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 COUNTRIES:

MOLDOVA POLICY BRIEF

July 2012

This report was produced for review by the United States Agency for International Development (USAID). It was prepared by Institute of Power Engineering (IE ASM) and International Resources Group (IRG).

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ACRONYMS

AEO	Annual Energy Outlook
IE ASM	Institute of Power Engineering of Academy of Sciences of Moldova
BAU	Business as Usual
CC	Combined cycle
CRES	Centre for Renewable Energy Sources
EC	Energy Community
ECS	Energy Community Secretariat
EE	Energy Efficiency
EIA	Energy Information Association (US)
ESEC	Energy Strategy of the Energy Community
ESD	Energy Services Directive
EU	European Union
GDP	Gross Domestic Product
GFEC	Gross Final Energy Consumption
GT	Gas turbines
HGVs	Heavy Goods Vehicles
ICE	Internal combustion engine
IE ASM	Institute of Power Engineering of Academy of Sciences of Moldova
IPA	International Policy Analysis
IRG	International Resources Group
LCVs	Light Commercial Vehicles
LDVs	Light Duty Vehicles
LPG	liquid petroleum gas
LWR	Light Water Reactor
MARKAL	MARKet ALlocation
MoE	Ministry of Economy of Moldova
NEEP	National Energy Efficiency Program of Moldova 2011-2020
NEEAPs	National Energy Efficiency Action Plans
NEED	New Energy Externalities Developments for Sustainability
NPV	Net Present Value
NREAP	National Renewable Energy Action Plan
O&M	Operation and maintenance

PC	Pulverized coal
PET	Pan-European TIMES model
RE	Renewable Energy
REDP	Regional Energy Demand Planning
RESMD	Regional Energy Security and Market Development
RPS	Renewable Portfolio Standards
SF	Steam fossil
SSP	SYNENERGY Strategic Planning
TPES	Total Primary Energy Supply
UK	United Kingdom
US	United States
USAID	US Agency for International Development

A. INTRODUCTION

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

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

This Policy Brief provides an overview of the analysis undertaken by the Moldavian Planning Team using their national MARKAL (MARKet ALlocation) integrated energy system model, MARKAL-Moldova. It particularly focuses on the role of energy efficiency (EE) and renewable energy (RE) in meeting future energy demand out through 2030 to support sustained economic growth and while considering 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, a review of key electricity sector assumptions, updated fuel prices, and improved emissions accounting, along with a more advanced approach to the energy efficiency analysis.

The analysis reflects several years of model development and use, jointly undertaken by the Ministry of Economy (MoE) and the Institute of Power Engineering of Academy of Sciences of Moldova (IE ASM), supported by International Resources Group (IRG) and the Centre for Renewable Energy Sources (CRES). The MARKAL-Moldova analysis undertaken uses a cross-sectoral, cost optimization approach to identify the most economic efficient set of measures, and produces a broadly similar mix to that being proposed in the Strategy.

This Policy Brief focuses on assessing the energy sector costs and benefits for the entire energy system of meeting energy efficiency and renewable targets in Moldova, as a Contracting Party of 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 of energy systems. Furthermore, what is important for decision-makers is that there is now a strategic planning platform available for Moldova, where model assumptions and policy scenarios may be readily changed and explored, that can provide analytic rigor and insights to underpin future national strategic planning and policy formulation.

The following supply and demand analyses have therefore been undertaken.

- Reference (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 meet national targets aimed at reducing final energy consumption (in line with National Energy Efficiency Action Plans or NEEAPs). 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. The EE scenario is fully discussed in Section D.

- Renewable Energy (RE) Target: This supply-side policy examines the requirements to successfully achieve a renewable energy target 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.

In addition, country-specific issues, in this case the decision by the Republic of Moldova to establish a national target for CO_2 emissions reduction, are examined in 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.

