fuel Expenditure	2006M€	6,564	-767	-11.69%
Power Plant New Capacity	MW	2,362	173	7.33%
Power Plant Investment Cost	2006M€	5,984	208	3.47%
Demand Technology Investments	2006M€	5,561	458	8.24%
Final Energy	Ktoe	18,874	-881	-4.67%
CO_2 Emissions	Kt	42,111	-3178	-7.55%

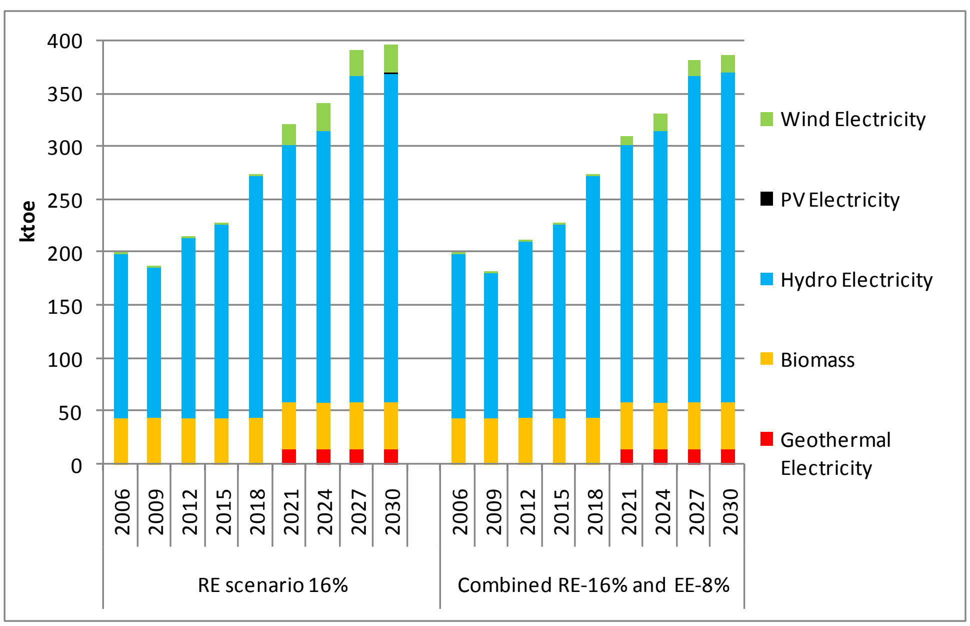
Figure 15 shows the change in annual energy system costs for the three policy scenarios relative to the Reference scenario. The bars show the increases (positive) and decreases (negative) in annual system cost components, and the change in net costs over time is shown as the red line. Overall, total system cost savings are achieved by increased upfront expenditures for renewable generation capacity and the additional costs of more energy efficient demand devices. These investments are more than offset by fuel savings (in light blue) in the two EE scenarios, reaching over 458€ million, or over 8%, in the combined scenario in a whole period.

Figure 15. Costs and Savings from Renewable and Energy Efficiency Policies



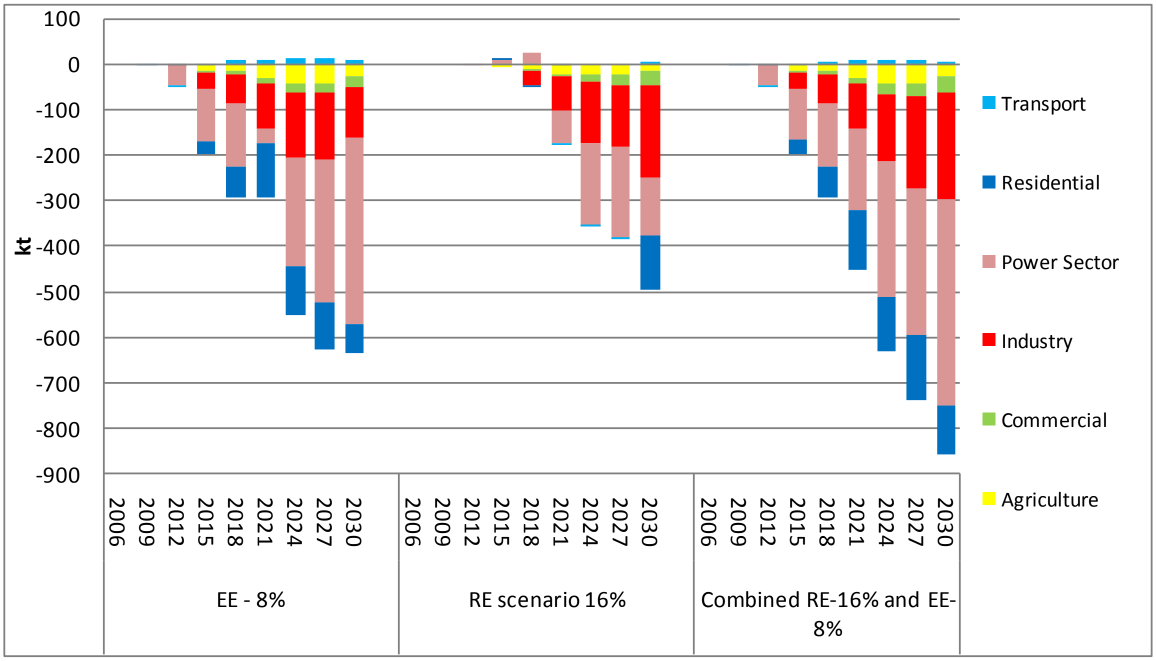
The combined scenario has only a modest impact on renewable generation builds compared to the RE target scenario, as illustrated in Figure 16 below. The implementation of energy efficiency measures reduces the amount of new wind capacity builds needed – the most expensive new capacity in the system – and the reduction of barriers to efficient device adoption allows the system to cost effectively reduce fossil consumption, reducing the total amount of additional renewable energy needed to meet the target.

Figure 16. Renewable Energy Consumption under RE and RE&EE Combined Cases



The important synergies arising from the combined policies are clear in Figure 17, which shows CO_2 emission reductions in the three policy scenarios. The combined policies yield significantly greater CO_2 emission reductions than either policy alone, at a net savings from the Reference scenario. The majority of the reductions occur in the industry and power sectors 14% and 34% respectively.

Figure 17. Sectoral CO_2 Emission Reductions under RE, EE, and RE&EE Combined Cases



G. ASSESSING NUCLEAR ALTERNATIVES IN ARMENIA

The focus of this sensitivity analysis is to look at what the Armenian system would look like in the absence of building a 1,000 MW nuclear plant as part of meeting the electricity-gas "swap" arrangement. That is, with less electric capacity and no "free" gas, what alternatives are there for Armenia, and at what cost?

There were four scenarios considered for this analysis as described below:

- Reference scenario – which is discussed in Section C and against which all comparisons are done.
- No Nuke scenario – where the current nuclear power plant closes in 2018, no new nuclear is built and the electricity-gas swap is absent.
- Optional Nuke (true least-cost) scenario – nuclear plant is not forced, but given as option from 2020 with maximum capacity of 1,000 MW and electricity-gas swap is absent.
- Georgian Electricity Imports – the possibility of importing electricity from Georgia by means of an Armenian dedicated hydro plant (400 MW plant able to come online in 2021) through a fixed contract arrangement, competing with the nuclear option but without the electricity-gas swap. The main results of the comparative analysis are given in the Table 9, and explored in the text and figures that follow.

