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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 MEMMBER AND OBSERVER COUNTRIES:

GEORGIA POLICY BRIEF

July 2012
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by World Experience for Georgia (WEG) and International Resources Group (IRG).

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ACRONYMS

AEO	Annual Energy Outlook
BAU	Business as Usual
CC	Combined cycle
CNG	Compressed Natural Gas
EC	Energy Community
ECS	Energy Community Secretariat
EE	Energy Efficiency
EIA	Energy Information Association (US)
ESD	Energy Services Directive
ESEC	Energy Strategy of the Energy Community
EU	European Union
GDP	Gross Domestic Product
GEOSTAT	National Statistics office of Georgia
GFEC	Gross Final Energy Consumption
GNEWRC	Georgian National Energy and Water Supply Regulatory Commission
GSE	Georgian State Electric Systems
GT	Gas turbines
HGVs	Heavy Goods Vehicles
ICE	Internal combustion engine
IRG	International Resources Group
LCVs	Light Commercial Vehicles
LDVs	Light Duty Vehicles
LPG	Liquid Petroleum Gas
MARKAL	MARKet ALlocation
MENR	Ministry of Energy and Natural Resources of Georgia
MESD	Ministry of Economy and Sustainable Development of Georgia
NBG	National Bank of Georgia
NEEAP	National Energy Efficiency Action Plan
NEEDS	New Energy Externalities Developments for Sustainability
NPV	Net Present Value
O&M	Operation and maintenance
PC	Pulverized coal
RE	Renewable Energy
REDP	Regional Energy Demand Planning
RESMD	Regional Energy Security and Market Development
RoR	Run-of-river

SF	Steam fossil
SSP	SYNENERGY Strategic Planning
UK	United Kingdom
US	United States
USAID	US Agency for International Development
WEG	World Experience Georgia

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 groundbreaking 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 Georgian Planning Team using their national MARKAL (MARKet ALlocation) integrated energy system model, MARKAL-Georgia, to examine the role of energy efficiency (EE) and renewable energy (RE) in meeting future energy requirements through 2030 to support sustained economic growth while considering anticipated Energy Community (EC) commitments and European Union (EU) accession directives.

This is a revised version of a previous Policy Brief drafted during the summer of 2011. This revision has been undertaken based on a range of model improvements including the inclusion in the model of transport/refining sectors, more detailed projections of economic growth by sectors, a review of key electricity sector assumptions, updated fuel prices, and improved emissions accounting, along with a more advanced approach to representing electricity export-import and conducting the energy efficiency analysis. The Reference scenario took into consideration ongoing construction of power plants and expected schedules of their commissioning.

The analysis reflects several years of model development and use, jointly undertaken by the Georgian Ministry of Energy and Natural Resources (MENR) and World Experience for Georgia (WEG), supported by International Resources Group (IRG). The MARKAL-Georgia analysis undertaken uses a cross-sectoral, least 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 energy demand throughout 2030. It also examines the effects of potential energy efficiency and renewable energy targets in Georgia, as an Observer party to the Athens Treaty establishing the Energy Community. It also considers how meeting the targets impacts key issues facing energy sector decision-makers – namely, how to foster energy security and diversification, and ensure competitiveness and affordability, while taking into consideration climate mitigation and other environmental issues, as part of promoting cost-effectiveness in energy planning.

The following supply and demand analyses have therefore been undertaken.

- Reference (or Business-as-Usual (BAU)) Development: The likely 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. The 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 reduce final energy consumption. The EE scenario is fully discussed in Section D. The scenario assumes policies that reduce impediments to the uptake of energy efficiency are in place as well as a target aimed at reducing consumption that is in line with the Energy Community goals for Contracting Parties as illustrative of what may be asked of Georgia in the future.

- Renewable Energy (RE) Target: This supply-side policy examines the requirements to successfully achieve a renewable energy target by 2020 (in line with that proposed by the Energy Community) 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**Error! Reference source not found.**.

In addition, country-specific issues have been examined. The critical question of the effect of natural gas price on energy mix and energy security of the country is studied, along with the alternative scenario of building a new Combined Cycle (CC) gas power plant (Section G).

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.

For convenience provided below is the energy unit and volume conversion table

	PJ	GCal	kToe	Mbtu	kWh
PJ	1	238800	24	948000	2778E05
GCal	4.19E-06	1	0.0001	3.968	1163
kToe	0.042	10000	1	39500	116.3E05
Mbtu	1.0551E-06	0.252	0.252E-04	1	295
kWh	3.6E-09	0.00086	0.086E-06	3.4E-06	1

1m³ =35.3cf= 6.29 bbl

B. KEY INSIGHTS FOR POLICY MAKERS

The analysis undertaken provides some important insights on the likely development of the energy sector, and how improving energy efficiency and promoting renewable energy impact national priorities of 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	• Large increase in gas imports • Hydro-dominated electricity generation system	• Increased use of domestic RE resources, mostly hydropower • Reduced gas imports by 3670Ktoe (-5%)	• Reduced fossil fuel imports by 4,831Ktoe (5%) • Lower direct energy and electricity consumption by 5,434Ktoe (4%)	• Increased use of domestic RE (although at lower absolute level than under RE case) • Final energy further reduced compared to RE (2069 Ktoe), by 5,715Ktoe • Cumulative total imports reduced by over 8%
Enhanced competitive-ness[1]	• Electricity system expansion at a total cost of 4,277 €M • Greater access to gas	• Stimulates investment in renewable market • Cuts payments for imported fuels, dropping by over 4% (1,443€ M)	• Lower fuel costs, saving 4% in fuel expenditure (1,536€ M) • Power sector investment reduced by 0.1% (4€ M)	• Lower fuel costs, saving 10.4% in fuel expenditure (3,948€M)
CO_2 mitigation	• Emissions more than double by 2030 due to increased use of natural gas	• Cumulative reduction of 4.5% due to use of less fossil energy (particularly gas) and lower total energy consumption	• Cumulative reduction of 4% due to lower total energy consumption	• Cumulative reduction of 8% due to more RE and lower energy consumption

ENERGY SECURITY AND DIVERSIFICATION

Under the RE and EE scenarios, import levels will be reduced by around 4% and 5% respectively, with an 8% reduction under the Combined scenario. This is due to increased use of

[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.

indigenous renewable energy under an RE target, and lower energy demand resulting from increased energy efficiency in the EE scenario. Gas imports are particularly affected. Under the RE scenario, imported gas is reduced by over 5% cumulatively, while in the EE scenario, the reduction is 6%, and in the Combined scenario, gas imports are reduced by 10%.

However, the energy supply becomes less diversified under the RE case, with an increased reliance on hydro generation, and a significant reduction in gas supply. Large increases in investment in hydro capacity need to be balanced against issues of supply diversity, particularly if hydrological patterns change in future years (due to climate change) and leave the system exposed to shortfall.

ENHANCED COMPETITIVENESS

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, despite the higher overall cost to the energy system. If policies that promote an increased uptake in energy efficiency are pursued without setting an explicit reduction target there is an overall savings seen of 591€ million; however, only around a 2.1% reduction is achieved rather than the 9% called for by the Energy Community directive. With the target in place total fuel expenditure savings (compared to the Reference case) reach 10% (in the Combined scenario case), for a cumulative saving of 3.948€ billion, nearly offsetting the cost of the more expensive efficient technologies. Once transformed, the energy system savings continue into the future. Having relatively low gas price (160$ per 1000 m^3) more aggressive EE target is not economical; however, in a case where gas price increases to regional level, the EE target brings more significant benefits relative to the Reference case, which is examined in Section G.

The proposed 2020 RE target moderately 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 of 40%, an additional 2,064 MW of renewable generation capacity will be required by 2020, with another 1,379 MW by 2030. Energy system costs are 0.8% higher (0.358€ billion Net Present Value (NPV)[2]). If the RE target is implemented in parallel with policies to promote energy efficient technologies, the cost of meeting the target is reduced by 0.4%. It is important to note that electricity prices increase to meet the RE target, 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 2,568€ billion(6.4%) cumulatively that can offset some of the more expensive generation and efficient device upfront costs and be rechanneled for other domestic priorities.

It should also be noted that the ancillary direct economic benefits arising from these domestic-centered polices, such as increased jobs to undertake a large number building retrofits and deploying renewable power generation alternatives, are not captured by this analysis.

[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.

CO_2 MITIGATION

The policies examined show strong synergies with potential objective of moving to a lower carbon footprint for the Georgian energy economy. The combined EE and RE policy leads to cumulative reductions of 8% (21.9 Mt) in CO_2 emissions compared to Reference scenario. This is accomplished by increasing renewable generation from hydro and wind power of the order of 47,770 TWh, coupled with the overall reduction in demand for energy due to the more efficient energy system.

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, Georgia is watching developments within the EC. The MARKAL-Georgia Reference scenario shows that rapid electricity demand growth requires electricity generation capacity by 2030 to reach 4,822 MW at a cost of nearly 4,277€ million. This translates into a challenging demand for average annual investment. of 235€ million over next 18 years 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-Georgia analysis shows that a 2.1% reduction in final energy consumption can be achieved at a net savings of 591€ million (or 1.3%), while achieving the more ambitious target of 9% (against 2006-2009 average consumption) requires only a modest cost increment over this value, with of 0.9% (415€ million) cost reduction compared to the baseline and 4.1% (1,536€ million) savings in fuel expenditures, 4.6% (4,964€ million) savings in imports, and 4.1% reduction of carbon emissions. Achieving these goals requires a 2.4% (1,099€ 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-Georgia model can be used, along with market analysis, 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 0.8% (358€ million) and requires 1550 MW more power sector capacity additions, and around 5,826€ million more in investment costs. Achieving the target, however, yields some substantial benefits: a 3.8% (4,125€ million) decrease in imports, a 7.4% (2,817€ million) decrease in fuel expenditures and 4.5% decrease in carbon emissions. Additional reliance on hydro power may increase the risks from a poor hydrological year, and these risks should be balanced against those arising from dependence on imported gas supplies. Further analysis using the stochastic formulation of MARKAL can explore uncertainty associated with future water availability and help formulate more robust hedging strategies.

Although the investment challenges are significant, pursuing the EE and RE strategies simultaneously leads to important synergies. The total system cost is decreased by 0.4% (171€ million). The savings are significant: a 10.4% (3,948€ million) decrease in fuel costs, 7.9% decrease in carbon emissions, and 7.7% (8,305€ million) decrease in imports. The benefits of

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

these investments extend beyond 2030, creating a lasting shift of the economy onto a lower energy intensity, more sustainable, and secure trajectory.

The analyses described herein also makes it clear that Georgia 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, appliance and retrofit subsidies.

C. GEORGIA BUSINESS-AS-USUAL ENERGY PATHWAY

To assess the impact of different policies and programs on the evolution of the energy system in Georgia, 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 near-term policy interventions. The Reference scenario is aligned with the government plans of developing Georgia's abundant hydropower potential based on the Renewable Energy 2008 Program as well as the strategy of positioning Georgia as electricity hub in the region. Once established, the Reference scenario can also produce baseline estimates of energy consumption and carbon emissions to measure trends with respect to achieving NEEAP and low emission development goals in future.

A key assumption underpinning the Reference scenario is that the rate of economic development achieved in recent years will be preserved and natural gas will be available at today's prices (corrected only for inflation) over the period until 2025 with subsequent transition to regional prices. In addition, all available national data sources (State Statistical Office Geostat, electricity and natural gas balances, etc.) were utilized. The full list of information sources is provided in Appendix I.

Under the Reference scenario, energy consumption is projected to grow significantly, by 148% in terms of final energy by 2030, driven by strong Gross Domestic Product (GDP) growth and increased per capita consumption. This will require expanding the electricity generation system from 3,295 MW to 4,822 MW and 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.

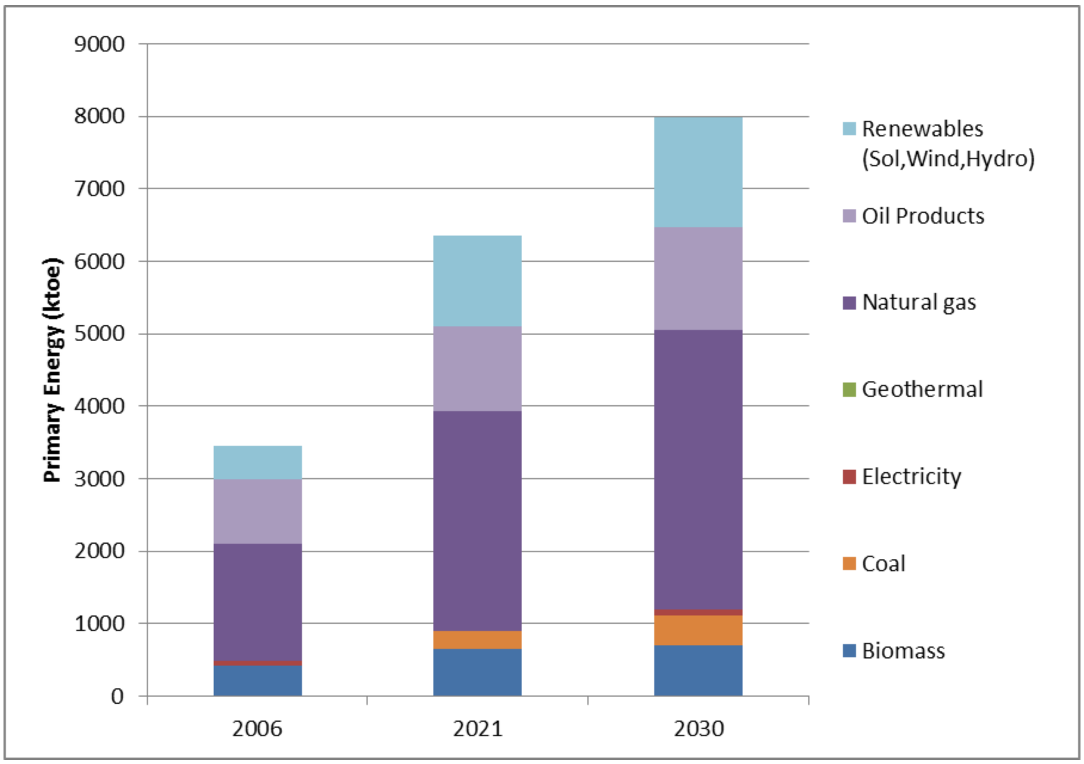
Table 2. Key Indicators for the Reference Scenario

Indicator	2006	2030	Annual Growth Rate (%)	Overall Growth (%)
Primary Energy (Ktoe)	3,463	7,989	5%	131%
Final Energy (Ktoe)	2,926	7,261	6%	148%
Power plant capacity (MW)	3,295	4,822	2%	46%
Imports (Ktoe)	2,556	5,598	5%	119%
CO_2 emissions (Kt)	6,291	14,693	6%	134%
GDP (€M)	6,187	23,426	5.7%	279%
Population (000s)	4,400	4,886	0.5%	11%
Final Energy intensity (toe/€000 GDP)	0.44	0.3	-1%	-33%
Final Energy intensity (toe/Capita)	0.665	1.468	5%	121%

Primary energy consumption in 2030 is projected to be 7989ktoe, increasing from 2006 levels by 131%. While 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 much lower than observed in 2006 – estimated to be 0.44 toe/1000€, a reduction of around 32%. This is a result of the continuation of current structural changes in the Georgian economy and natural technological progress underway throughout the world.