B. KEY INSIGHTS FOR POLICY MAKERS

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

Table 1. 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 diversifica-tion	• Increasing coal imports • Decreasing dependency on gas	• Increased use of domestic RE resources • Reduces fossil fuel imports by 1820 Ktoe (2.8%)	• Reduces fossil fuel imports by 2275 Ktoe (3.5%) • Lowers direct energy and electricity consumption by 4140 Ktoe (6.3%)	• Increased use of domestic RE (although at lower level than under RE case) • Cumulative total imports reduced by over 7.3%
Enhanced competitive-ness[1]	• Energy efficiency gains across sectors	• Higher cost electricity generation • Reduce cost of imported fuels, which drop by over 2.8%	• Lower fuel costs, saving 3.3% in fuel expenditure (990€M)	• Lower fuel costs, saving 3.3% in fuel expenditure (965€M)
CO_2 mitigation	• Emissions increase by 70% in 2030 due to increased use of coal in power sector	• Cumulative reduction of 3.7% due to switching to more biomass, away from coal in power sector, and to for heating in residential sector	• Cumulative reduction of 4.4% due to lower total energy consumption	• Cumulative reduction of 10.5% due to more RE and lower energy consumption

ENERGY SECURITY AND DIVERSIFICATION

Under both RE and EE scenarios, import levels will be reduced by around 2.8% and 3.5% respectively, or a 7.3% reduction under the combined scenario case. This is due to increased use of indigenous renewable energy under an RE target, and lower energy demand resulting from increased energy efficiency. Under the EE case, the types of fuel imports reduced include gas and coal (over 50% and 30% respectively) while under the RE case, it is mainly coal imports that are reduced, due to a switch to biomass in both power generation and use in end-use sectors.

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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.

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 actually an overall cumulative saving in fuel expenditure of 670€ million, however only around a 2.2% 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) amount to a reduction of over 3% (in the combined scenario case), or cumulative saving of 990€ million, nearly offsetting the cost of the more expensive efficient technologies. Once transformed, the energy system savings continue into the future making the Moldova energy system more competitive over time.

The proposed 2020 RE target increases the cost of the energy system due to the additional renewable generation investment required. To meet the target, an additional 200 ktoe of RE is required by 2020, and is met by additional small hydro, wind, biomass combined heat and power (CHP), biofuels, and biomass for heating in end-use sectors. This highlights that a range of options is needed. Energy system costs are 0.65% higher (200€ million Net Present Value (NPV)[2]). Implementing the RE target in parallel with policies to promote energy efficient technologies highlights strong synergies between policy objectives. However, cost reductions are not larger in the combined case because the RE target wants more biomass use while the EE case wants to reduce this due to inefficiency of its use.

In addition, a combined EE+RE policy can substantially reduce imports by 7.3%, saving valuable foreign exchange funds, amounting almost 1€ billion cumulatively that can be rechanneled for other domestic priorities to offset some of the more expensive generation and efficient device upfront costs.

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 of building retrofits and deploying renewable power generation alternatives, are not captured by this analysis.

CO_2 MITIGATION

The policies examined show strong synergies with a goal of moving to a lower carbon footprint for the Moldova energy economy. The combined EE & RE policy leads to cumulative reductions of 10.5% in CO_2 emissions. This is accomplished by increasing renewable generation from wind and biomass generation, increasing direct biomass use primarily in the end-use sector, coupled with the overall reduction in demand for energy owing to the more efficient energy system.

Introducing an ambitious CO_2 target in parallel with RE/EE targets does not add significant cost due to the synergies discussed above. The RE/EE targets on their own achieve a reduction target of 45% (relative to 1990 baseline) in 2021.

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[3] (ESEC) 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 Euros, a figure that dwarfs actual investment in new capacity

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

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

over the past two decades. The MARKAL-Moldova Reference scenario shows that rapid electricity demand growth requires a more than doubling of electricity generation capacity by 2030 to 950 MW at a cost of nearly 680 €million. At the same time, policy priorities to ensure secure, diverse supplies and mitigate carbon dioxide emissions increase the challenges.