The most important insights for an Armenia without the nuclear plant and electricity-gas swap agreement include:

- The overall system cost increases, but only by at most 1.56% (358€ million over the 20 year planning horizon).
- Less electricity exports lead to less thermal generation and reduction in natural gas consumption in the power sector.
- The possibility of increased electricity imports from Georgia further reduces the added costs to just 170€ million(though this scenario needs additional analysis with further investigation of investment costs (including transmission line), seasonality of electricity production, etc.).
- Alternatives to existing plans of 1,000 MW nuclear and the electricity-gas swap can lead to decrease in overall CO_2 emissions, ranging from 3.4% to 13.9%.

Table 9. Cumulative Comparative Impact of the Alternate Scenarios

Indicator	Units	Refer-ence	No Nuke		Nuke Optional		Georgian Electricity Imports	
			Change	%	Change	%	Change	%
Total Energy System Cost (Discounted)	M€2006	23,004	358	1.56%	347	1.51%	170	0.74%
Primary Energy Supply	Ktoe	33,549	-9,307	-27.7%	-8,857	-26.4%	-9,298	-27.7%
Imports	Ktoe	30,833	-8,788	-28.5%	-8,254	-26.8%	-9,379	-30.4%
Electricity exports	Ktoe	3,104	-2,962	-95.4%	-2,948	-95.0%	-2,746	-88.5%
Fuel Expenditure	M€2006	6,564	2,200	33.5%	2,051	31.2%	1,887	28.7%
Power Plant New Capacity	MW	2,362	-788	-33.4%	-813	-34.4%	-632	-26.8%
New Nuclear Capacity	MW	1,000	-1,000	-100%	-819	-82%	-1,000	-100%
Power Plant Investment Cost	M€2006	5,984	-4,596	-76.8%	-3,915	-65.4%	-4181	-69.9%
Final Energy	Ktoe	18,874	-10	-0.05%	-38	-0.2%	-67	-0.35%
CO_2 Emissions	Kt	42,111	-4,890	-3.38%	-5,710	-13.6%	-5,868	-13.9%

As a result of neither constructing the new nuclear plant nor continuing the electricity-gas swap (labeled No Nuke scenario), the total system cost increases, but only by 1.56% (358€ million). This is mainly due to an overall drop in imports by 28%, since there is no need for nuclear fuel after 2018 and a 13% drop in natural gas since it is no longer "free" or needed for generation electricity to support exports. As a result, fuel costs increase in all three scenarios, which is partly compensated by not incurring the cost of the new nuclear plant.

Electricity exports, according to the international swap agreement, mostly come from the nuclear plant, and in that case up to 96% of imported gas is received at no cost in 2021-2030. In the Reference needs to import only 0.09-0.8billion m3/year of gas from Russia in 2021-2030, but without the nuclear plant and associated swap gas, Russia is the only source and 2.1-2.82 billion m3/year needs to be imported at market value. Below are presented gas prices and electricity export prices according to swap (3kWh = 1cub. meter of natural gas).

Natural gas import price (€/1000 cub. m)*

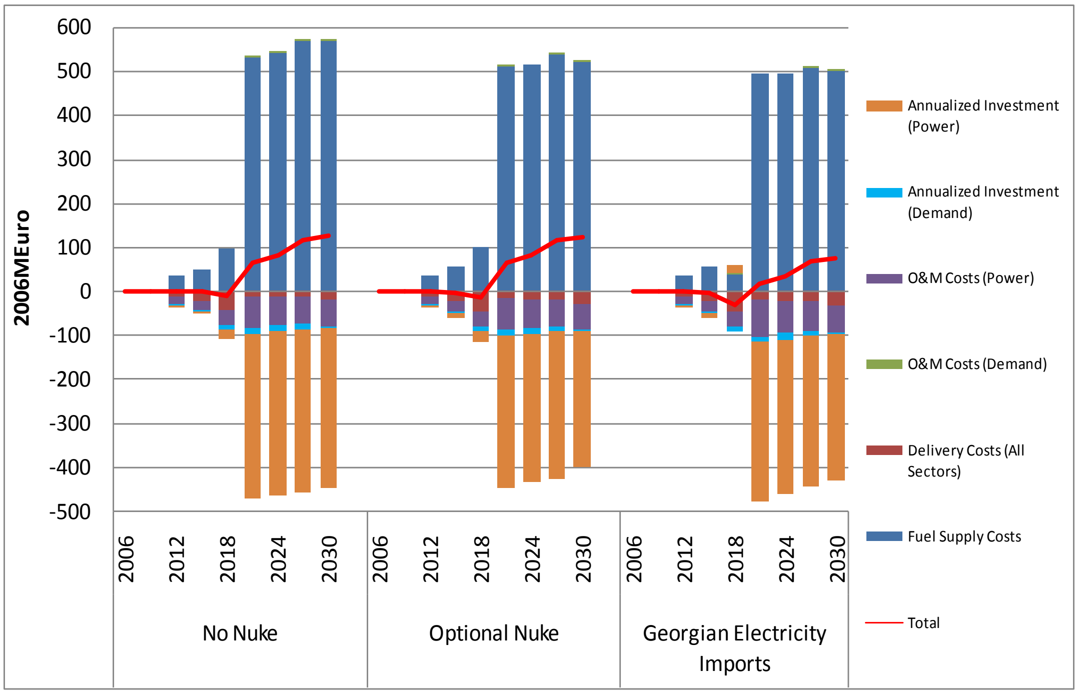
2012	2015	2018	2021	2024	2027	2030
223	239	246	253	261	271	282

Price for 1kWh exported electricity (€cent)

7.43	7.97	8.2	8.43	8.7	9.03	9.4

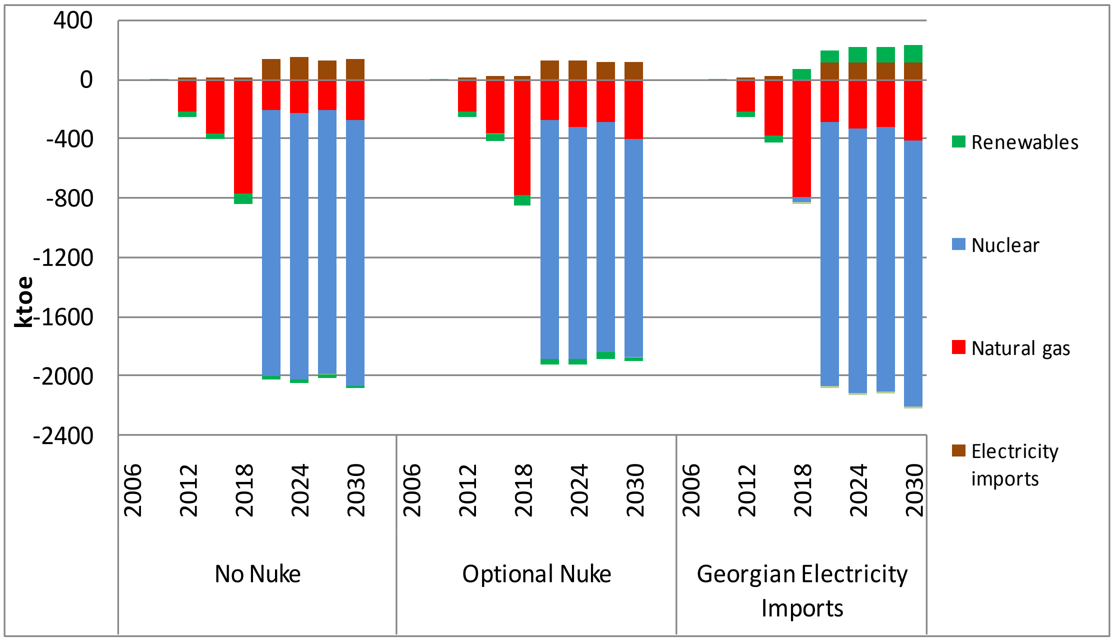
From 2021, when new nuclear plant would have comes online, the price for natural gas is so high that the swap is equivalent of selling the electricity at 8.2 €cents and higher. Since the cost of producing electricity is substantially below these export prices the total system cost for the Reference scenario is lower than when new nuclear plant and swap agreement are not considered. Figure 18 shows the changes in system expenditures and benefits compared to Reference scenario.