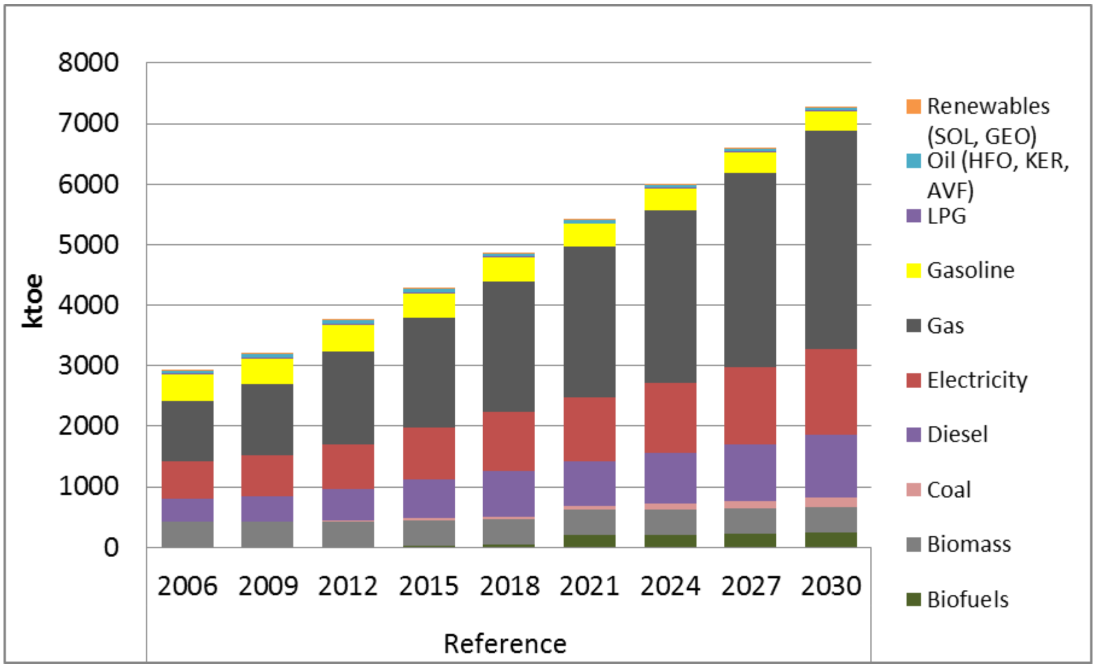
Observed growth in primary energy does not lead to significant changes in supply mix. As shown in Figure 1, primary energy supply more than doubles with imported natural gas accounting for 48% of total supply. The growth in transport demand is reflected in the increase in oil products (imported), although the share in primary energy is similar. The contribution of renewable energy sources (excluding biomass) to total primary energy increases from 19% to 20% over the years 2009-2030. The biomass share drops from 12% to 9% in total primary energy while it increases in absolute volume.

Figure 1. Primary Energy Supply



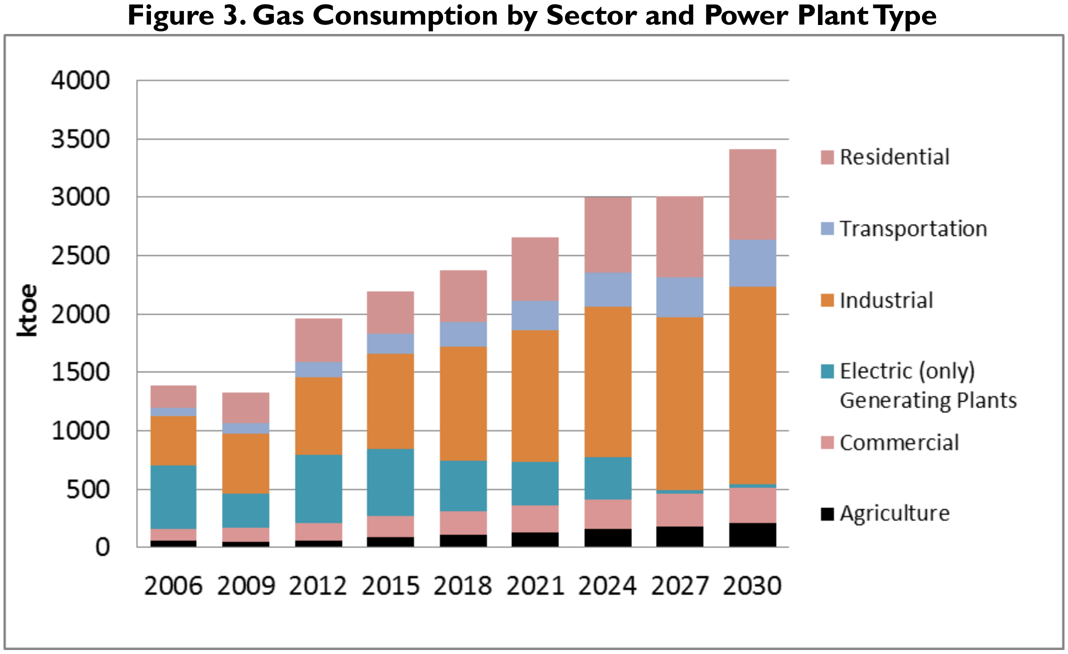
Total final energy consumption grows by over 148% over the planning horizon, as shown in Figure 2, remaining proportionally similar with the exception of the increasing role for gas and coal and introduction of biofuels.

Figure 2. Final Energy Consumption by Energy Type



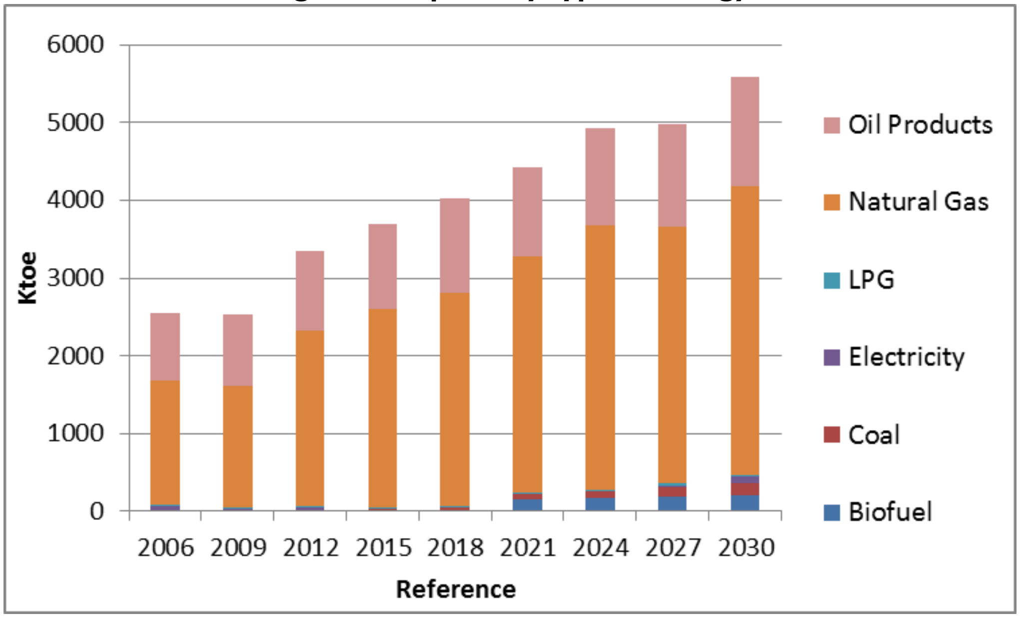
A more detailed view of gas consumption by sector is shown in Figure 3. It shows that the majority of gas is used in the residential, commercial, and industry sectors with significant reduction in gas for power generation. In the residential and commercial sectors, gas is used primarily for space/water heating and cooking. Gas is used across most industry sectors for the production of high temperature heat for a number of different processes. Gas consumption increases most rapidly in the industrial sector, as can be expected due to anticipated development of industrial zones.

Figure 3. Gas Consumption by Sector and Power Plant Type



The majority of Georgia's fossil energy requirements are imported. Demand for natural gas increases import dependency, resulting in an almost tripling of imports by 2030 (relative to 2009 levels). The high consumption of gas in the end-use sectors reflects the criticality of the need for energy diversification and shows the vulnerability of economic and social development to external factors, and thus is an important issue for sensitivity analysis.

Figure 4. Imports by Type of Energy

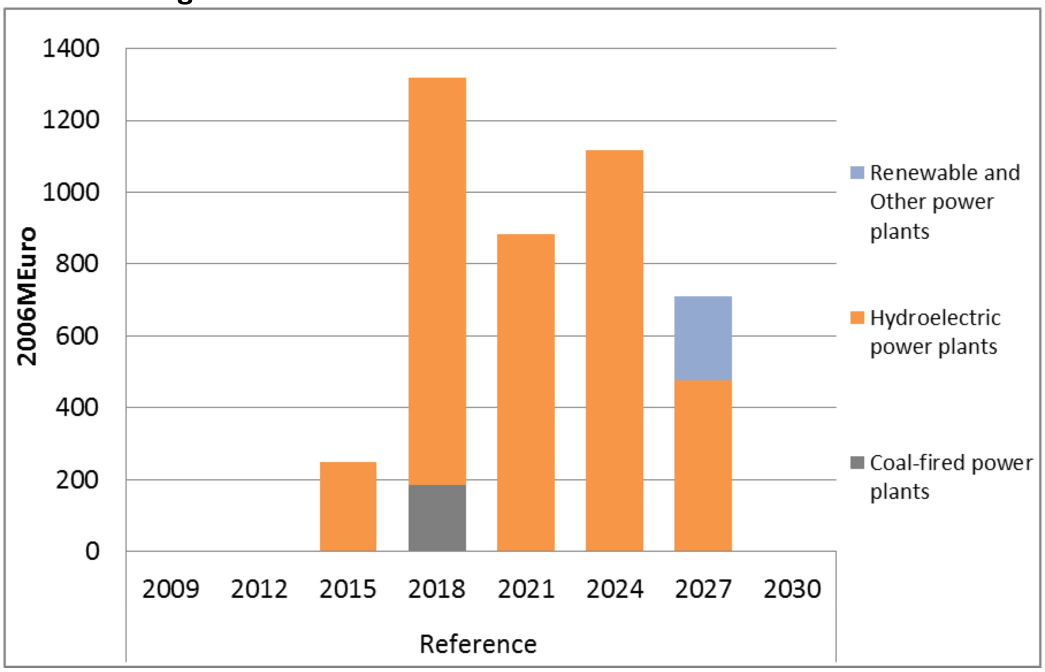


New power generation capacity additions in each three-year period are shown in Table 3, with the corresponding costs shown in Figure 5. Continued expansion of hydro power is the most prevalent trend with a cumulative additional capacity of 2,052 MW by 2030. A number of ongoing construction projects are taken into account as must build plants. This includes several hydro plants and a coal-fired power plant, which come online in 2015-2017. Notably, gas-fired plants are not included as an option in the Reference scenario, in order to examine the results of government policy for reduction of gas share in electrify generation and satisfying domestic demand primarily with hydro power. Wind also makes an important contribution by the end of the planning horizon due to decommissioning of a gas-fired power plant, increase in gas price to regional levels, and lack of cheap hydro alternatives. Capacity additions and the retirement of old power plants results in 4,822 MW of total installed generation capacity in place in 2030.

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

Plant Type	Total Installed 2009	2015	2018	2021	2024	2027	Total Additional Capacity
Coal-fired			160				160
Gas-fired	615						0
Hydroelectric	2680	175	632.3	420	297.6	127.1	1,652
Renewable and Other						240	240
Total New Capacity		175	792.3	420	297.6	367.1	2,052
% of Installed Capacity		5%	24%	13%	9%	11%	62%

Figure 5. 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, for both the power sector and demand devices, 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, shown in Table 2. A breakdown of the energy system cost components is presented in

Table 4. Annual Energy System Expenditure (M€)

, showing the growth in expenditure for fuel (extraction, import, and sector differential charges), operating and maintenance (O&M) costs (fixed and variables), 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 (M€)[4]

Expenditure Type	2009	2012	2015	2018	2021	2024	2027	2030
Fuel Costs (All Sectors)	877	1,180	1,562	1,750	1,999	2,283	3,107	3,652
O&M Costs (Demand+Power)	528	580	659	744	810	882	964	1,047
Annualized Investment (Demand)	412	1,072	1,431	1,903	2,247	2,460	2,716	2,986

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.