Investment in energy efficiency is a key strategy to meet these priorities. The MARKAL-Moldova analysis shows that a 2.6% reduction in final energy consumption can be achieved at a net savings of 230 € million (or 0.8%) by reducing barriers to the uptake of energy efficiency. while achieving the more ambitious NEEAP target of 9% requires only a modest cost increment of 0.2% (55 € million) over the baseline, while saving 990 € million in fuel expenditures and reducing both imports and carbon emissions by 4%. Achieving these goals does require an 8% increase in investment (or 500 € million) for more efficient demand devices, resulting in a nearly 50 € million reduction in new power plant expenditures. The most cost effective areas for energy efficiency investment identified in this analysis include residential and commercial space heating, and industrial process heat. The MARKAL-Moldova 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, without simultaneously promoting energy efficiency,, increases energy system costs by 0.7% (or just under 200 € million) and requires a 20% increase in the required power sector capacity additions, at 100 € million in investment costs. Achieving the target yields substantial benefits: a 3% decrease in imports and 4% reduction in carbon emissions.

Although the investment challenges are significant, pursuing the EE and RE strategies simultaneously leads to important synergies that enhance the benefits just mentioned. The increase in system cost is limited to under 1% (or just over 300 € million). The savings include over 3% saving in fuel costs (almost 1 € billion), 10.5% decrease in carbon emissions, and over 7% decrease in imports. The benefits of these investments extend beyond 2030, creating a lasting shift of the economy onto a lower energy intensity, more sustainable and secure trajectory.

The analyses described herein also make it clear that Moldova 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 national goals, and to evaluate Energy Community proposals to assess the national implications. Key areas for future analysis include assessing optimal design for feed-in tariffs to encourage renewables development, and developing targeted energy savings policies, including standards and appliance and retrofit subsidies.

C. MOLDOVA BUSINESS-AS-USUAL ENERGY PATHWAY

To assess the impact of different strategies or policies on the evolution of the energy system in Moldova, the Planning Team developed a Reference scenario, which takes into account specific characteristics of the Moldova 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 Energy Strategy of Moldova to year 2020, and draft Energy Strategy to year 2030. In addition, all other available national data sources (State Statistical Office, National energy balances, etc.) as well as some international databases (e.g., International Energy Agency) were utilized. The full list of information sources is provided in Appendix I. Once established, the Reference scenario can also produce baseline estimates of energy consumption and carbon emissions to measure trends with respect to achieving NEEP and low emission development goals.

Energy demand growth is driven by the rather optimistic assumption regarding economic growth, averaging around 5% per annum, so the resulting requirements for the energy system may be on the high side of what will actually be needed. A key assumption underpinning the Reference scenario is that by 2015 a coal-fired power plant will be readily available to power generation.

Under the Reference scenario, energy consumption is projected to grow significantly, by 40% in terms of final energy by 2030, driven by strong Gross Domestic Product (GDP) growth and increasing per capita consumption. This will require a more than doubling of the electricity generation system from 360 to 950 MW. Growth in demand will result in higher imports as well as significant growth in CO_2 emissions. Key indicators from the Reference scenario are shown in Table 2 and summarized subsequently.