Figure 18. Costs and Savings Compared Against the Reference Scenario



The change of total primary energy compared with the Reference scenario is presented in Figure 19 below, which shows the substitution of imported electricity, which reaches over 1.8 billion kWh for gas. Final energy consumption remains at about the same level. It should be noted that the absence of 1,000 MW of forced nuclear capacity significantly reduces the total primary energy. In the case of Georgia, the share of renewables is greater compared with other scenarios, a result of the use of a Georgian hydro plant.

Figure 19. Change in Primary Energy



In the No Nuke case, electricity exports are regulated by the regional market prices and limited by transmission line capacity(not forced by agreements). Electricity exports decrease until 2018 and there are no exports after that. Under the Georgian scenario there are electricity exports (0.2-1.2 billion kWh). Because there is no need to export electricity and no gas available from the swap, production in gas-fired combined cycles also goes down by over 1 billion kWh.

Figure 20. Electric Generation Scenarios

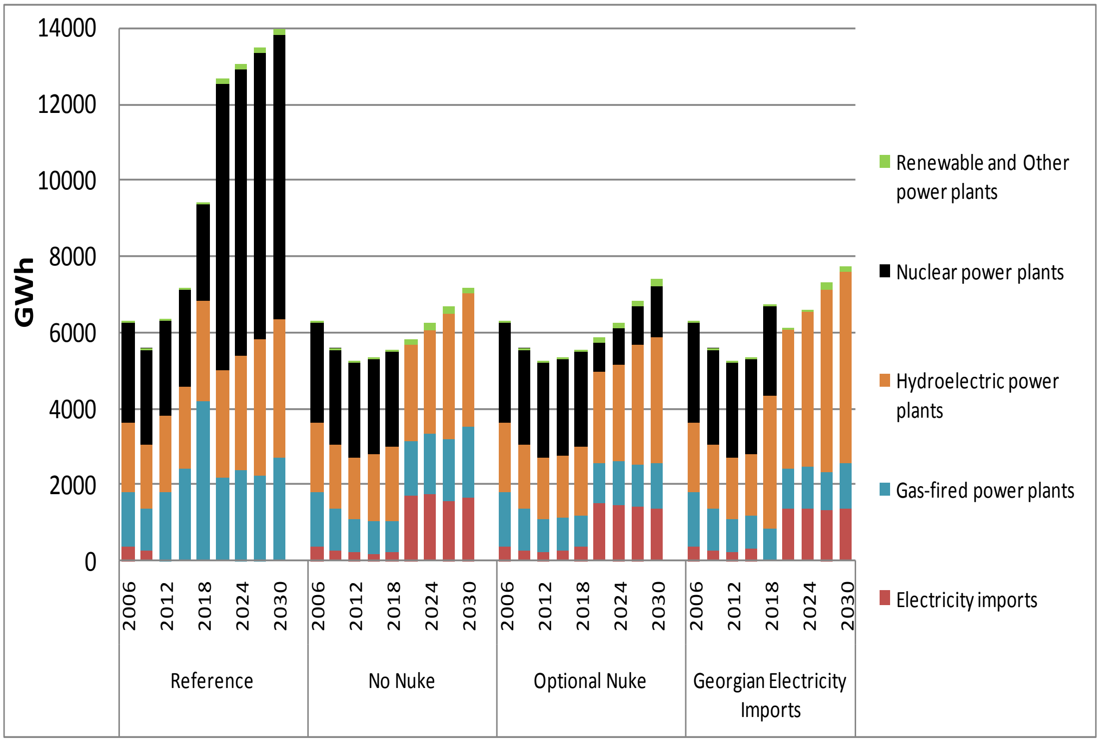
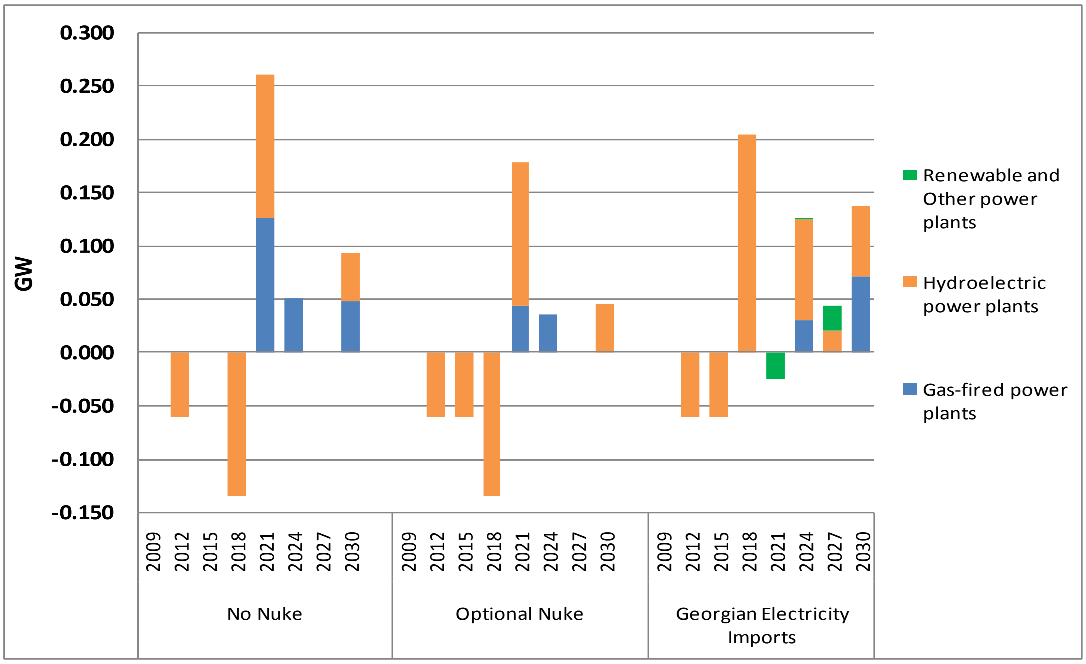


Figure 21 shows the change in construction of new power plants. There is an additional 230 MW in thermal capacity in the No Nuke compared to the Reference scenario to replace low efficiency thermal plants with more efficient ones. Hydro capacity is reduced by 15MW. In general, the No Nuke scenario has almost 800 MW less new power capacity than the Reference scenario and correspondingly less investment for power plants by 77%. When there is a possibility to construct a nuclear (Optional Nuke) the model adds (an implausible) 181 MW nuclear built - allowed simply to show that the 1,000 MW plant is really only warranted with robust export options available to Armenia. The Georgian Imports scenario has 265 MW additional hydro and 100 MW more thermal capacity than the Reference, but no nuclear is being constructed. In total, Georgian Imports has 632 MW less power plant capacity than the Reference scenario.