Expenditure Type	2009	2012	2015	2018	2021	2024	2027	2030
Annualized Investment (Power)	0	0	19	118	185	269	324	324
Total	1,817	2,832	3,670	4,515	5,241	5,894	7,111	8,010

Under the Reference scenario assumptions. 2,052 MW of new generation capacity is needed by 2030, requiring a total investment of 4,277€ million, which translates to average annual payments on the order of 324€ million by 2030. At the same time, over 634€ million annually will be required to cover the cost of new demand devices, with the majority of this investment made by the private sector, including household vehicle purchases. Fuel supply costs will also increase significantly, driven by growing demand and increasing prices, from 877€ million per year today to 3,700€ million in 2030. This will have a significant impact on country's foreign trade balance.

D. EXAMINATION OF THE PROMOTION OF ENERGY EFFICIENCY IN GEORGIA

Observer status to the Energy Community does not entail an obligation to comply with the Decision of Ministerial Council of the Energy Community 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). However, although Georgia doesn't have a requirement to submit the National Energy Efficiency Action Plan (NEEAP), it would be worthwhile to examine what it will take for Georgia to reduce its energy consumption profile and the ancillary benefits arising from increased energy efficiency such as heightened energy security.

Since there is no NEEAP for Georgia, which would set targets for energy savings and conservation, this analysis uses an approach similar to that of EC member countries that do have NEEAPs, and provides insights into what would be required to meet a target that calls for a 9% decrease in final energy consumption compared to the average 2006-2009 consumption levels (note that since the 9% target is applied starting 2018 based upon the earlier lower consumption level, the cumulative reduction will be less than 9%). This analysis can be used as a first step in this direction, by identifying cost-effective policies and measures to reduce energy consumption.

But the costs to overcome barriers to the uptake of efficiency technologies can be significant, and require strong policies and programs. Such barriers are highlighted in the World Bank (2010) report *Status of Energy Efficiency in the Western Balkans*.[5] The costs attributed to such barriers (e.g., long payback period, lack of familiarity, inconvenience, high transaction costs) and extra hidden costs (e.g., appliance and building standards, information campaigns, low interest (subsidized) loans, "giveaway" programs for the poor) are accounted for in this analysis by the inclusion of so-called hurdle rates,[6] as discussed in Appendix II.

As a result of barriers, the energy saving 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. However, finding the balance between policies, programs, and targets is important to ensure that goals are achieved without undue burden on the economy or individuals. Under such a scenario (no energy reduction target but reduced barriers to uptake), there is only about 2.1 reduction in final energy consumption though with an overall savings to the energy system of 591€ million (or 1.3%), pointing out that there may be attractive cost-effective options available in Georgia today that should be considered and pursued.

Policies that promote increased energy efficiency while achieving the Energy Community target have significant benefits, as described below.

- Energy system savings of 0.9% (415€ million NPV) are observed where there is an energy efficiency target and programs and policies reduce barriers to uptake of more

[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).

energy efficient technologies. Over 4.6% cumulative reductions (4,964ktoes) in imports are observed , enhancing energy security goals and reducing the country's current account deficit by reducing the imported fuel cost by 1,395€ million.

- Cumulative reductions in final energy of 4.1% are observed (5,434ktoes).
- There are strong synergies with low emission development, CO_2 emissions are reduced by 4.1% (or 11,533 Kt).

The basis for the energy efficiency target is percentage reduction calculated from the 2006-2009 average final energy consumption levels, achieved in 2018 and maintained later, which results in total reduction requirements from the Reference scenario levels as shown below. Table 5 shows the key results as change between the EE and Reference scenarios. All of the key cumulative metrics (other than investment in new demand technologies) are reduced due to efficiency savings. For example, power plant investment reduces by 0.1%, imports drop by 4.96% and fuel expenditure goes down by 4.1%; saving 4€ million/4,964ktoe/1,536€ million respectively.

The overall savings of 0.9% or 415€ million arises due to reductions in payments for fuel that are partially offset by increased expenditures for better performing demand devices, which, despite policies and programs, still command a premium over conventional devices. Note that when only policies and programs to reduce barriers to the update of more efficient devices are considered, that no target is imposed, energy savings are 1.3% (591€ million NPV), but only a 4.1% drop in consumption is observed.

Table 5 shows the key results as a change between the Reference EE scenarios. The *Energy Efficiency Promotion* illustrates the benefits of EE policies and measures that lower the barriers associated with the uptake of more efficient devices. The *Energy Efficiency + Target* represents the same promotion of policies and measures but also with the requirement that a 9% consumption reduction target be met. In the first case, this represents a situation where only the most cost-effective technologies are taken up, incentivized by policies and programs that have been put in place. It illustrates that cost savings can be made by EE promotion, to reduce the socio-economic barriers to uptake of more efficient technologies. In the second case, a target "forces" the model to go beyond this economically efficient level, and deploy additional higher cost technologies to meet the target level, with associated costs and benefits.

Although EE + Target is more expensive than EE without target, it reduces energy consumption more significantly, especially natural gas, contributing more to energy security. Moreover, higher penetration of efficient technologies stimulates economic activity, since new businesses are developed, contributing to technological progress as well.

Table 5. Cumulative Impacts of Energy Efficiency (Change Compared to Reference Scenario)

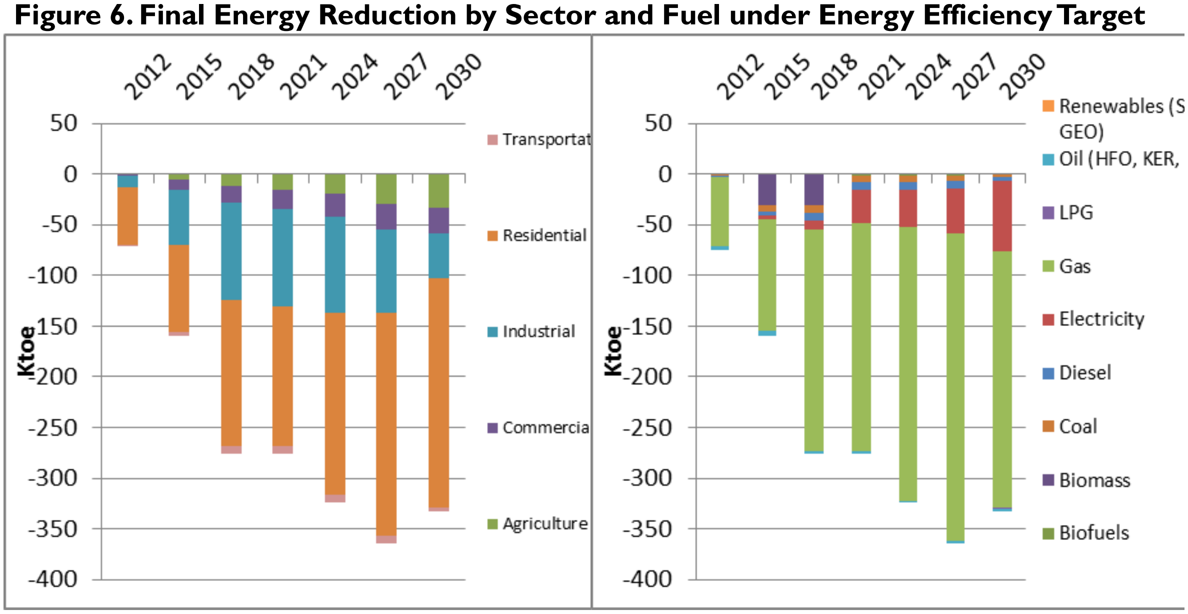
Indicator	Units	Reference	Energy efficiency Promotion		Energy Efficiency + Target	
Total Discounted Energy System Cost	2006€ M	45,560	-591	-1.3%	-415	-0.9%
Primary Energy Supply	Ktoe	153,029	-2,733	-1.8%	-5,289	-3.5%
Imports	Ktoe	108,236	-2,366	-2.2%	-4,964	-4.6%
Fuel Expenditure	2006€ M	37,854	-943	-2.5%	-1,536	-4.1%

Indicator	Units	Reference	Energy efficiency Promotion		Energy Efficiency + Target	
Power Plant New Capacity	MW	2,052	0	0%	0	-0%
Power Plant Investment Cost	2006€ M	4,277	-4.0	-0.1%	-4.0	-0.1%
Demand Technology Investments	2006€ M	45,680	17	0.0%	1,099	2.4%
Final Energy	Ktoe	132,742	-2,812	-2.1%	-5,434	-4.1%
CO_2 Emissions	Kt	278,800	-5,284	-1.9%	-11,533	-4.1%

This reduction in cumulative energy consumption is roughly equivalent to a 4% reduction of annual consumption with respect to Reference scenario by year 2030.

The contribution of different sectors to the EE target is shown in Table 6, indicating that energy saving potential is economy-wide, and that all sectors provide a significant contribution. Under the energy efficiency target, the residential sector provides the largest savings (58% of total savings), followed by the industry sector (26%), commercial (7%), and agriculture (6%).

Figure 6. Final Energy Reduction by Sector and Fuel under Energy Efficiency Target

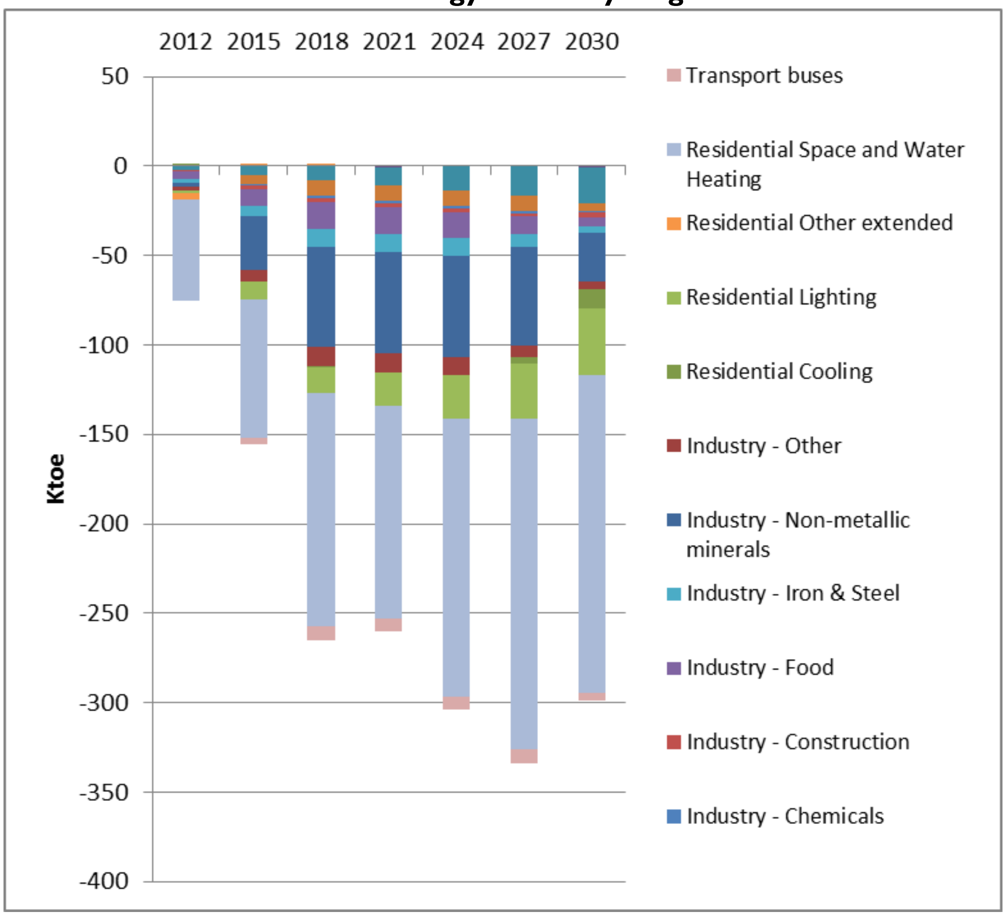


In terms of fuels, the largest near-term reductions come from natural gas, coal, and biomass (residential), coal (industry), and diesel (transport). The overall net reduction is lower than these reductions suggest due to an increase in gasoline and biofuel being used in more efficient technologies. Later in the time horizon (2024 onwards), large reductions in gas for space heating are partly offset by reduction in biomass in favor of more efficient gas devices.

A more detailed overview of savings by energy service demands are shown in Figure 7**Error! Reference source not found.**. The most cost-effective reductions occur from more efficient space and water heating, with a strong uptake of heat pumps (using electricity) and more efficient appliances. This leads to a fairly strong reduction in gas consumption and moderate reduction in electricity consumption. For the transport sector, there is an increasing uptake of hybrid vehicles across light duty vehicles (LDVs), light commercial vehicles (LCV)s, heavy goods vehicles (HGVs), and increase in compressed natural gas (CNG) use in all passenger vehicles. The bus fleet moves towards more advanced internal combustion engine (ICE) technology.

In industry, savings are most prevalent in non-metallic mineral industries, where efficiency savings from process heat are realized. Much of the commercial savings are in lighting, followed by heating and hot water, where most of the savings are from more efficient appliances, including increased penetration of heat pumps.

Figure 7. Final Energy Reduction by Energy Service Type under Energy Efficiency Target



It is important to highlight that there are significant uncertainties concerning the potential of opportunities for energy efficiency including the overhead costs of policies and measures for their implementation. Therefore, it is important to continually review the data in the model for use in future analyses, assessing new data available in Georgia to further improve the robustness of the analysis.

Under the EE target, costs are shown to decrease as a result of significant reductions in fuel expenditures saving of more than 1.5€ billion during the planning horizon. While the cost of demand technologies increases (due to the use of more advanced types), this additional cost is more than offset by the savings in fuel payments. Economic benefits may in fact be greater if the wider economic benefits that come from energy efficiency, in terms of export competitiveness or stimulating new industries are captured; however, these macro effects are not accounted for in this analysis.

At the same time, significant co-benefits arise from pursuing energy efficiency goals, including CO_2 reductions (4% or 11.533Mt) and energy security through reduced imports (4.6% reduction, reducing foreign payments by 1,395€ million).