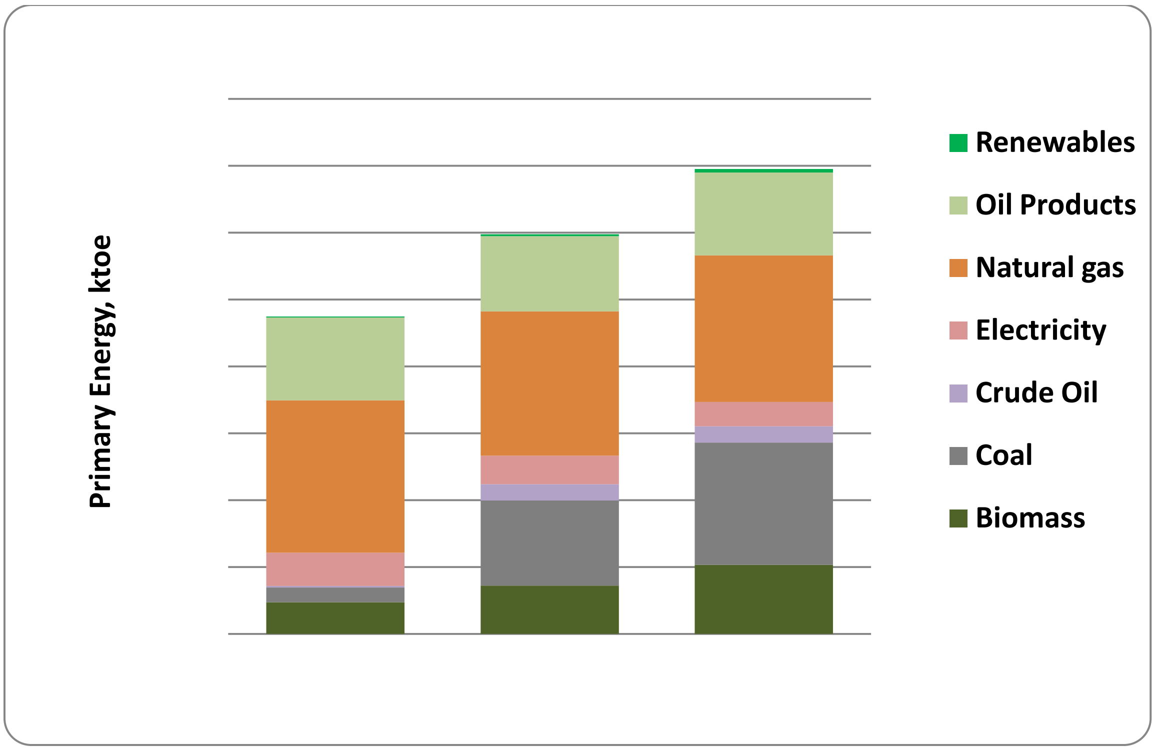
Table 2. Key Indicators for the Reference Scenario

Indicator	2006	2030	Annual Growth Rate (%)	Overall Growth (%)
Primary Energy (Ktoe)	2,374	3,477	1.6%	46.5%
Final Energy (Ktoe)	2,052	2,871	1.4%	39.9%
Power plant capacity (GW)	0.361	0.953	4.1%	163.9%
Imports (Ktoe)	2,110	2,806	1.2%	33.0%
CO_2 emissions (Kt)	4,781	8,143	2.2%	70.3%
GDP (€ Mill.)	7,000	22,576	5.0%	222.5%
Population (000s)	3,589	3,842	0.3%	7.0%
Final Energy intensity (toe/€000 GDP)	0.293	0.127	-3.4%	-56.6%
Final Energy intensity (toe/Capita)	0.572	0.747	1.1%	30.7%

Primary energy consumption in 2030 is projected to be nearly 3,500 ktoe, increasing from 2006 levels by 47%. Whilst growing GDP and increasing household energy intensity are driving up energy demand, it is also important to note that energy intensity per unit of economic output is significantly lower than observed in 2006 – estimated to be 0.127 toe/1000€, a reduction of around 57%. This is a result of the continuation of current structural changes in the economy and natural technological progress underway throughout the world.