Figure 21. Change in New Power Plant Capacity[7]

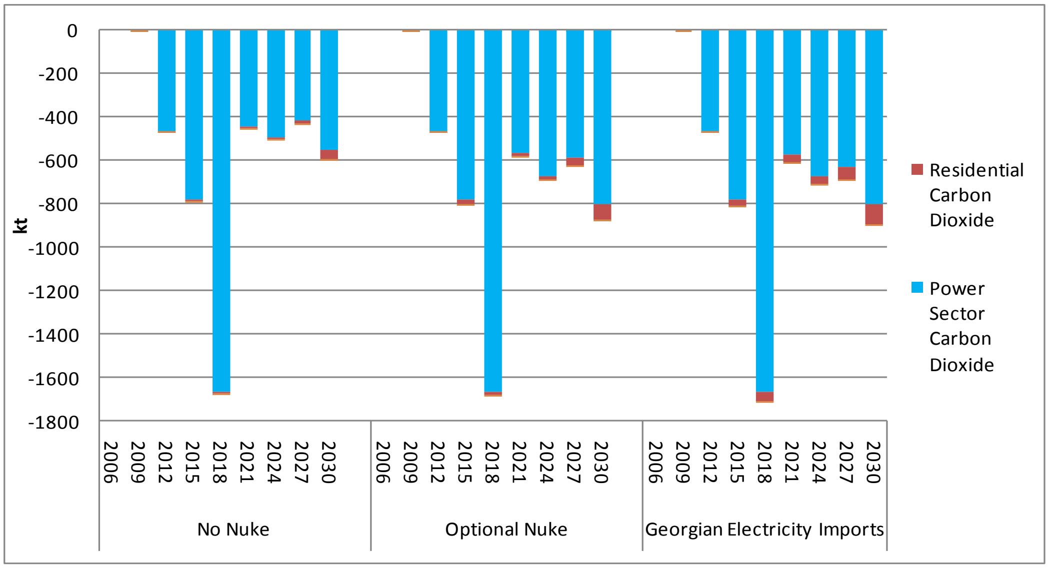


Change of CO_2 emissions is presented in Figure 22. Most reduction occurs in the power sector as a result of less thermal generation (since gas is now expensive and there are less exports).These reductions reach over 13% for the Optional Nuke and Georgian Imports scenarios.

Another analysis of the nuclear option was done, where 1GW new nuclear is forced to be built in 2021, but electricity-gas swap is absence. In this case total system cost increase by 3.43% (788M€). While some of this increase is due to no cheap gas source, it is also due to electricity being exported at a much lower price than under the swap agreement. However, this exporting is not uniform year round (most occurring in the Spring when there is lots of hydro from neighboring countries), which should be the case for a baseload nuclear plant. Refining the analysis to better consider the actual potential and timing regional electricity trade using the extra generation is thus important, as even this first look makes it clear that building the 1GW nuclear plant is only viable if there is a corresponding major export market. Additional possibility for export decreases the overall system cost by the export revenues, if the demand is there.

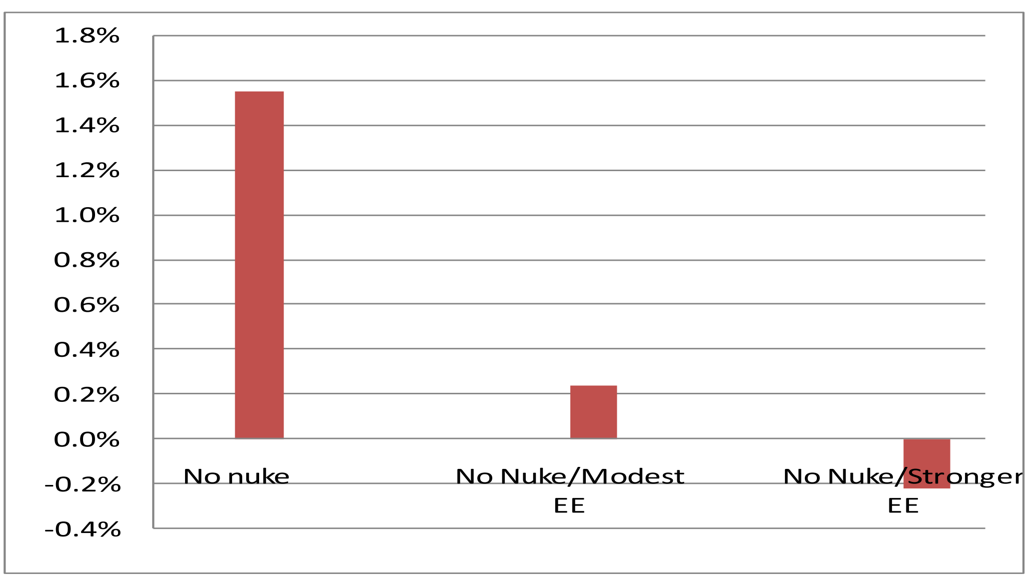
[7] Not shown is the drop in nuclear, which is the full 1,000MW for No Nuke and Georgian Hydro, and 820MW in the Optional Nuke case where an "indicative" 180MW nuclear plant is called for.

Figure 22. Change in Carbon Dioxide Emissions



There is another mechanism available to Armenian decision-makers to compensate if the nuclear plant is not built and the electricity-gas swap ends. Energy Efficiency measures that are economically attractive (that is, where policies and programs lower barriers to the adoption of improved devices, but no energy savings target is imposed) can achieve up to 7.4% decrease of electricity consumption in 2021 and 10.8% in 2030 (total consumption reduction of 3.9% in 2021 and 4.4% in 2030) compared to the No Nuke scenario. This results in a decrease in the overall system cost of 1.3%; thus, it is almost the same as the Reference scenario level (just 0.24% difference). Stronger measures can result in a 8.4% decrease of electricity consumption in 2021 and 13.9% in 2030 (total consumption reduction of 1.6% in 2021 and 4.5% in 2030) compared to the No Nuke Scenario. This results in a decrease in the overall system cost for this scenario by 1.75% (actually saving -0.22% or 50€ million against the Reference case). Figure 23 shows the difference of the system cost against the Reference case.

Figure 23. Change in Total System Cost Compared to Reference



APPENDIX I: DATA SOURCES AND KEY ASSUMPTIONS

The Armenia analysis is based on numerous data inputs and assumptions, and therefore requires a set of key national data sources. The sources of this information are listed by data requirement in Table 10 below.

Table 10. Key Data Sources

Data Requirement	Source
2006 Energy Balance	Second National Communication on Climate Change (SNCCC), International Energy Agency (IEA), ArmRusGasProm (ARG), Customs Service of Armenia (Customs)
Domestic Energy Prices	Public Services Regulatory Commission of RA (PSRC)
Resource Potential, including imports/exports	Ministry of Energy and Natural Resources of RA (Minenergy), Scientific Research Institute of Energy (SRIE)
Installed capacity and characterization of existing electricity, heating and CHP plants	Minenergy, SRIE, Power System Operator (Operator)
Electricity generation by plant (type)	PSRC
Timing of demands for energy services	According to analysis of annual load curve for 2006 and RESMD
Fuel consumption patterns by energy service	National Statistical Services of RA (ArmStat), Minenergy, ARG, SRIE
Demand Drivers	National Statistical Services of RA (ArmStat), Minenergy, SRIE
Known energy policies	Energy Sector Development Strategies in the Context of Economic Development in Armenia, Armenian Ministry of Energy Action Program according to the National Security Strategy, National Program on Energy Saving and Renewable Energy of Republic of Armenia

Drawing on these data sources provisions the resulting model is reasonably strong. However, there are some specific areas where data availability and quality could be further improved, either through better coordination with statistical agencies or based on further research.

The Planning Team has ensured (to the extent possible) that current or planned policy is reflected in the Reference scenario (e.g. Feed-in tariffs for renewable energy, natural gas import policy, CO_2 taxes). They have also consulted with different sector experts to ensure that the Reference scenario in the model is reasonable, and does not diverge significantly from other analyses undertaken e.g. for the Energy Strategy, Renewable Energy Strategy, or Energy Efficiency Strategy.

A set of key assumptions provide the basis for developing the Reference case, which properly reflects the situation in Armenia (see Tables 11to 13 below).