The modeling also suggests that a more aggressive target can be achieved at only modest additional cost. The case of more aggressive 9% reduction against the Reference scenario (vs. NEEAP type 9% against 2006-2009 consumption) has been also examined (though not reported on here) and results in a cost increase of 0.2% compared to the Reference scenario. Such insights are useful for reference and comparison to the EU ambition to reduce primary energy by 20% by 2020 (relative to projected primary energy consumption). In fact, the EU has adopted a new Directive (*Directive of the European Parliament and of the Council on Energy Efficiency, June 2012*) that is seeking to ensure that the 20% energy efficiency target can be met by 2020 – as current legislation (including the ESD) will not achieve this goal.

E. ASSESSMENT OF A RENEWABLE ENERGY STRATEGY FOR GEORGIA

A Renewable Energy Directive for the EU sets targets for Member States in order to achieve the objective of getting 20% of energy from renewable sources by 2020. This Directive is devised to enable the EU to cut greenhouse gas emissions and make it less dependent on imported energy. In addition, this will help develop the clean energy industry, encourage technological innovation and employment.

The Energy Community Secretariat (ECS) commissioned a study in 2009 examining illustrative RE targets for the contracting parties,[7] adopting the RE Directive methodology for allocating targets, with biofuels assumed to contribute 10% of transportation sector energy requirements. This study has subsequently been updated with revised targets based upon reducing estimated Gross Final Energy Consumption (GFEC).[8] While Georgia has no obligations under its EC Observer status and has not developed an RE strategy, the current analysis can serve as an illustrative case to assess the mix of options that might be required to meet a target similar to that currently being proposed by the EC for Member Countries. This assessment should help to provide underlying evidence for a future strategy of renewable energy development beyond hydro power. Based upon the EC approach, a renewable target of 4-% was chosen for Georgia for 2020.

Key insights are summarized in Table 6 and elaborated upon in the rest of this section.

- Cumulative energy system costs (to 2030) are 0.8% higher. While this is a relatively modest increase, it is important to highlight that significant additional power sector investment is needed out to 2030 increasing by 136%, to add 1,550 MW to power system generation capacity. Part of the electricity produced from this additional renewable capacity is then exported, and income generated from this export reduces the overall system cost.

- Energy security is enhanced with a 3.8% cumulative decrease in the imports required, saving 1,443€ million in foreign payments.

- Demand for final energy reduces by 1.6% as a result of increased use of indigenous electricity and increase of biofuel use in the transport sector.

- A lower emissions pathway, with cumulative CO_2 reduction reaching almost 4.5% (nearly 12.424Mt between 2009-2030), arises. It is noteworthy that increased levels of export of additional "clean energy" energy would results in emission reductions in other countries for which Georgia may be able to obtain carbon offsets.

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[7] Study on the Implementation of the New EU Renewable Directive in the Energy Community to Energy Community Secretariat, IPA Energy + Water Economics, United Kingdom, February 2010.

[8] Updated calculation of the 2020 RES Targets for the Contracting Parties of the Energy Community, Presentation by ECS to 8th Renewable Energy Task Force meeting, 06 March 2012.

Table 6. Cumulative Impacts of the RE Target on the Energy System

Indicator	Units	Reference	RE Target Change	
Total Discounted Energy System Cost	2006€ M	45,560	358	0.8%
Primary Energy Supply	Ktoe	153,029	1,104	0.7%
Imports	Ktoe	108,236	-4,125	-3.8%
Fuel Expenditure	2006€ M	37,854	-2,817	-7.4%
Power Plant New Capacity	MW	2,052	1,550	75.5%
Power Plant Investment Cost	2006€ M	4,277	5,827	136%
Final Energy	Ktoe	132,742	-2,069	-1.6%
CO_2 Emissions	Kt	278,800	-12,424	-4.5%

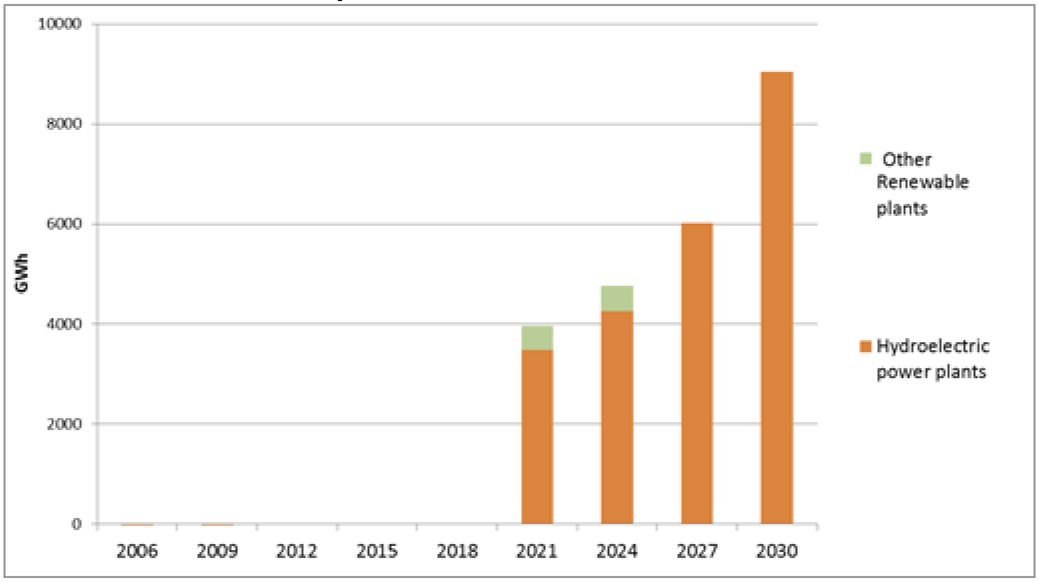
The Reference scenario showed an increase in new hydro and wind power generation capacity of about 1,892 MW out of a total of 2,052 MW new capacity additions. In other words, renewable electricity generation is playing a crucial part in meeting future demand (see Figure 8) even without an established renewable energy target. However, to further enhance energy security and address climate change, pursuing an even more aggressive renewables strategy has additional merit, though at a cost.

Under the RE target, cumulative additions in RE capacity amount to 3,442 MW out of total new capacity of 3,602 MW. Comparing this to the Reference case, this means an additional 1,550 MW of RE capacity, is needed, only a small portion of which is wind generation. This suggests that meeting the target and sustaining it beyond 2020 will require attracting higher levels of capital for expanding the power generation sector. This additional capital required under the RE target in the is estimated at 5.827€ billion over the planning horizon. The large increases in capacity above the Reference case are well illustrated in.

A consequence of this substantial increase in more expensive renewable generation is an increase of electricity price (based on the levelized cost of generation calculated in the model). While overall electricity consumption increases, the higher price does incentivize the uptake of more efficient devices, which is why combining the EE and RE policies has merit, as discussed in the next Section.

A summary of the change in renewable energy use for centralized electricity is provided in Figure 8**Error! Reference source not found.**. There is only a slight increase in direct consumption of other renewable energy.

Figure 8. Additional Renewable Energy under RE Target, Compared to the Reference Scenario



Sustaining the target after 2020 becomes significantly more difficult due to the overall growth of the energy system (making the same percentage share much higher in absolute terms). This results in some investment in wind (240M W), and a small uptake of biomass (particularly once less expensive hydro potential is taken). This suggests that it is important for decision-makers to take into consideration the post-2020 regime while planning to keep the RE target share.

Adapting the energy system to meet the target increases total energy system costs by 0.8%, or 358€ million relative to the Reference scenario over the entire planning horizon. In the power sector alone, a 136% increase in cumulative (undiscounted) investment, or 5.827€ billion is needed. At the same time energy efficiency devices reduce cumulative final energy consumption by 1.6% compared to Reference case.

While the challenges of ramping up investment to meet the target are clear, a significant shift to renewables has two important co-benefits. Energy imports drop by over 3.8% (saving 2,404€ million in foreign payments) and CO_2 emissions are reduced (cumulatively) by almost 4.5% relative to the Reference scenario. This suggests strong synergies between renewable policy and other policies relating to low emission strategies, energy security, and competiveness. Furthermore, as discussed in Section F, coordinating with the policies that encourage energy efficiency can dramatically enhance the benefits and lower the cost of meeting a renewables target.

It is also worth highlighting the issue of the system's climate resilience. Increasing investment in hydro generation, with limited diversification, could leave Georgia more vulnerable to climate change impacts, particularly reduced precipitation levels. Therefore, further sensitivity analysis needs to be undertaken to explore how Georgia can achieve the RE target if it reduces its reliance on a hydro-dominated system.

F. COORDINATED RENEWABLES AND ENERGY EFFICIENCY POLICIES FOR GEORGIA

Promoting both energy efficiency and renewable energy goals in parallel may have strong policy synergies. This analysis looked at assessing both objectives simultaneously and highlights the fact that doing so is more cost-effective.

Key insights include:

- Energy system costs decrease by 171€ million or -0.4% as compared with an 0.8% increase seen to reach the RE target without a coordinated EE promotion policy.
- The efforts to reduce final energy through energy efficiency (by 6%) means a lower level of renewable energy required, resulting in lower overall costs.
- CO_2 emissions and imports are each reduced by 8%, saving foreign payments and fostering a less carbon intensive energy system.

Table 7 shows the key result changes between the combined RE&EE scenario and the Reference scenario.

Table 7. Cumulative Impacts of Combined RE&EE Targets on the Energy System (Compared to Reference Scenario)

Indicator	Units	Reference	EE &RE Targets Change	
Total Discounted Energy System Cost	2006€ M	45,560	-171	-0.4%
Primary Energy Supply	Ktoe	153,029	-5,006	-3.3%
Imports	Ktoe	108,236	-8,305	-7.7%
Fuel Expenditure	2006€ M	37,854	-3,948	-10.4%
Power Plant New Capacity	MW	2,052	1,181	58%
Power Plant Investment Cost	2006€ M	4,277	4,439	104%
Demand Technology Investments	2006€ M	45,680	1,921	4.2%
Final Energy	Ktoe	132,742	-7,784	-5.9%
CO_2 Emissions	Kt	278,800	-21,888	-7.9%

Figure 9 **Error! Reference source not found.**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, costs increase due to the additional investment needs for renewable generation capacity, and the additional costs of energy efficient demand devices. However, fuel savings (in dark blue) can be seen in all scenarios, reaching over 169€ million per annum in the combined scenario by 2030 that almost offset the more expensive investment requirements. However, the combined scenario is also more cost-effective since, thanks to energy efficiency, lower levels of renewable energy being required, since the renewable target is relative to the now reduced total (gross) final energy consumption.

Figure 9. Costs and Savings from Renewable and Energy Efficiency Policies

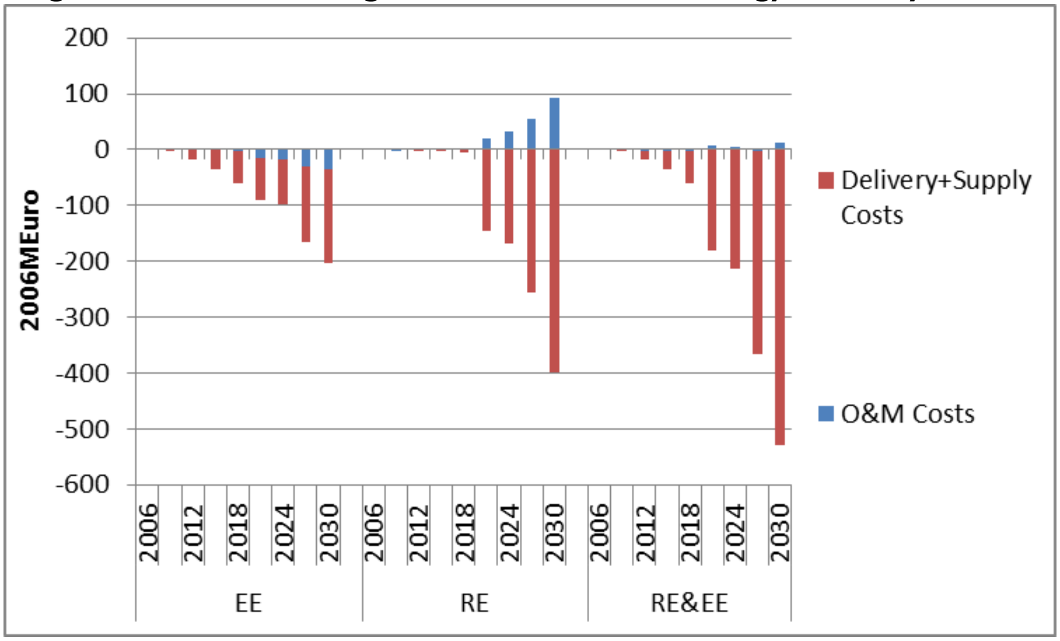
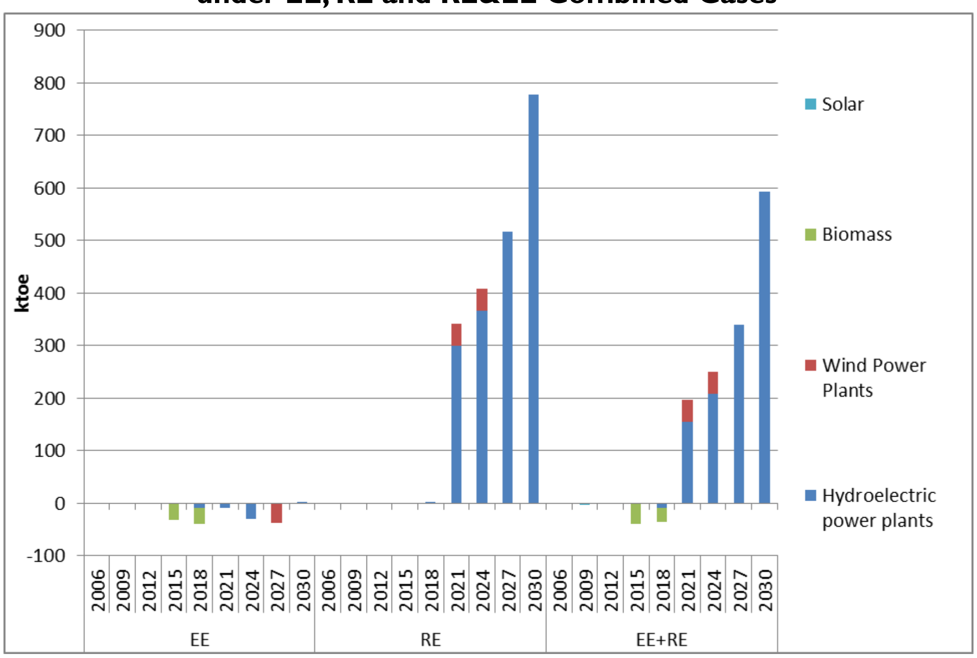