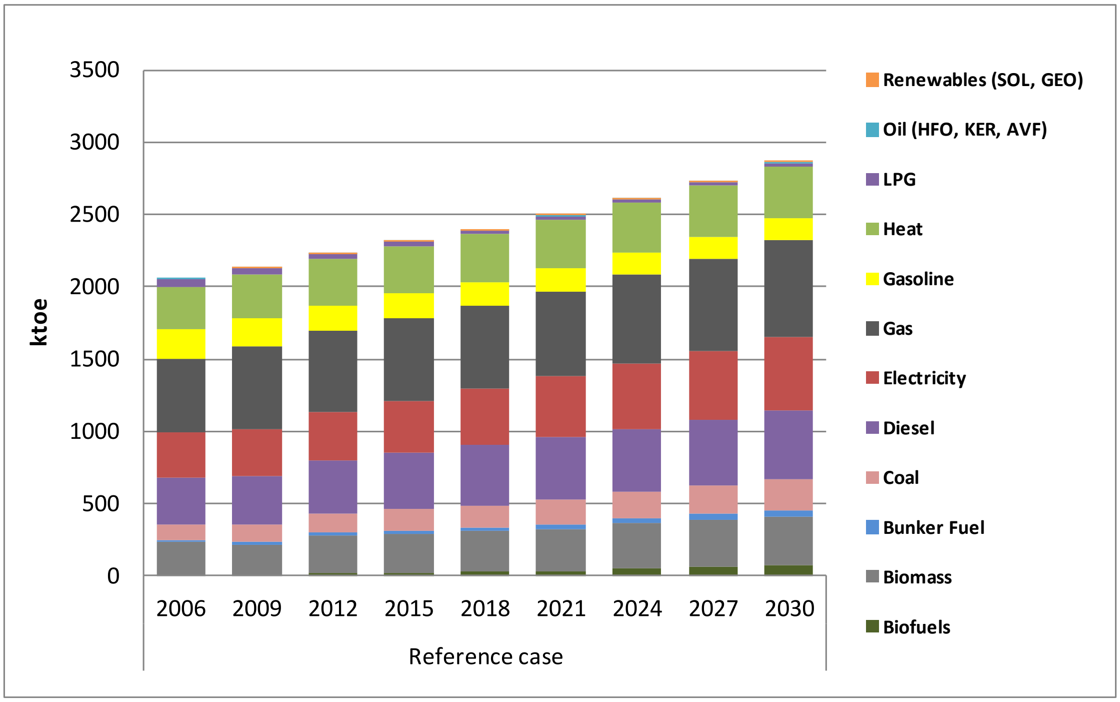
In addition to the growth in primary energy supply, it becomes more diverse. As shown in Figure 1, there is a shift to coal, accounting for 26% of total supply by 2030, up from 4%, owing to the new coal-fired power plant. Gas supply is reduced as a share of the total, from 48% to 32%, due to less use for power and heat generation; however, it remains a critical source of energy in Moldova, at a similar level in 2030 as observed currently. The increased level of crude oil (from 0.5 to 4%) is due to an increase in domestic refining capacity. The biomass contribution increases from 10% to 15% of total supply, as households switch to more modern forms of biomass energy. (The growth in biomass use is extremely uncertain and could be lower if more households decide to switch to conventional forms of energy, despite the cost advantage of biomass).

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



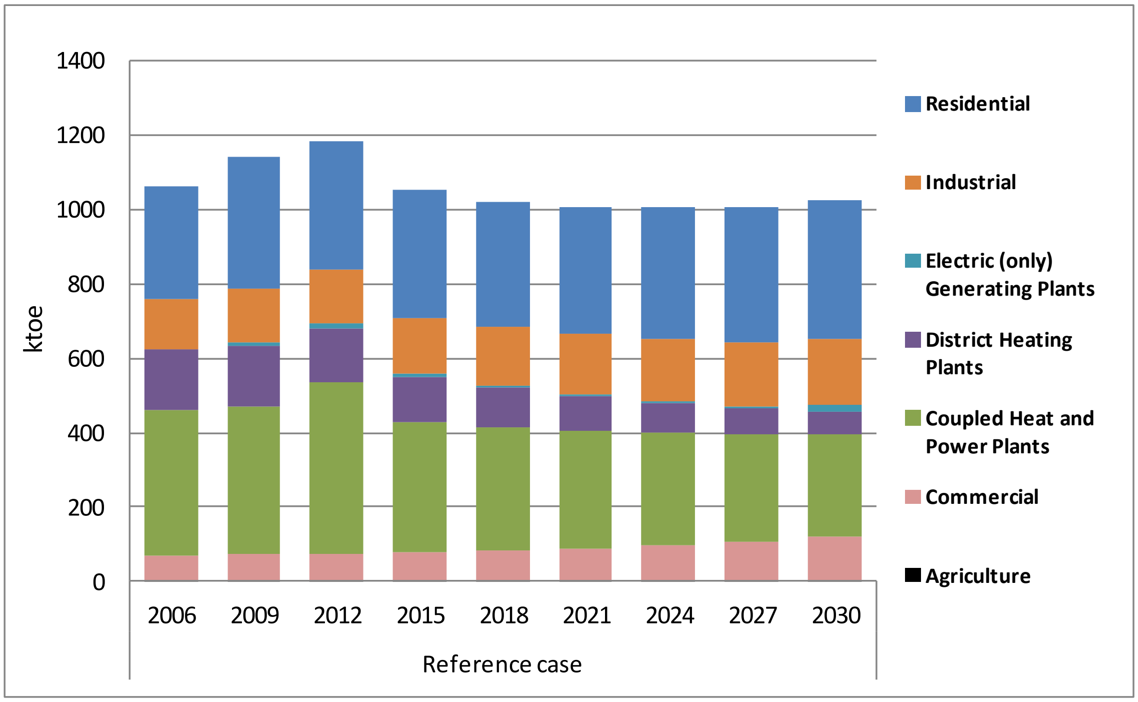
Total final energy consumption grows by approximately 40% over the planning horizon, with gradual growth across most fuel types, as shown in Figure 2. Broadly, the mix of fuels remains relatively similar to the shares observed in the current system.