Table 11. Key Assumptions in the Reference Scenario: Power Sector - Hydro

A. Plant Performance Data

Power sector - Hydro	Technology performance									
	Available from (in model)	Life	Installed or Available Capacity	Efficiency	Seasonal Load Factor				Annual Load Factor	Contribution to peak
					Winter	Spring	Summer	Autumn		
		Years	MW	%	Fraction				Fraction	Fraction
Existing plant										
Sevan-Hrazdan HPP cascade	2006	30	556	-	0.060	0.240	0.100	0.030	0.12	1
Vorotan HPP cascade	2006	30	404	-	0.220	0.330	0.300	0.300	0.29	1
Existing plant - Small HPPs	2006	30	115	-	0.160	0.350	0.150	0.190	0.23	1
New build				-						
Meghri HPP	2027	90	140	-	0.23	0.56	0.27	0.28	0.652	0.8
Loriberd HPP	2018	90	60	-	0.23	0.56	0.27	0.28	0.381	0.8
Shnokh HPP	2018	90	75	-	0.23	0.56	0.27	0.28	0.457	0.8
New build - Small HPPs	2012	90	375	-	0.23	0.56	0.27	0.28	0.419	0.8

B. Plant Cost Data

Technology costs

	Investment	Full project cost	Fixed O&M	Var. O&M
	€/kW	€ million	€/kW	€ cent/kWh
New build				
Meghri HPP	1593	223	28.32	0.57
Loriberd HPP	1239	74	28.32	0.4
Shnokh HPP	1549	116	28.32	0.4
New build - Small HPPs	1115	418	59	0.2

Table 12. Key Assumptions in the Reference Scenario: Power Sector – Other

Power sector - Other	Technology performance						Technology costs			
	Available from (in model)	Life	Installed or Available Capacity	Efficiency	Annual Load Factor	Contribution to peak	Investment	Full project cost	Fixed O&M	Var. O&M
		Years	MW	%	Fraction	Fraction	€/kW	€ million	€/kW	€ cent/kWh
Hrazdan TPP	2006	25	700	30.5	0.12	0.94	-	-	-	-
Armenian NPP	2006	15	395	33	0.74	0.8	-	-	-	-
Lori Wind Farm	2006	25	2.6	-	0.16	0.15	-	-	-	-
New NPP	2021	40	1000	33	0.856	0.8	4755	4755	42.5	0.98
Hrazdan new block	2012	35	445	40	0.909	0.94	800	356	30	1.53
Erevan new block	2012	35	242	42	0.909	0.94	324	78.408	30	1.53
Zod Wind Farm	2015	30	70	-	0.346	0.15	1440	100.8	40	-
Karakhach Wind Farm	2015	30	210	-	0.444	0.15	1440	302.4	40	-
Geothermal (decentralised)	2020	30	25	-	0.74	1	2400	60	184	1.2
Solar PV (centralised)	2012	30	2	-	0.1	0.1	4000	8	29	-

Table 13. Key Assumptions in the Reference Scenario: Energy Prices / Infrastructure

Import Commodity Price Assumptions	Units	2006	2009	2012	2015	2018	2021	2024	2027	2030
Russian gas	€2006M/PJ	4.75	5.94	6.66	7.14	7.34	7.55	7.79	8.09	8.42
Uranium	€2006M/PJ	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Gasoline	€2006M/PJ	11.82	9.87	12.31	15.36	16.88	18.29	19.27	20.25	21.24
Coal	€2006M/PJ	1.62	2.51	2.52	2.52	2.65	2.75	2.81	2.86	2.9

Other key assumptions

	Units	2006	2009	2012	2015	2018	2021	2024	2027	2030
Electricity system										
Transmission losses	%	3.00%	2.85%	2.09%	1.33%	1.25%	1.16%	1.16%	1.16%	1.16%
Distribution losses	%	19.84%	19.00%	18.16%	17.32%	16.48%	15.64%	14.80%	13.96%	13.12%
Gas Transmission/Distribution										
Losses	%					7.61				
Transmission investment	m€/PJ/a					1000				

The primary data for technologies used in the non-transport end use sectors draws on the technology characterizations employed in the EU NEEDS model. This is a pan-European MARKAL/TIMES model that has evolved into a standard planning framework for numerous EU countries, as well as the EU Joint Research Centre, and used for key EU policy analysis (such as RES2020 examining the RES directive http://www.res2020.eu/).

Technology characterizations depict the current typical technology available in 2009, and then assumptions are made that reflect the cost and performance improvement of more efficient alternatives. There are more than 300 instances of these core technologies, and then up to three levels of improved devices available to the analyst to include in their model. The cost (M€/PJa) and performance characteristics for a subset of the key base devices are shown in Table 14.

Table 14. Characterization of Key Base Demand Devices

Energy Service Demand	Demand Device	Investment Cost (€/GJ)	Efficiency (Fraction)
Commercial cooling	Central air conditioning	2.90	3.00
	Air heat pump	6.70	4.40
	Split air conditioner	4.20	3.60
Commercial lighting	Incandescent bulbs	5.35	1.00
	Halogen lamps	32.11	2.00
	Fluorescent lamps	21.41	4.00
Commercial space heating	Electric furnace	7.45	0.85
	Gas furnace	8.71	0.76
Commercial water heating	Electric water heater	10.70	0.90
	Gas water heater	21.41	0.70
	LPG water heater	21.41	0.70
Iron & Steel High temperature heat	High temperature heat (Gas)	21.41	0.72
Iron & Steel Mechanical drive	Motor drive (Electricity)	5.35	0.85
Iron & Steel Low temperature heat	Low temperature heat	10.7	0.75
Residential space heating	Electric Furnace	5.14	0.86
	Gas Furnace	5.22	0.70
	Thermal insulation improvement	116.10	1.00
Residential cooling	Ground source heat pump	1.651	2.55
	Solar heat pump	3.302	0.64
	Air source heat pump	1.056	2.00
Residential lighting	Incandescent bulbs	128.4	1.00
	Halogen	160.5	2.80
	CFL	139.1	4.60
Residential hot water	Electric water heater	10.7	0.90
	Gas	21.41	0.70

The characterization of the improved devices varies by end-use, but in general, for a series of efficiency improvements by, for example 20/30/505%, the base purchase price may increase a corresponding 0.74/1.34/2 times. All these assumptions may be adjusted for national circumstances, though most use this standard approach as described.

Due to the unavailability of process-level data on Armenian industry, an approach that calibrates fuel consumption to the current energy intensity of each industrial demand is used to depict the current situation. Then up to three options with incremental price/performance improvements in the future is used to represent the generic alternatives available in each industry.

The transport sector is a key new sector added to the model in the last six months. It uses data from a range of sources, summarized below.

- Default values for new vehicle efficiencies and activity data are taken from a study funded by the European Commission called *EU Transport GHG: Routes to 2050 project*, which can be found at http://www.eutransportghg2050.eu. The data values are taken from the project's Sultan Tool (see Table 15) but adjusted to take account of country specific data / assumptions
- Information on the relative efficiencies across different types of LDVs and the difference in costs (now and in future years) is based on information from the Annual Energy Outlook (AEO) 2011.[8] Only the relative efficiency numbers are used and applied to information from the Sultan Tool mentioned above. Relative cost values are applied to user-provided information on standard gasoline/diesel vehicles.
- Marine and aviation estimates are from the best available data from the United States (US)/United Kingdom (UK) National MARKAL models. This approach is satisfactory as these subsectors in the model are not subject to technology choice.