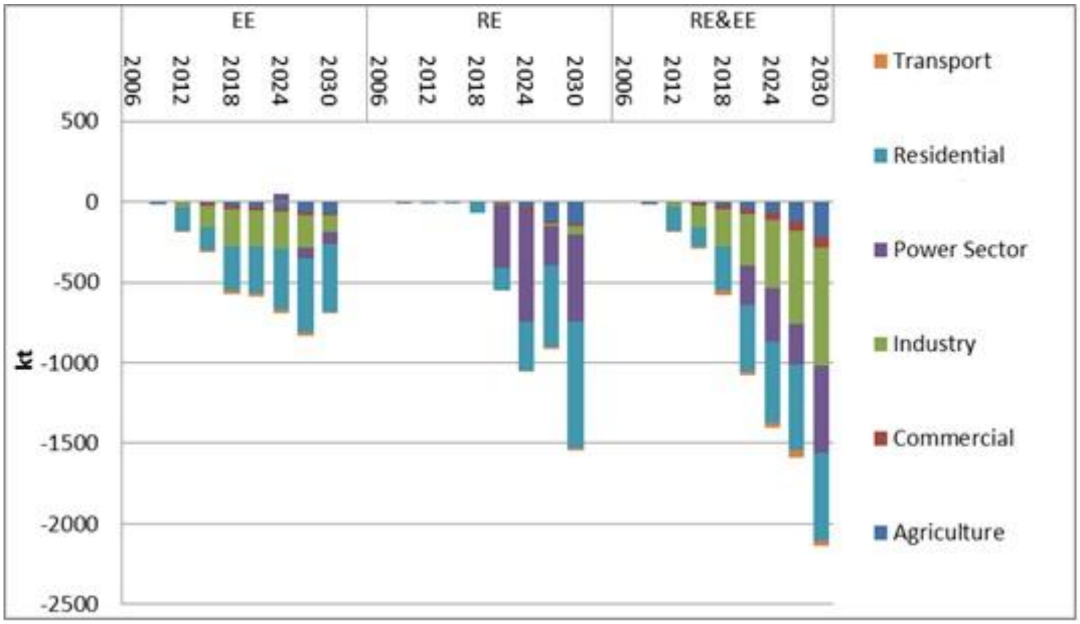
Figure 10. Renewable Energy Consumption under EE, RE and RE&EE Combined Cases



CO_2 emission reductions are shown in Figure 11, illustrating the avoided emission by sector associated with energy efficiency and renewable policy. The highest CO_2 emissions savings are observed in the Residential sector, which, among other economic sectors, currently is the least efficient. Therefore, increased efficiency can sufficiently affect energy consumed by the Residential sector. On the other hand, the Commercial sector currently is the most efficient, and there is no substantial CO_2 emissions savings in this sector. Additionally, in the case of RE, there is an increase in indigenous use of electricity which is generated from hydro and is clean.

Also, there are substantial CO_2 emissions savings in the Power sector under the RE and RE&EE cases, since construction of new hydro plants substituted thermal plants.

Figure 11. Sectoral CO_2 Emission Reductions under RE, EE, and RE+EE Combined Cases



One can see that EE strongly affects emissions in the industry and residential sectors, while the RE target reduce power sector emissions. The Residential sector is the most responsive to CO_2 reduction policies.

G. EXPLORING ADDITIONAL NATIONAL ISSUES – GAS PRICE AND ADVANCED POWER PLANT

NATURAL GAS AT REGIONAL PRICE

The Reference scenario points to an increasingly important role for natural gas in the energy system. The current low gas price originates from Georgia's ability to obtain the in-kind fee and cheap optional gas from the transit of natural gas between neighboring countries. Gas is not monetized and used as source for revenue to the government, rather is subsidized. A sensitivity analysis was undertaken to assess the economic and energy system impacts if gas is provided at a regional price of $300 per thousand cubic meters (GRP scenario). Along with potential change in gas price policy, this scenario also examines the option where the proceeds from gas transit will not be adequate to keep the gas price in Georgia at the current low level as assumed in the Reference scenario. The key findings are summarized below, and reflected in Table 8 and figures that follow.

The higher gas price obviously leads to increases in the cost of the energy system and requires reduction in gas consumption and development of indigenous energy sources, improving energy security. The cost difference is estimated at 2,452€ million, or a 5.4% increase in total system cost compared to the Reference scenario. On the other hand, if the gas price increases due to monetization at international prices, this additional cost to the energy system might be considered as additional revenue to the government and might be used by the latter for additional strengthening of the system by more investment. This cost estimate in a way reflects the cost of increased security of supply resulting from reduced use of gas and switching to indigenous renewable energy sources.

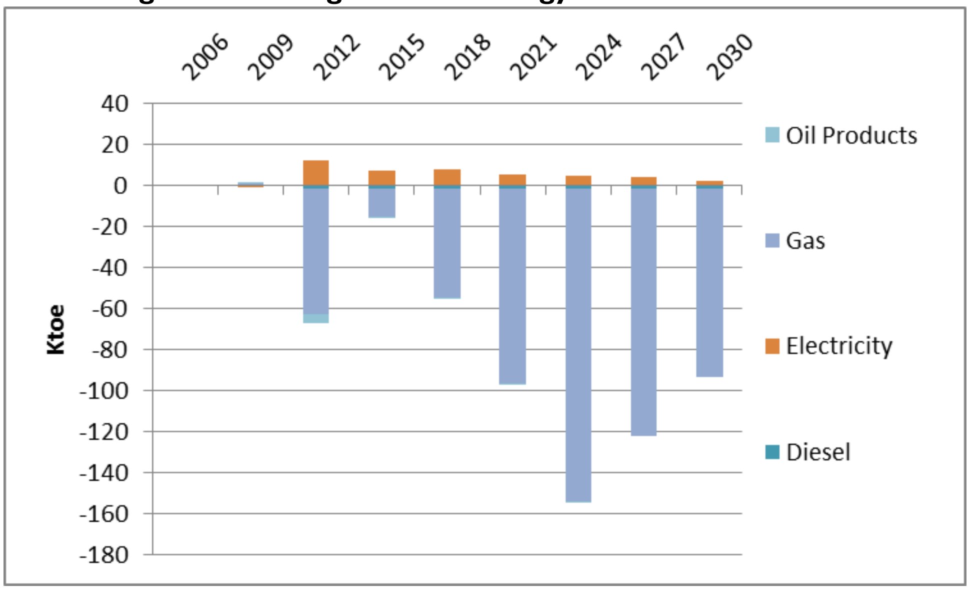
There is an increase in costs for more efficient demand technologies of 114€ million (between 2015-2027), which is 2.7% of total system cost. Implementation of efficient technologies helps to reduce final consumption by 1,673ktoe, or 1.3%. There is an increase in demand for electricity, due to the fact that electricity substitutes for the now more expensive gas. Energy imports drop by over 4.7% compared to the Reference case, while CO_2 emissions drop by 3.6% (cumulatively), due to the uptake of more efficient technologies. The main parameters of Gas price increase scenario are presented below in Table 8.

Table 8. Key Results: Gas price sensitivity (Cumulative) Difference

Indicator	Units	Reference	High Gas Price Change	
Total Discounted Energy System Cost	2006€ M	45,560	2,452	5.4%
Primary Energy Supply	Ktoe	153,029	-4,146	-2.7%
Imports	Ktoe	108,236	-5,141	-4.7%
Fuel Expenditure	2006€ M	37,854	6,373	17%
Power Plant New Capacity	MW	2,052	0	0%
Power Plant Investment Cost	2006€ M	4,277	0	0%
Final Energy	Ktoe	132,742	-1,673	-1.3%
CO_2 Emissions	Kt	278,800	-10,153	-3.6%

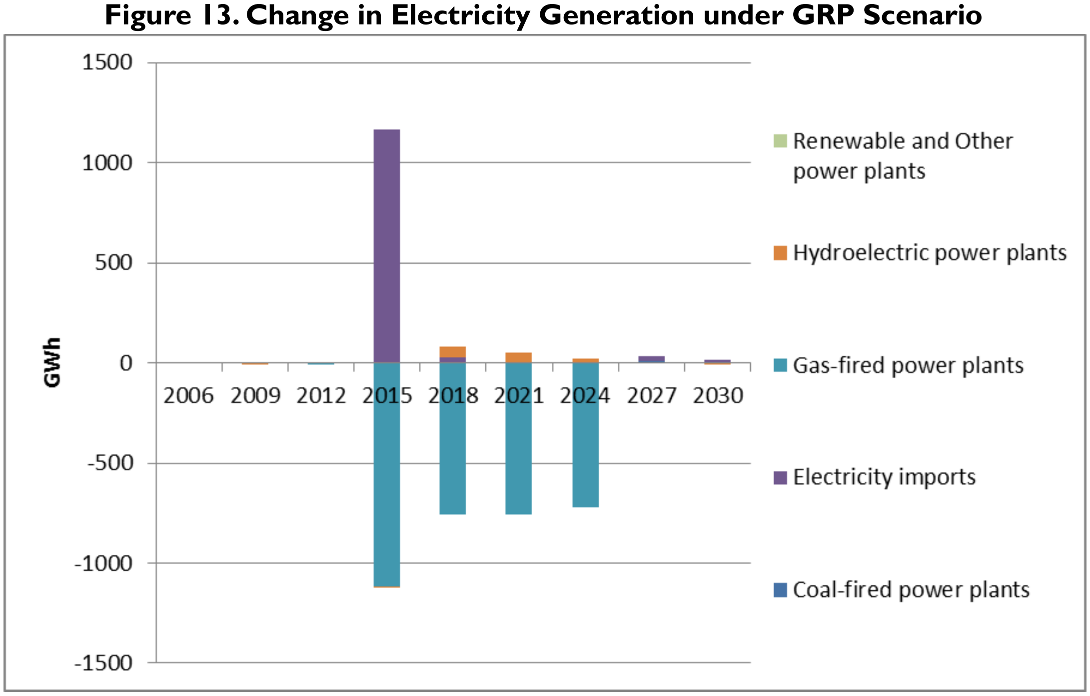
The high gas price scenario also leads to a substantial decrease in electricity exports. Annual average export drops by about 600 GWh over 2018-2024. This is why no new power plant capacity is added. Decrease in consumption of gas is followed by a minor decrease in diesel and oil. While consumption of these fuels is observed across most sectors, oil demand decreases in the residential sector, consumption of gas decreases in commercial and residential sectors, and electricity consumption increased in transport and residential sectors.

Figure 12. Change in Final Energy under GRP Scenario



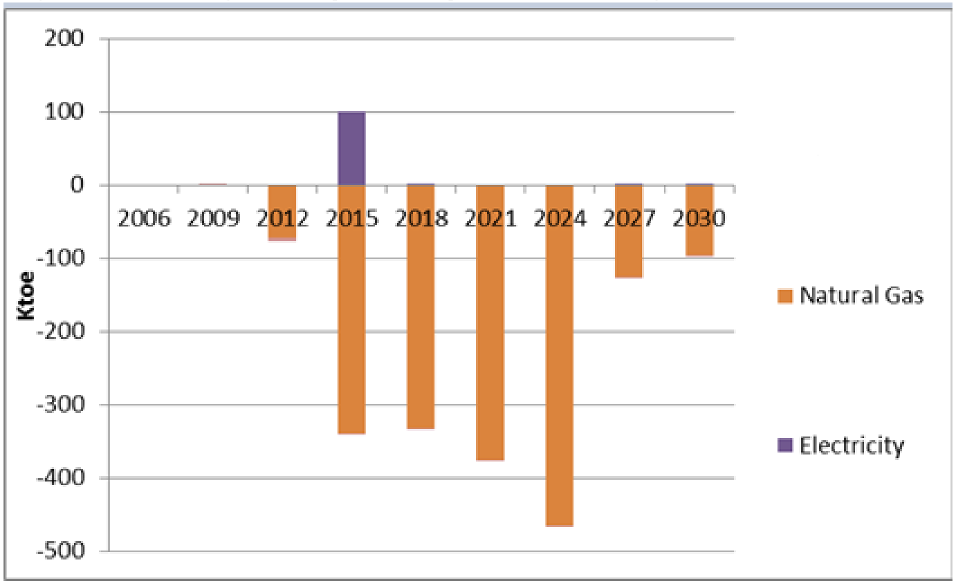
The increase in electricity consumption leads to an increase of electricity imports in 2015 when the new power plants are still not operational to cover the increased demand in electricity, as shown in Figure 13.

Figure 13. Change in Electricity Generation under GRP Scenario



The main consequence of the high price of natural gas is the drop in imports. The total reduction in gas imports is 5,413ktoe or 6.5 billion m^3 of gas. This is equivalent to about 1.6€ billion reduction in foreign trade balance, assuming that all the gas needed to make up Georgia's energy balance is purchased at regional prices. The reduction in imports compared to the Reference case is greater in 2015-2024. Some decrease in gas import remains in later periods irrespective of the fact that in the Reference scenario gas has the same regional price after 2025. This can be attributed to non-gas end-use technologies proliferated in the market in high-gas-price scenario in previous years. Also, compared with the Reference case, there is an increase in imports of electricity (e.g. in 2015) to bridge the gap before the hydro power plants builds catch up with demand.

Figure 14. Change in Imports/Exports under High Gas Price Scenario



In summary, this sensitivity analysis shows that a higher price for natural gas reduces imports and lowers energy consumption; it does so with an overall increase in energy system cost compared to the Reference case.