[8] AEO refers to Annual Energy Outlook. This is an annual publication focusing on energy projections prepared by the US Energy Information Association (EIA). For more information, go to http://www.eia.gov/analysis/

Table 15. Sultan Tool Values on Vehicle Efficiencies, Payloads, and Annual Activity

Vehicle type		Fuel	Efficiency		Payload	Activity	
			mvkm/PJ	mpkm OR mtkm/PJ	Persons/ tonnes	km per yr	pkm / tkm per yr
Buses		DST	110	1659	15.05	43817	659331
		ELC	330	4968	15.05	43817	659331
Cars		GSL	428	700	1.64	13189	21573
		DST	449	735	1.64	13189	21573
		LPG	427	698	1.64	13189	21573
Motorcycles		GSL	984	1078	1.10	5664	6209
Heavy trucks		DSL	91	781	8.54	49201	420233
		CNG	69	588	8.54	49201	420233
Medium trucks		DSL	204	328	1.61	15992	25674
Rail Pass.		DSL	20	2453	124.61		
		ELC	32	3949	124.61		
Rail Freight		DSL	14	5431	392.98		
		ELC	22	8721	392.98		

Figure 24. LDV Efficiency by Type in Armenia MARKAL Model

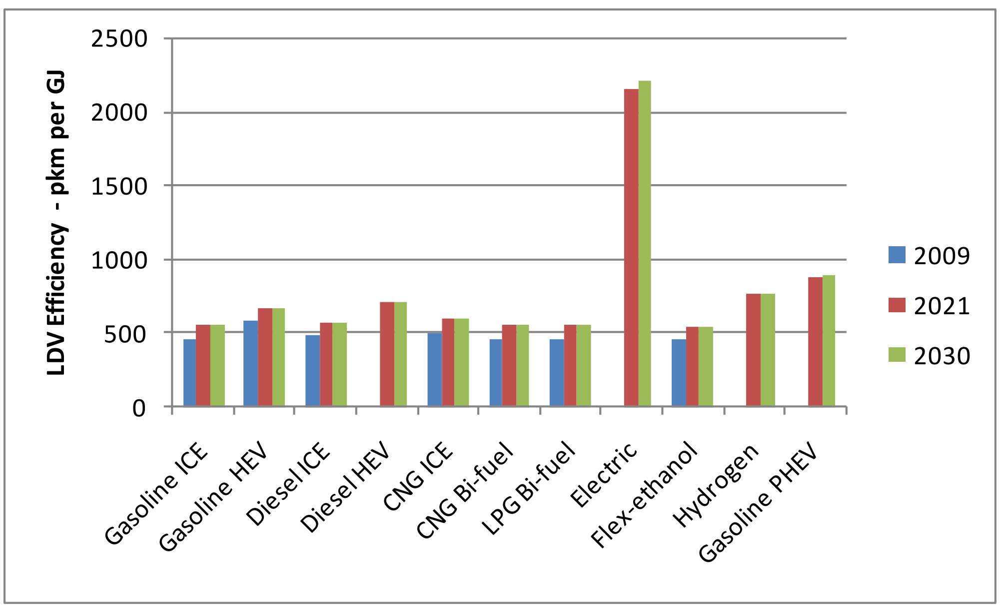
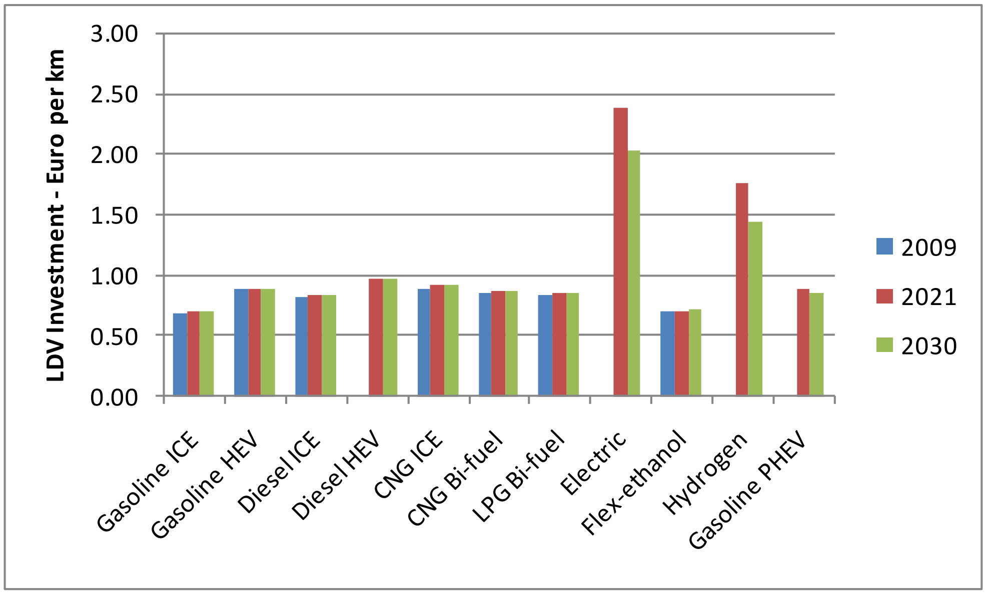


Figure 25. LDV Investment by Type in Armenia MARKAL Model



For 2006, the transport sector is calibrated to the national energy balance. The transport sector energy totals have been disaggregated using Armenian statistics and other information sources, such as those provided by the OECD.

Transport demands use the same core drivers that are used in other sectors, namely annual GDP growth rates and population growth. Different transport subsectors are subject to different projections approaches. LDVs and two-wheelers use a vehicle ownership – GDP per capita relationships, with elasticity factors (from IEA) that capture the strength of the relationship based on different income bands. Other freight-based subsectors use a more simple approach based on GDP growth rates. All derived drivers are based on information from IEA.

APPENDIX II: A CLOSER LOOK AT MODELING ENERGY EFFICIENCY POLICIES AND MEASURES

As MARKAL/TIMES is a least-cost optimization modeling framework, it evaluates competing alternatives within an energy system based strictly on lifecycle costs, within other constraints imposed on the model. The lifecycle costs are the purchase price + operating costs + payments for fuel spread over the entire operational lifetime of the device. This approach tends to favor energy efficient devices because the fuel savings accrued over the lifetime will be greater than the costs associated with the investment and operation of the device. However, in reality, consumers do not necessarily evaluate purchasing on this basis. Decisions may be impacted by a range of factors which act as barriers to investment in EE devices including:

- Risks and uncertainty around new technologies (perhaps due to lack of information)
- High transaction costs (affecting the ease of choice)
- Problems accessing capital (as EE devices often have higher purchase prices)
- Other costs not included or missed in typical economic analysis (known in the literature as hidden and missing costs)
- Consumer inertia (perhaps due to non-economic factors, e.g. stick with what you own (even if past performance lifetime), buy only what you know, style)
- Longer pay-back periods undermining the attractiveness of making the alternative investment with higher upfront cost

These factors often lead to energy efficient appliances being overlooked even though under strict economic principles, they should be selected. Such barriers to uptake are widely acknowledged in the field of energy efficiency research.

To deal with this "behavior" within a MARKAL/TIMES model, there are basically two main options: 1) impose firm upper limits on the rate of uptake of new devices or 2) use sector/technology-specific discount rates (so-called "hurdle" rates) to take account of barriers that prevent these investments from happening. This second approach enables some aspects of consumer behavior that typically may be characterized as economically irrational (in a perfectly competitive market) to be reflected in the model. The additional costs associated with overcoming the above barriers could be seen as representing the cost of policies and programs that might be associated with overcoming such barriers (e.g. labeling, information campaigns, appliance/building standards).