NATURAL GAS AT REGIONAL PRICE WITH ENERGY EFFICIENCY

Below, the effect of energy efficiency improvements are examined in combination with gas prices at regional level. A sensitivity analysis was undertaken to assess the economic and energy system impacts if gas is provided at regional price of $300 per thousand cubic meters (GRP scenario) and at the same time the energy saving policies and measures are applied. The key findings are summarized below, and reflected in Table 9 and the figures that follow.

Policies that promote increased energy efficiency have significant benefits when higher gas prices are considered, resulting in higher savings as described below. Key insights include:

- Energy system savings of 0.6% (308€ million NPV) are observed where there is an energy efficiency target and programs and policies reduce barriers to uptake of more energy efficient technologies.
- About 5% of cumulative reductions (5.116ktoes) in imports are observed , enhancing energy security goals and reducing the country's current account deficit by reducing the imported fuel cost by 3857€ million.

- Cumulative reductions in final energy of 4% are observed (5,311ktoes).
- There are stronger synergies with low emission development, CO_2 emissions are reduced by 4.4% (or 11,827Kt) or 0.4% more than in EE scenario.

Table 9 shows the key results as change between the high gas price (GRP) and EE+GRP scenarios. All of the key cumulative metrics (other than investment in new demand technologies and power plants) are reduced due to efficiency savings. Power plant investments stay almost the same, while imports drop by 5% and fuel expenditure goes down by 4,7%; saving 2.1€ million/1,536€ million respectively.

The slight reduction of total discounted system cost of 0.6% or 308€ million results from the liberal EE target of a 9% reduction in final energy consumption compared to the 2006-2009 average. The overall savings arise due to reductions in payments for fuel that are partially offset by increased expenditures for better performing demand devices. Table 9 shows the key results as a change between the Reference EE scenarios.

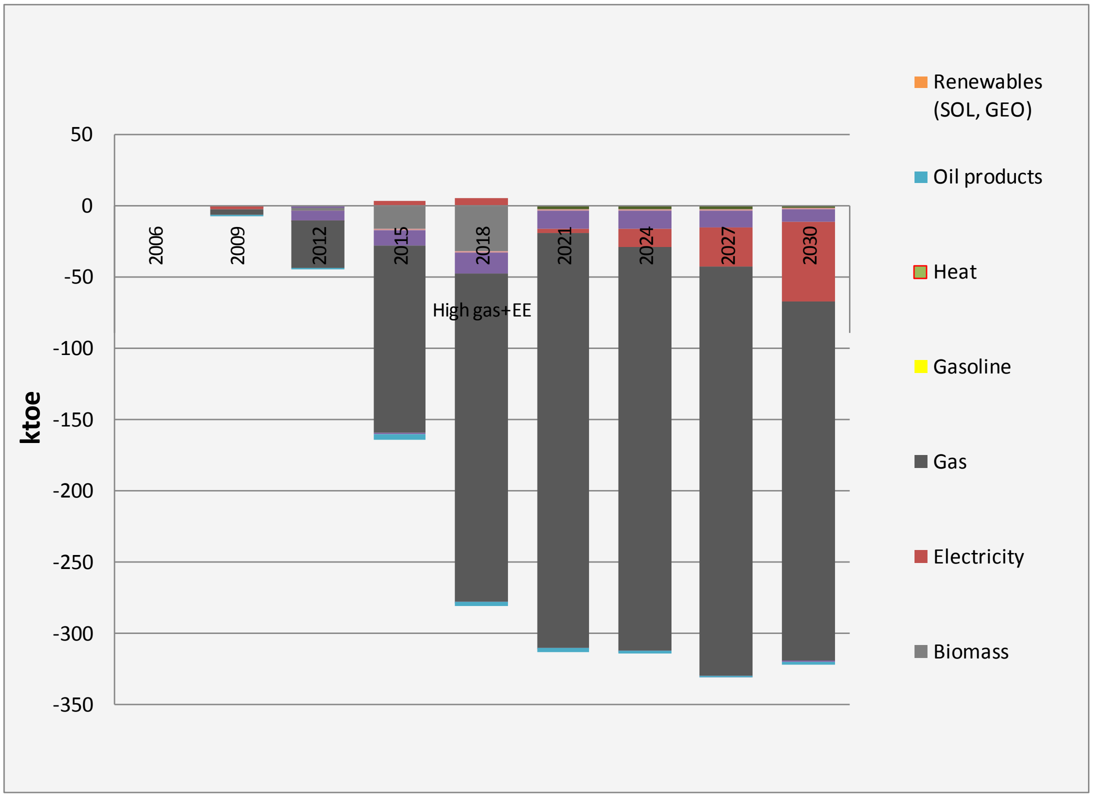
As in EE application to Reference scenario, some reduction in system costs (0.6%) is also observed here. Reduction in primary energy supply is the same as in the EE scenario (4.6%) while savings on energy imports (5%) and fuel expenditure are higher for the obvious reason of having a higher gas price.

Table 9. Key Results: Gas price sensitivity (Cumulative) Difference

Indicator	Units	High Gas Price	High Gas Price +EE Change	
Total Discounted Energy System Cost	2006€M	48,012	-308	-0.64%
Primary Energy Supply	Ktoe	148,884	-5,280	-3.5%
Imports	Ktoe	103,095	-5,116	-4.96%
Fuel Expenditure	2006€M	44,227	-2,062	-4,66%
Power Plant New Capacity	MW	2,052	0	0%
Power Plant Investment Cost	2006€M	4,277	-2	-0.04%
Final Energy	Ktoe	131,069	-5,311	-4,05%
CO_2 Emissions	Kt	268,647	-11,827	-4.4%

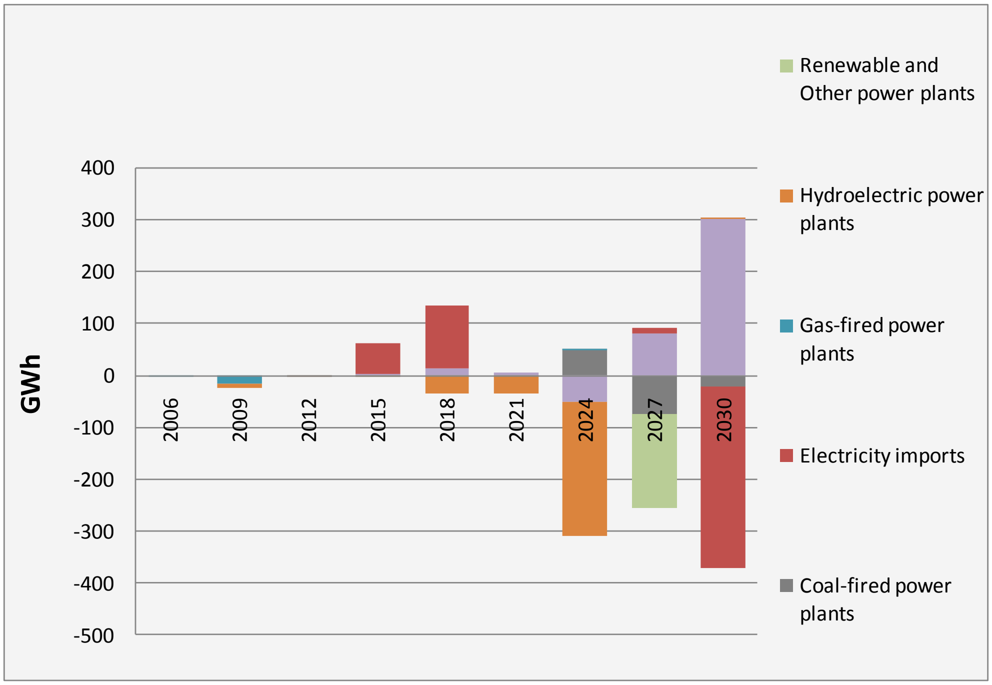
The high gas price scenario also leads to substantial decrease in electricity exports. Annual average export drops by about 600 GWh over 2018-2024. This is why no new power plant capacity is added. Decrease in consumption of gas is followed by a minor decrease in diesel and oil. While consumption of these fuels is observed across most sectors, oil demand decreases in the residential sector, consumption of gas decreases in commercial and residential sectors, and electricity consumption increased is observed in transport and residential sectors.

Figure 15. Change in Final Energy under High Gas Price + Efficiency Scenario



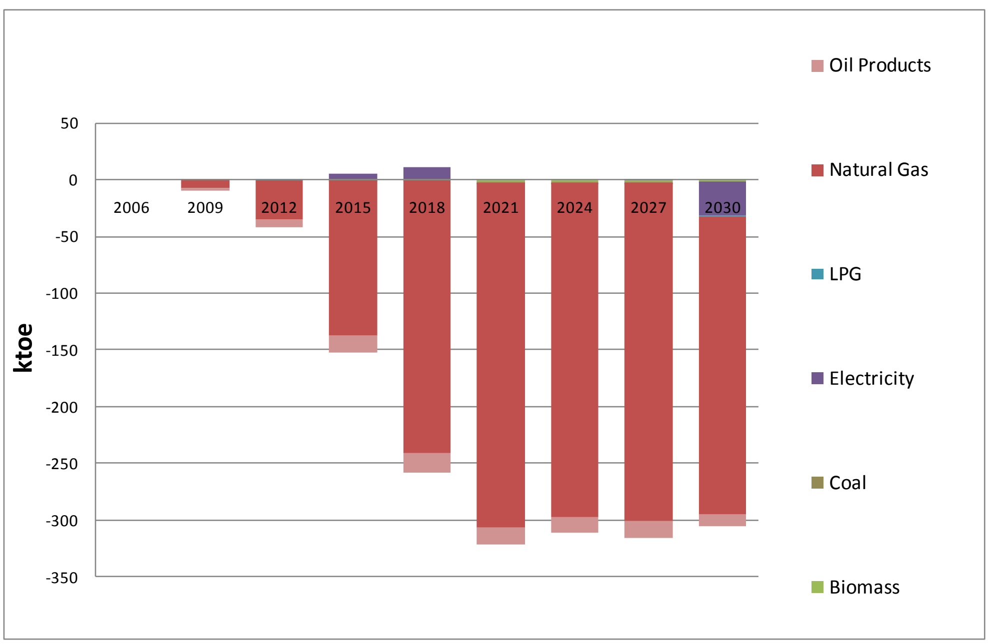
The increase in electricity consumption leads to an increase of electricity imports in 2015 when the new power plants are still not operational to cover the increased demand in electricity, as shown in Figure 16.

Figure 16. Change in Electricity Generation under High Gas Price+ Efficiency Scenario



Compared to the GRP case, there is a minor decrease electricity supply after 2024.

Figure 17. Change in Imports/Exports under High Gas Price+ Efficiency Scenario



In summary, this sensitivity analysis shows that energy efficiency in high gas price case reduces imports and lowers energy consumption; it does so with an overall decrease in energy system cost of 308€ million but substantially reduces fuel expenditure and corresponding foreign trade deficit by about 2€ billion.

COMBINED CYCLE POWER PLANT

In the Reference scenario the possibility of building a Combined Cycle gas power plant has not been included in the model, in order to reflect the official policy of satisfying the electricity demand with country's own hydro potential. However, recently, the Ministry of Energy started considering the possibility of building a new combined cycle unit in Gardabani. Although the project has not yet started, it is important to examine the consequences of such a project on the overall system development over the long-term period. For this purpose a 250 MW combined cycle plant was included in the new power plant options with the potential to come on line from 2016 (reflected in run year 2018). The model chooses this option and shows that this is an economical solution. The key findings are summarized below, and are reflected in Table 10 and figures that follow.

The presence of a combined cycle plant helps reduce overall energy system costs by 156€ million or 0.3%. This can be attributed mostly to higher efficiency of the combined cycle plant that requires less fuel to generate electricity as well as less investment cost for the capacity of CC plant. As a result, fuel expenditures are reduced by 386€ million or 1%.

There is a significant decrease in cost of investments in new capacity of 969€ million or 23%. This is mainly due to a reduction of 160 MW in new hydro plants capacity with high investment costs, as well as a reduction of 150 MW wind capacity. Along with the 250 MW combined cycle capacity, the model adds about 230 MW of hydro power to the system as well.

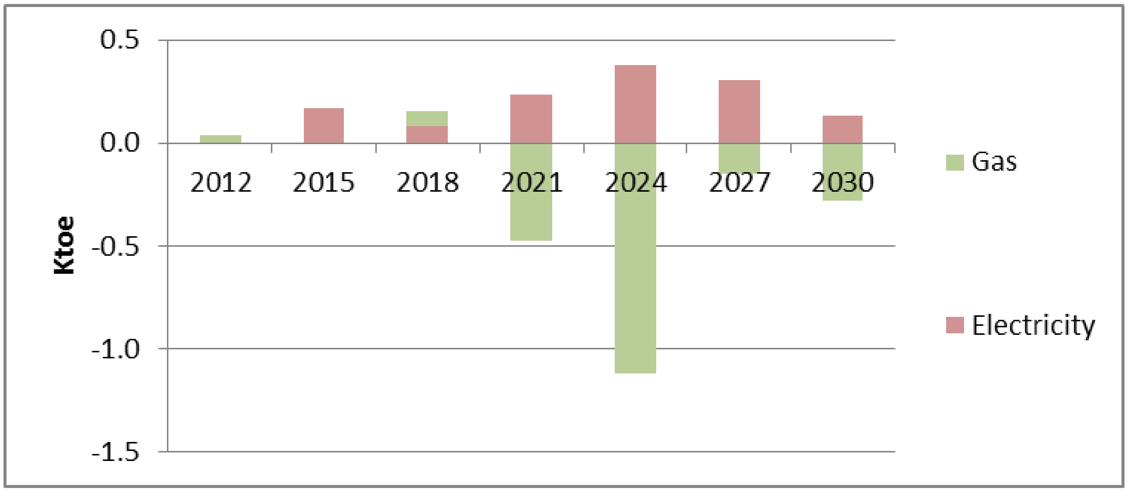
Imports increase by 2.4% due to increase of import of natural gas, while CO_2 emissions increase by 4,827kt or 1.7% due to the operation of combined cycle plants.