The first approach (*firm constraints)*, used previously for the RESMD EE analysis, has the disadvantage of underestimating the costs of EE (which was a criticism of the earlier work) and tends to be an all-or-nothing choice by the model. In addition, it is difficult to use in association with an EE target.

The second approach (*flexible constraints)* is considered a less rigid, more flexible approach as the model is free to find the cost-effective penetration level for the EE devices, taking into consideration these extra costs (but with no firm limits as per the first approach). The difficulty with it is that there is only limited empirical evidence on what the "hurdle" rates should be for each technology, though research in the United States (US) and United Kingdom(UK) point to a 15-25% premium.

The set-up of these different approaches for the baseline run and energy efficiency policy run are summarized in the table below.

Scenario / Approach	Previous approach – "firm constraints"	Revised approach – "flexible constraints"
Baseline	In general, energy efficiency devices are restricted to 10% uptake as a share of a given technology category.	Energy efficiency uptake is calibrated to the levels seen under the "firm constraints" approach – but using hurdle rates not firm constraints.
Energy efficiency	The constraints were relaxed to 50% (or whatever a country thought was appropriate) of new devices purchases in 2030 to determine the economically efficient uptake. The approach was used to demonstrate the impact of energy efficient devices but was not policy driven targets. It did not capture the additional costs associated with energy efficiency devices (as reflected in the hurdle rates).	Two mechanisms are applied to the baseline – an energy efficiency target was introduced and hurdle rates were reduced to a level based on an empirical basis. The big advantage of this approach is that it is target based (so policy relevant) and reflects much of the costs associated with implementing energy efficiency measures.

The sections below describe in greater detail how to implement the revised approach, where "hurdle" rates are used to keep the EE devices out of the Reference scenario (for the most part), based upon the assumption that without policies and programs people will tend to buy what they know and what has the lowest upfront cost.

CALIBRATING NEW DEMAND DEVICE UPTAKE IN THE REFERENCE SCENARIO

As summarized in the table above, an approach has been established that uses hurdle rates (technology specific discount rates) to control new technology uptake. The benefit of such an approach is that alternative scenarios (e.g., consumption reduction targets) can be explored without the requirement to adjust constraints that impose hard bounds (limits) on the rate of penetration of advanced technologies, because now their uptake is limited on the basis of cost rather than using fixed limits.

The calibration process for various RESMD models uses hurdle rates in the 20-40% range to achieve the dampening of the new device updates to the original Reference scenario level. This reflects the fact that in the absence of policy it is highly unlikely that (most) people will recognize the cost savings over the lifetime of an advanced improved device and overcome the higher upfront cost. Then, as EE policies and programs incentivize uptake, these hurdle rates are reduced. Under the EE target case, hurdle rates are reduced to the range of 10-20%, reflecting the impact of policies (e.g., appliance standard – that eliminates inefficient options from the market place) and programs (e.g., low interest loans for building shell improvements and the purchase of efficient appliances).

CONDUCTING EE ANALYSIS

Empirical evidence in the UK/US literature indicates that there is a required rate of return perceived by consumers for EE measures of between 15-25%. These hurdle rates can be reduced by incentives, programs, and campaigns (such as those called for in NEEAPs) to reduce the barriers seen by consumers. Thus rates in the range of 10-20%, reflecting low interest loans or simply the cost of credit card purchase for the high efficiency devices are reflective of the environment under such policies.

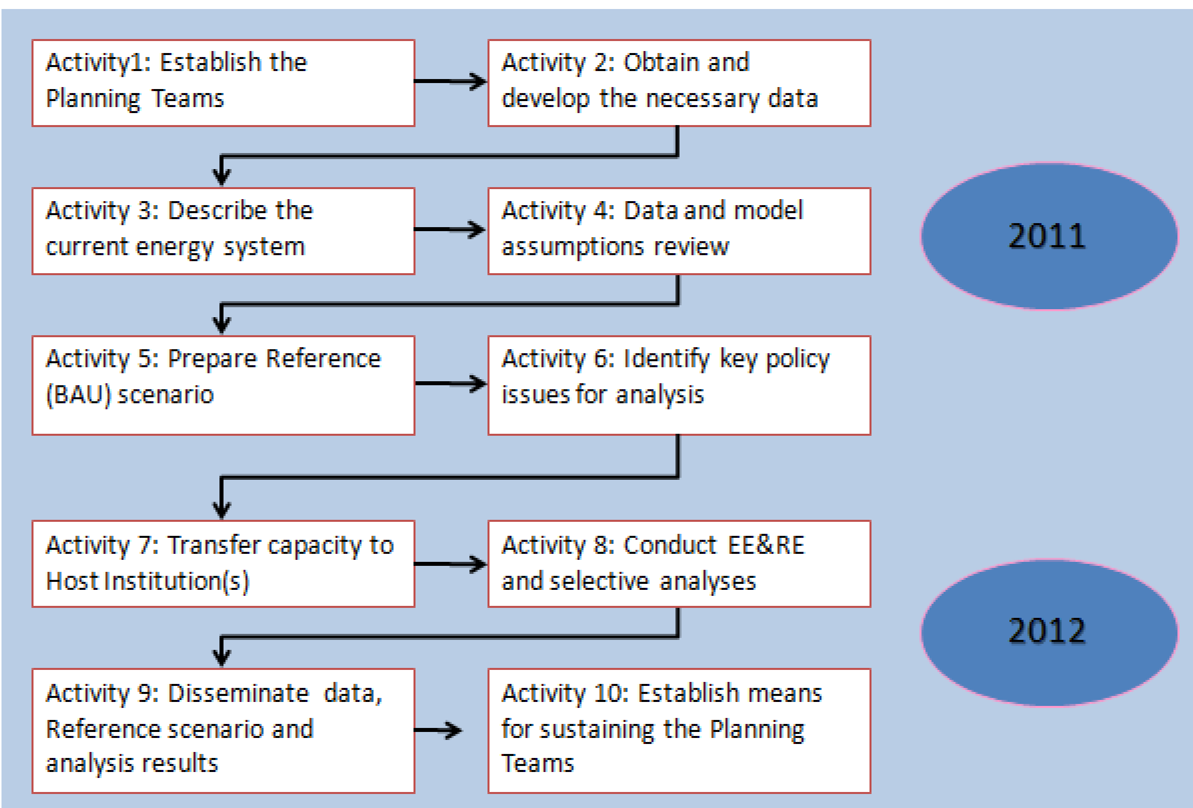
APPENDIX III: PROJECT ACTIVITIES AND METHODOLOGY EMPLOYED

MAJOR PROJECT ACTIVITIES

The consultant teams for International Resource Group (IRG) and the Centre for Renewable Energy Sources (CRES) worked with key personnel from the Scientific Research Institute of Energy, with the support of Georgian Expert and coordinated by Ministry of Energy and Natural Resources to establish a credible MARKAL-Armenia model, and guide this Planning Team's use of the model to assess and analyze several policy alternatives aimed at improving energy efficiency and increasing the use of renewable energy resources.

Over the course of two years, the joint SYNENERGY Strategic Planning (SSP) effort undertaken by the US Agency for International Development (USAID) and Greece Hellenic Aid was able to introduce new methods, implement these methods and transfer the capabilities to the national counterparts in a sustainable manner (see Figure 25). The figure shows that data development and team building came first, taking much of Year One to arrive at an accurate quantitative description of the country's current energy system, and identify the options available for consideration over the next 20 years. For the Planning Teams that were involved in the precursor to SYNENERGY Activities, the USAID-sponsored Regional Energy Demand Planning (REDP) undertaking, Activities 1 - 5 were replaced by improvements to their initial models built and updating of their Reference Scenario, along with supplemental training for new members of those Planning Teams.