Table 10. Key Results: CC Scenario Difference

Indicator	Units	Reference	CC Change	
Total Discounted Energy System Cost	2006€ M	45,560	-156	-0.3%
Primary Energy Supply	Ktoe	153,029	2,430	1.6%
Imports	Ktoe	108,236	2,628	2.4%
Fuel Expenditure	2006€ M	37,854	-386	-1%
Power Plant New Capacity	MW	2,052	90	4.4%
Power Plant Investment Cost	2006€ M	4,277	-969	-23%
Final Energy	Ktoe	132,742	-2	0%
CO_2 Emissions	Kt	278,800	4,827	1.7%

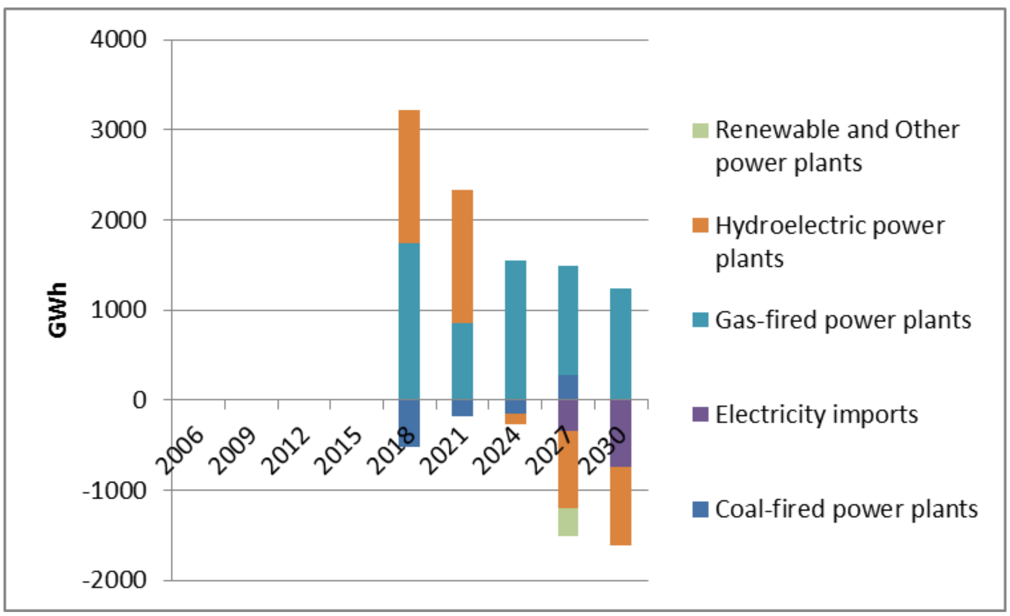
The presence of combined cycle does not significantly change the pattern of energy consumption across sectors. Electricity export is reduced in 2018-2024 compared to the Reference scenario; however, in following years, electricity exported is more than in the Reference case. Final energy consumption is almost unaffected and the deviation from the Reference scenario is below 0.4 in all years except 2024 (1ktoe).

Figure 18. Change in Final Energy under CC Scenario



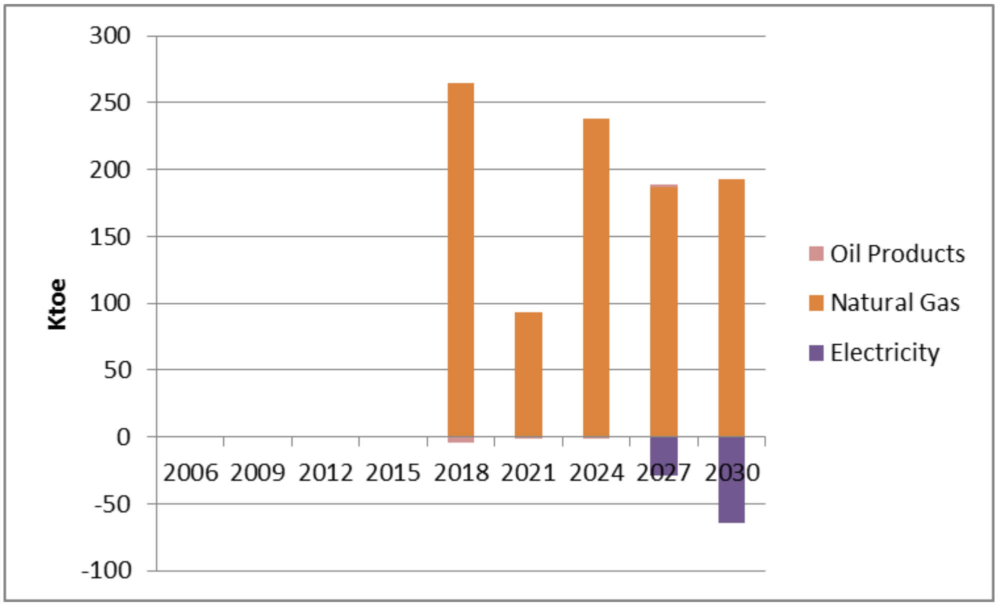
Along with the CC plant, the model suggests construction of more hydro power in initial years, which, however, is subsequently compensated by fewer new hydro plants added in subsequent years. The construction of this new capacity is accompanied by a boost of electricity generation and export of an average of additional 2 TWh over the period of 2018-2024. The figure below shows how the electricity generation pattern differs from that of the Reference scenario.

Figure 19. Change in Electricity Generation under CC Scenario



Compared to the Reference case, there is an increase in import of natural gas, with a slight reduction in oil import and electricity import dropping in the later periods.

Figure 20. Change in Imports under CC Scenario



In summary, this sensitivity reflects that building of CC plants can reduce energy system cost; however, dependency on imported fuel will increase, which weakens energy security. The exact benefits of this scenario depend crucially on the prices of natural gas and export of electricity.

APPENDIX I: DATA SOURCES AND KEY ASSUMPTIONS

The Georgia analysis is based on numerous data inputs and assumptions, and therefore requires a set of key national data sources. This information with their sources are listed by data requirement in Table 11.

Table 11. Key Data Sources

Data Requirement	Source
2006 Energy Balance	Georgia Energy Balance 2006 prepared by WEG
2009 Electricity and Natural Gas Balances	Ministry of Energy and Natural Resources (MENR), GNEWRC
Domestic Energy Prices	Ministry of Economy, Trade and Energy, Georgian National Energy and Water Supply Regulatory Commission (GNEWRC)
Resource Potential, including imports/exports	MENR, General Directory of Customs , Georgia State Electric Systems (GSE), USAID studies (WEG)
Installed capacity and characterization of existing electricity, plants	MENR, GSE
Electricity generation by plant (type)	Georgia MENR, GSE
Fuel consumption patterns by energy service	Georgia MENR, GEOSTAT, WEG/NATELI 2010
Demand Drivers	Ministry of Finance, GEOSTAT, National Bank of Georgia (NBG)
Known energy policies	Main Directions of State Energy Policy 2006, Government Program "Renewable Energy 2008

Drawing on these data sources 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 or surveying.

The Planning Team has ensured (to the extent possible) that current or planned policy is reflected in the Reference scenario (e.g. accelerated construction of power plants, natural gas import policy, no supportive policies to EE or RE other than hydro). They have also consulted with different sector experts to ensure that the Reference scenario in the model is reasonable.

A set of key assumptions provide the basis for the Reference case, which properly reflects the situation in Georgia today (see Table 12 to Table 15).

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

A. Plant Performance Data

Power Sector - Hydro	Available from (in model)	Life	Installed or Available Capacity	Seasonal Load Factor			Contribution to peak
				Summer	Winter	Other	
		Years	MW	Fraction			Fraction
Existing plant - Cascade							
Enguri HPP and Vardnili HPP	2006	29	1640	0.38	0.22	0.19	1
Other regulating HPP	2006	29	440	0.28	0.39	0.29	1
Existing Plant - Run of River HPP	2006	29	605	0.43	0.46	0.45	1
New build - Cascade							
Khudoni	2021	90	702	0.36	0.07	0.14	1
KHobi1	2018	90	46.5	0.58	0.38	0.49	1
Namakhvani	2017	90	450	0.27	0.19	0.29	1
Zoti	2018	90	36	0.39	0.41	0.45	1
Pharavani	2018	90	78	0.38	0.53	0.44	1
Khobi2	2018	90	39.5	0.61	0.41	0.52	1
Mtkvari	2018	90	43	0.49	0.56	0.50	1
Nenskra	2021	90	210	0.80	0.56	0.51	1
Dariali	2015	90	109	0.83	0.194	0.398	1
New build - Small hydro (less than 15)	2015	90	111	0.66	0.38	0.55	0.8
New build - Small hydro (more than 15)	2015	90	240	0.61	0.64	0.70	0.8

B. Plant Cost Data

	Technology Cost (on 2006 Euro basis)					
	Investment	Full project cost	Fixed O&M	Var. O&M	Fuel costs	Levelised cost (calculated
	(EUR/kW)	€M	Euro/kW	Euro c/kWh	Euro c/kWh	Euro /kWh
New build - Cascade						
Khudoni	1115	621.27	5.8	0.4	n/a	0.0433
KHobi1	1505	64.821	8.6	0.4	n/a	0.0255
Namakhvani	2062	800. 1	23.0	0.4	n/a	0.0490
Zoti	1929	64. 296	8.6	0.4	n/a	0.0400
Pharavani	1436	99. 996	8.6	0.4	n/a	0.0241
Khobi2	1422	51. 982	8.6	0.4	n/a	0.0234
Mtkvari	1306	51. 987	8.6	0.4	n/a	0.0255
Nenskra	2563	464. 1	8.6	0.4	n/a	0.0387
Dariali	1070	108. 019	8.6	0.4	n/a	0.0215
New build - Small hydro (less than 15 MW)	1503	160. 506	13	0.2	n/a	0.0251
New build - Small hydro (more than 15 MW)	1657	368. 4	13	0.2	n/a	0.0414

- The model has four seasons including "Winter" December-March, "Gazapkhuli" April-July, Summer August-September and Fall – October-November. This choice is determined by the seasonality of hydropower potential and demand on electricity as well as gas for heating.
- The lifetime of power hydro power plants is not limited. Thermal power plants are being either decommissioned or retrofitted within the planning horizon.
- The existing construction projects (Paravani, Khobi, Dariali, Larsi, coal-fired power plant) are included as must-run plants starting from their respective scheduled completion periods. Other HPPs are left for the model choice to be commissioned.
- Investment cost was calculated using future values approach in order to account for construction period.

Table 13. Key Assumptions in the Reference Scenario: Power Sector - Other

Power Sector - Thermal+Other	Technology Performance										
	Start	Life	Available Capacity	Efficiency	Annual Load Factor	Contribution to Peak	Investment	Fixed O&M	Var. O&M	Fuel costs	Levelised Cost
		Years	MW	%	Fraction	Fraction	Euro/ kW	Euro/ kW	Euro c/kWh	Euro c/kWh	Euro c/kWh
Lignite Coal Power Plant	2018	40	160	36	0.742	1	1,160	25	1.2	2.74 for lignite - 0.37 for heavy oil	0.0625
Power plant, wind medium farms	2015	20	50	100	0.25	0.15	1,000	40	0	n/a	0.0904
Power plant, wind large farms-Kutaisi	2015	30	150	100	0.258	0.15	1,000	40	0	n/a	0.0526
Power plant, wind large farms - Chorokhi	2015	30	90	100	0.249	0.15	1,000	40	0	n/a	0.0545

- Levelized cost was calculated to compare electricity cost generated from different sources.
- The model was forced to build lignite coal power plant of full capacity

Table 14. Key Assumptions in the Reference Scenario: Energy Prices

Import Commodity Price Assumption										
	Unit	2006	2009	2012	2015	2018	2021	2024	2027	2030
Oil	€2006/GJ	8.4	7.0	8.8	11.0	12.1	13.1	13.8	14.5	15.2
Gas	€2006/GJ	4.26	4.26	3.74	3.97	4.21	4.47	4.75	8.52	4.26
Coal	€2006/GJ	2.61	2.61	2.62	2.62	2.75	2.86	2.92	2.97	3.02
Electricity	€M2006/PJ	13.56	13.56	13.56	14.39	15.27	16.20	17.19	18.25	19.36
Export Commodity Price Assumption										
Electricity to Russia	€M2006/PJ	8.89	8.89	8.89	9.43	10.01	10.62	11.27	11.96	12.7
Electricity to Turkey	€M2006/PJ	13.33	13.33	13.33	14.15	15.02	15.94	16.91	17.95	19.04

- Electricity is imported only from Russia
- Price for imported electricity equals to $0.06 and from 2015 it rises to account for inflation
- Price of exported electricity to Russia is $0.04, while in Turkey it is exported for $0.06. Both priced are rising from 2015 to account for inflation
- Price of imported gas is $160 per 1000 m^3 and from 2012 it rises to account for inflation
- Coal is imported from Ukraine and its price is $100. Coal price was adjusted for inflation as well

Table 15. Key Assumptions in the Reference Scenario: Infrastructure

Existing Transmission and Distribution Infrastructure		Existing Capacity	Life	Annual Availability	Base year capacity factor	Losses (TS)								
						2006	2009	2012	2015	2018	2021	2024	2027	2030
Natural gas		PJ/a												
	Existing Pipeline	170	30	100%	39.8%	3.8%								
	Commercial distribution	8.26	30	100%	50.0%	0.0%								
	Power sector trunk lines	46.11	30	100%	50.0%	0.0%								
	Industry distribution	35.38	30	100%	50.0%	0.0%								
	Residential distribution	29.97	30	100.0%	50.0%	0.0%								
Electricity		GW												
	Transmission of Electricity			100%		4.9%	4.7%	4.6%	4.4%	4.3%	4.1%	4.0%	3.8%	3.7%
	Distribution of Electricity			100%		8.1%	7.3%	6.5%	5.6%	4.8%	3.9%	3.1%	2.3%	1.4%

The primary data for technologies used in the non-transport end-use sectors draws on the technology characterizations employed in the EU New Energy Externalities Developments for Sustainability (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 analysts to include in their model. The cost (M€/PJa) and performance characteristics for a subset of the key base devices are shown in Table 16.