Figure 26.Sequence of Project Activities



Once the data and information systems were established it was possible to reproduce a valid energy balance for each of the countries. These energy balances, relying on best available information and a consistent management framework, provide the foundation for useful policy analysis and assessment.

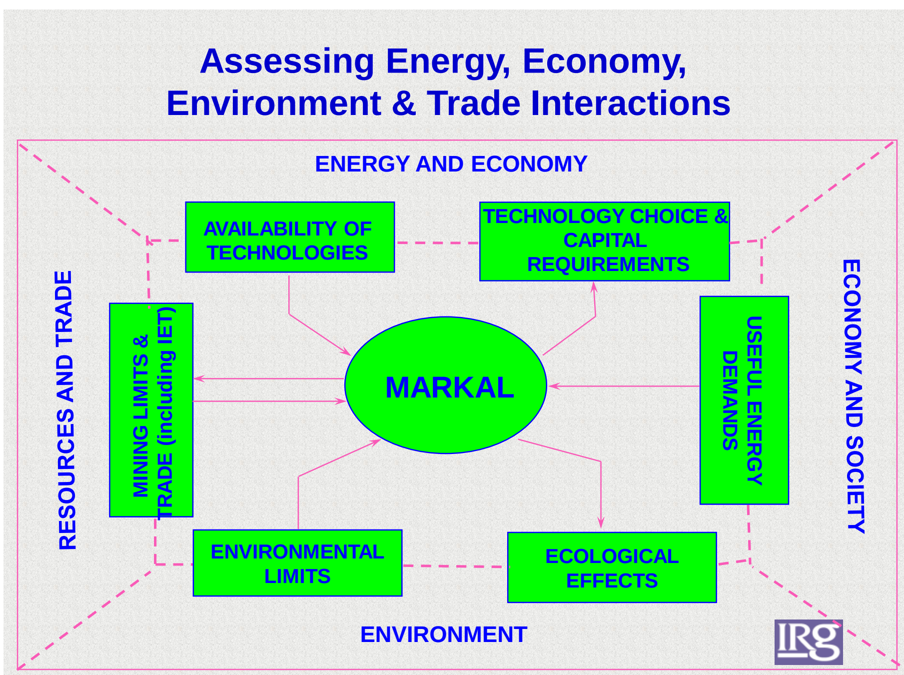
At least as important as the energy balances themselves, and the accompanying information systems, is the process of building a team of professionals in each country who can work with the data, maintain the information systems, and support higher level analytical approaches. This team-building should be considered a major benefit of the project for the region. However, to date, only a couple of the countries have moved actively on Activity 10 and looked to established means for sustaining the Planning Teams, so this will be more actively pursued in the next phase of the project.

METHODOLOGY EMPLOYED

Patterned after successful efforts in other countries, this project has transferred significant energy system modeling and analytical capabilities, along with a practical approach to decision support. Such capabilities are focused on the use of a consistent framework for analysis and assessment, the MARKAL/TIMES model, making collaborative efforts among the participating countries simpler and more transparent.

The MARKAL/TIMES model produces robust, scenario-based projections of a country's energy balance, fuel mix, and expenditures required for the energy system over time. The model relates economic growth to the necessary resources, trade and investments, incorporating a nation's environmental standards (or goals), depicting the least-cost energy future (see Figure 26).

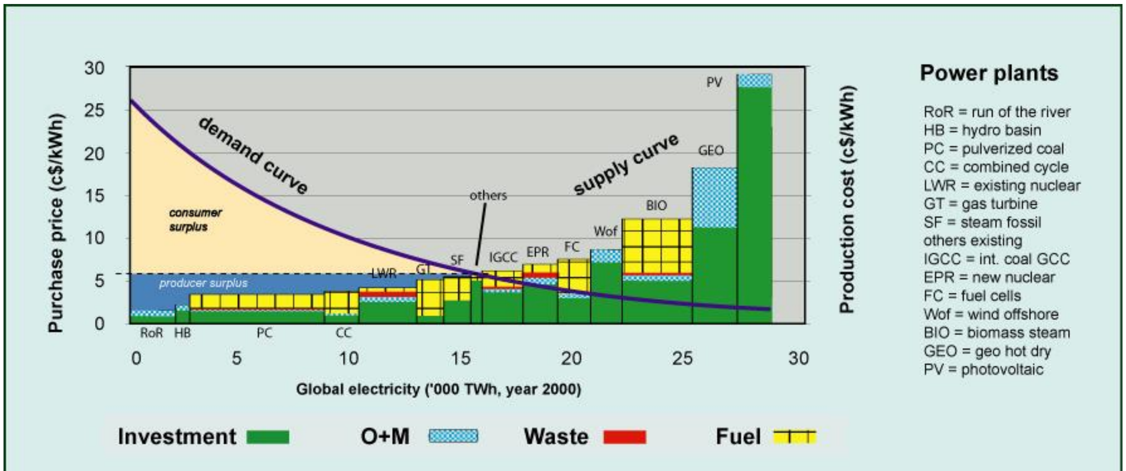
Figure 27. Interactions in the MARKAL/TIMES Model



The MARKAL/TIMES model simulates energy consumption and investment/supply decisions on the basis of a simple calculus of costs and benefits. Producers will supply the market as long as consumers will pay a price equal to or greater than the cost of supply. The model performs this calculation simultaneously for each energy form and all the energy service demands, solving for the least cost solution for the energy required to support economic growth.

In the example below (Figure 27) the model meets electricity demand by first dispatching run-of-river (RoR) hydro plants, then pumped hydro (HB), next pulverized coal (PC), then combined cycle (CC), nuclear (LWR), gas turbines (GT), and finally steam fossil (SF) up to a price of $.06/kWh. If more electricity needs to be delivered, the model will turn to more expensive types of power plants, but at some point the consumer will switch to some other fuel (e.g., gas for space heating) rather than pay more for electricity. This basic principle is applied across the board to ensure that the least-cost deployment of technologies and consumption of fuels is realized, within the constraints imposed on the model. A fuller description of MARKAL/TIMES and its use internationally may be found at www.etsap.org.

Figure 28. Power Plant Dispatch in the MARKAL/TIMES Model



Typical representation of an energy commodity in MARKAL - TIMES.
The algorithm maximises the global surplus over thousands such markets.

One of the most relevant suite of studies conducted recently is that sponsored by the European Union that employ MARKAL/TIMES to represent the pan-European energy picture as a closely tied integration of the national energy systems. The initial incarnation of this was realized as part of the New Energy Externalities Developments for Sustainability (NEEDS)[9] undertaking. The Pan-European TIMES model (PET)[10]evolved from the original NEEDS model and has been employed for series of high profile EU projects, including RES2020[11]examining the EU renewables directive,[12] REALISEGRID[13] looking to promote the optimal development of the European national transmission grid infrastructure, and the Risk of Energy Availability: Common Corridors for Europe Supply Security (REACCESS).[14] Another pair of high-profile uses of MARKAL/TIMES is the IEA Energy Technology Perspectives[15] and UK Climate Change Policy "White Paper."[16]

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[9]http://www.isis-it.net/needs/

[10]http://www.res2020.eu/files/fs_inferior01_h_files/pdf/deliver/The_PET_model_For_RES2020-110209.pdf

[11]http://www.res20202.eu

[12]http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2009:140:0016:0062:EN:PDF

[13]http://realisegrid.rse-web.it/

[14]http://reaccess.epu.ntua.gr/TheProject/ProjectObjectives.aspx

[15]http://www.iea.org/techno/etp/index.asp.

[16]http://www.ukerc.ac.uk/ResearchProgrammes/EnergySystemsandModelling/ESM.aspx.

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