Table 16. Characterization of Key Base Demand Devices

Energy Service Demand	Demand Device	Investment Cost (€/GJ)	Efficiency (Fraction)
Commercial cooling	Central air conditioning	2.74	3.00
	Air heat pump	6.26	3.40
	Split air conditioner	2.74	3.00
Commercial lighting	Incandescent bulbs	5.00	1.00
	Halogen lamps	30.00	2.00
	Fluorescent lamps	20.00	4.00
Commercial space heating	Electric furnace	3.90	0.85
	Gas furnace	4.88	0.76
	Oil furnace	5.37	0.70
	Solar thermal (with oil)	23.42	0.68
	Solar thermal (with gas)	15.75	0.70
Commercial water heating	Electric water heater	10.00	0.90
	Gas water heater	20.00	0.70
	LPG water heater	20.00	0.70
	Oil water heater	12.00	0.65
Iron & Steel High temperature heat	High temperature heat (Gas)	20.00	0.75
Iron & Steel Mechanical drive	Motor drive (Electricity)	5.00	0.88
Iron & Steel Low temperature heat	Low temperature heat	10.00	0.72
Residential space heating	Electric Furnace	4.49	0.86
	Gas Furnace	4.39	0.67
	Oil Furnace	6.17	0.62
	Solar thermal (with oil)	15.85	0.68
	Solar thermal (with gas)	8.96	0.70
	Ground source heat pump	20.13	3.33

Energy Service Demand	Demand Device	Investment Cost (€/GJ)	Efficiency (Fraction)
	Solar heat pump	16.78	4.00
	Biomass furnace	5.72	0.55
	Coal furnace	5.72	0.57
	LPG furnace	6.45	0.67
	Heat pumps	13.42	1.90
Residential cooling	Ground source heat pump	1.54	2.55
	Solar heat pump	3.09	0.64
	Air source heat pump	0.99	2.00
Residential lighting	Incandescents	15.28	1.00
	Halogen	19.10	2.80
	CFL	16.55	4.60
Residential hot water	Electric water heater	10.00	0.90
	Gas / LPG water heater	20.00	0.70
	Oil water heater	12.00	0.65
	Biomass water heater	14.00	0.60
	Solar (with electric) water heater	60.00	0.90
	Solar (with gas) water heater	70.00	0.70

The characterization of the improved devices varies by end-use, but in general, for a series of efficiency improvements by, for example 20/30/50%, the base purchase price may increase a corresponding 0.74/1.34/2 times. All these assumptions may be further adjusted for national circumstances, although currently this standard approach is used.

Note that due to lack on data on the process details of Georgia industry an approach that calibrates to the current energy intensity of each industrial demand, with up to three generic options with similar price/performance improvements in the future, rather than representing specific processes/devices is employed.

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 13) 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.[9] Only the relative efficiency numbers are used and applied to information from the Sultan

[9] 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/

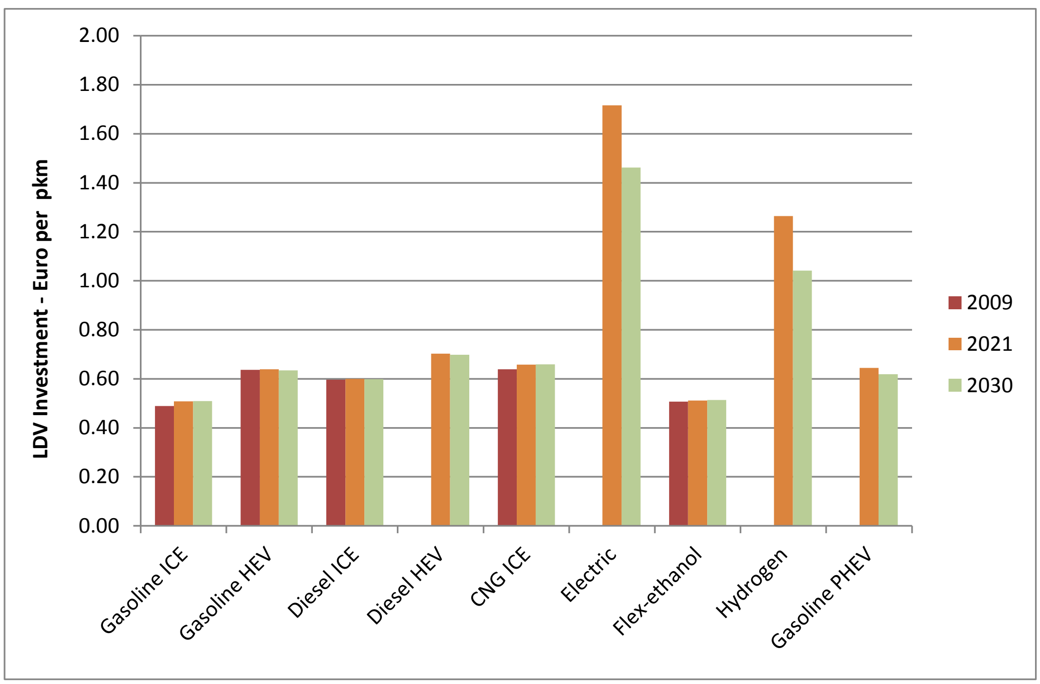
Tool mentioned above. Relative cost values are applied to user provided information on standard gasoline/diesel vehicles.

- 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.

Table 17. 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	43,817	659,331
	ELC	330	4968	15.05	43,817	659,331
Cars	GSL	428	700	1.64	13,189	21,573
	DST	449	735	1.64	13,189	21,573
	LPG	427	698	1.64	13,189	21,573
Motorcycles	GSL	984	1078	1.10	5,664	6,209
Heavy trucks	DSL	91	781	8.54	49,201	420,233
	CNG	69	588	8.54	49,201	420,233
Medium trucks	DSL	204	328	1.61	15,992	25,674
Rail Pass.	DSL	20	2453	124.6		
	ELC	32	3949	124.6		
Rail Freight	DSL	14	5431	393.0		
	ELC	22	8721	393.0		

Figure 21. LDV Efficiency by Type



Representation of the transport sector needs to be developed further both in terms of data quality as well as proper representation of technology options. The information on the existing vehicle fleet is not sufficiently detailed and model is not given a choice for retrofitting the existing gasoline-fuelled vehicles to use of dual-fuel vehicles, using mostly CNG, which represents a considerable current trend due to relatively cheap gas price compared to gasoline. In the current model, penetration of CNG vehicles is fixed as an external parameter rather than free choice of the model.

Due to these deficiencies in modeling, the transport sector attempted to "isolate" it to draw conclusions for other sectors with confidence. Indeed, the transport sector is practically the sole and main user of oil products. Electricity use by transport is limited to railway and metro and has been properly depicted in the model. Penetration of other electric transport (plug-in hybrids and electric vehicles) is weak and does not significantly affect the projections of electricity demand.

For 2006, the transport sector is calibrated to the national energy balance. The transport sector energy totals have been disaggregated using Georgia 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 describes 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 basis of cost rather than using fixed limits.

The calibration process for various RESMD models uses hurdle rates of 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.

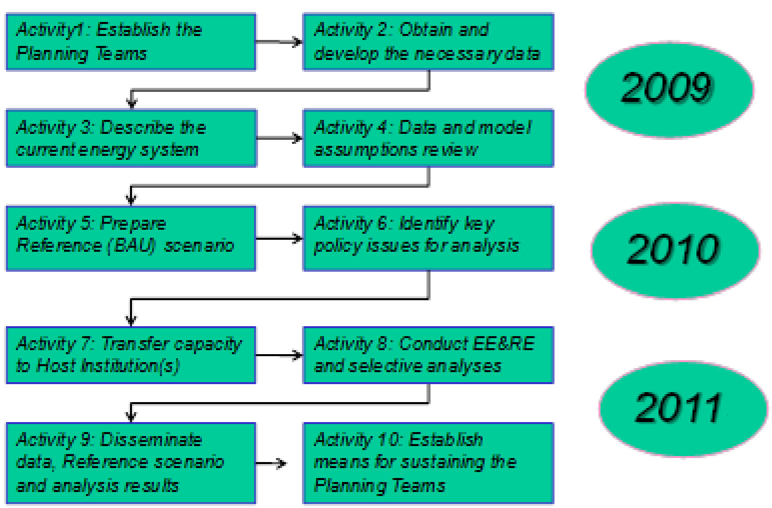
APPENDIX III: PROJECT ACTIVITIES AND METHODOLOGY EMPLOYED

MAJOR PROJECT ACTIVITIES

The consultant teams for International Resource Group (IRG) worked with key personnel from the Georgian Ministry of Energy and Natural Resources and World Experience for Georgia to establish a credible MARKAL-Georgia model, and guide the 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 as well as other country specific alternative scenarios.

Over the course of two years, the joint SYNENERGY Strategic Planning (SSP) effort undertaken by the US Agency for International Development (USAID) was able to introduce new methods, implement these methods, and transfer the capabilities to the national counterparts in a sustainable manner (see Figure 21). 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 21. 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.

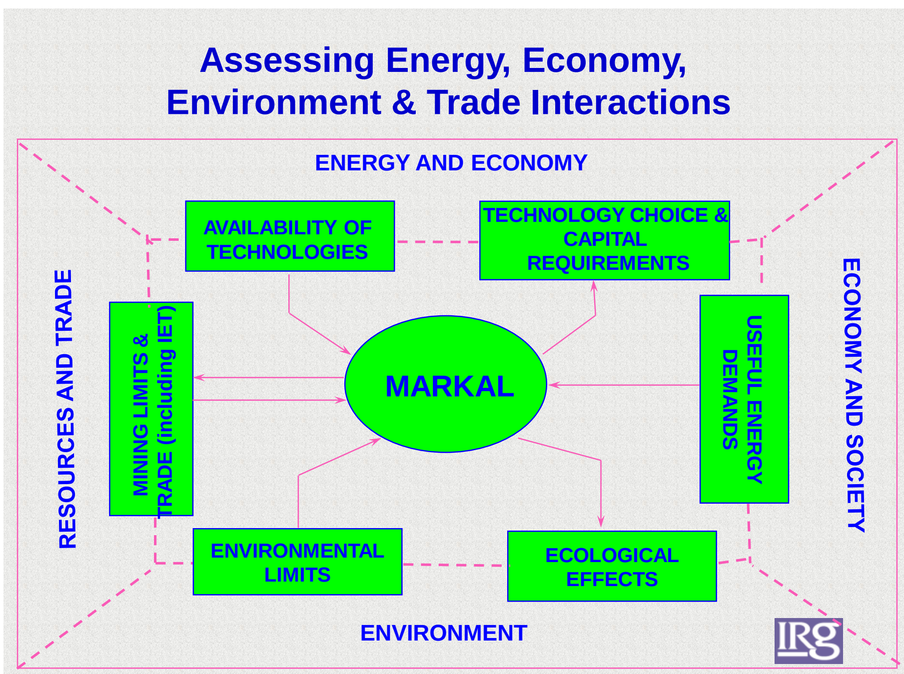
At least as important as the energy balances themselves, and the accompanying information systems, is the process of building a team of professionals in each country who can work with the data, maintain the information systems, and support higher level analytical approaches. This team-building should 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 22).

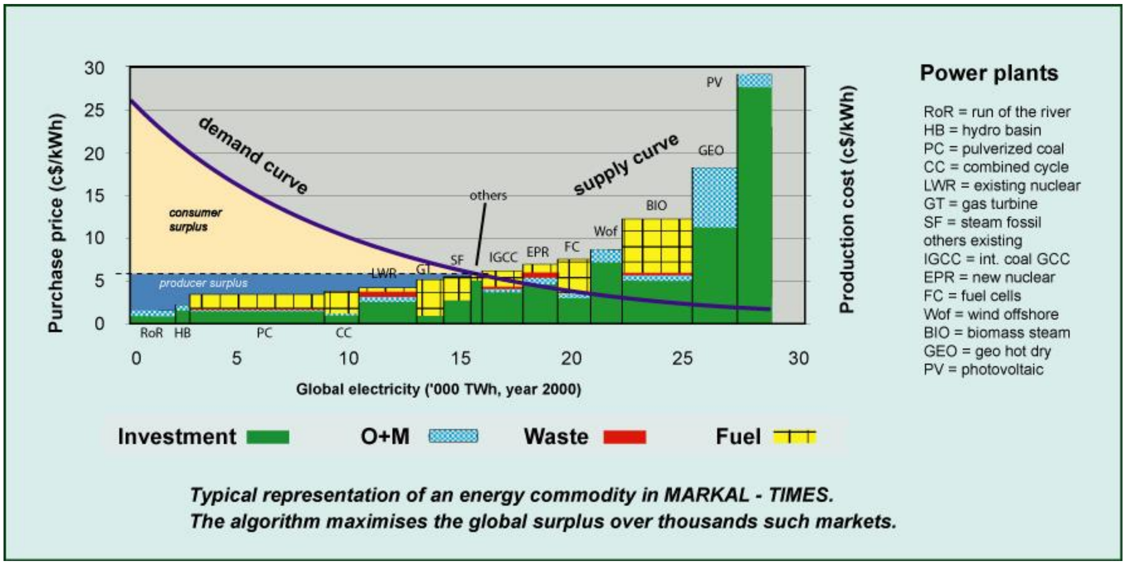
Figure 22. Interactions in the MARKAL/TIMES Model



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 23) 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, 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 23. Power Plant Dispatch in the MARKAL/TIMES Model



One of the most relevant suite of studies conducted recently is the one sponsored by the European Union that employs 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) [10] undertaking. The Pan-European TIMES model (PET)[11]evolved from the original NEEDS model and has been employed for series of high profile EU projects, including RES202 [12] examining the EU renewables directive, [13] REALISEGRID[14] 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).[15] Another pair of high-profile uses of MARKAL/TIMES is the IEA Energy Technology Perspectives[16] and UK Climate Change Policy "White Paper."[17]

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

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

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

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

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

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

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

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

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