Figure 2. Final Energy Consumption by Energy Type



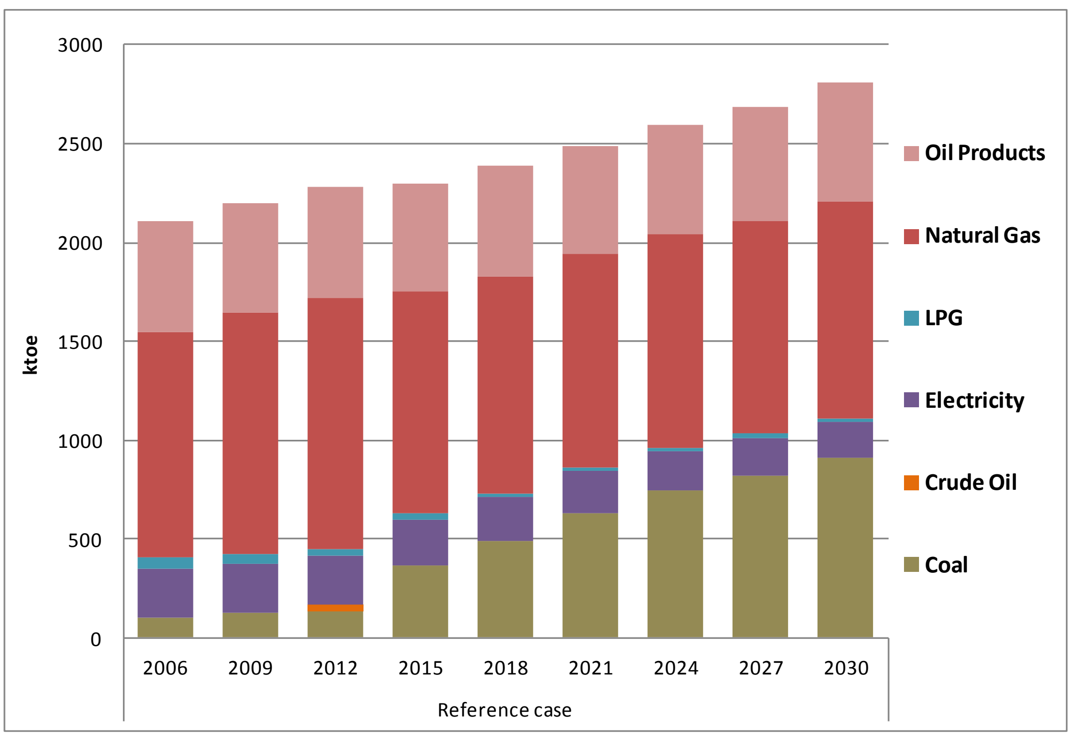
A more detailed view of gas consumption by sector is shown in Figure 3. It shows that the majority of gas is used in the residential and industry sectors as well as for coupled heat and power generation. However, with the availability of coal for CHP and power generation from 2015, the gas use in CHP and heating plants declines. In the residential sector, gas is used primarily for cooking and space/water heating, and remains a key source of energy, as it does in industry, where it is used for the production of high temperature heat for a number of different processes.

Figure 3. Gas Consumption by Sector and Power Plant Type



The majority of fossil energy requirements are imported. The main growth in imports is from coal, used for power generation. The share of imports increases from 6% to 32% by 2030. A resulting drop in the share of gas imports is observed, from 56% to 39% over the model horizon.

Figure 4. Imports by Type

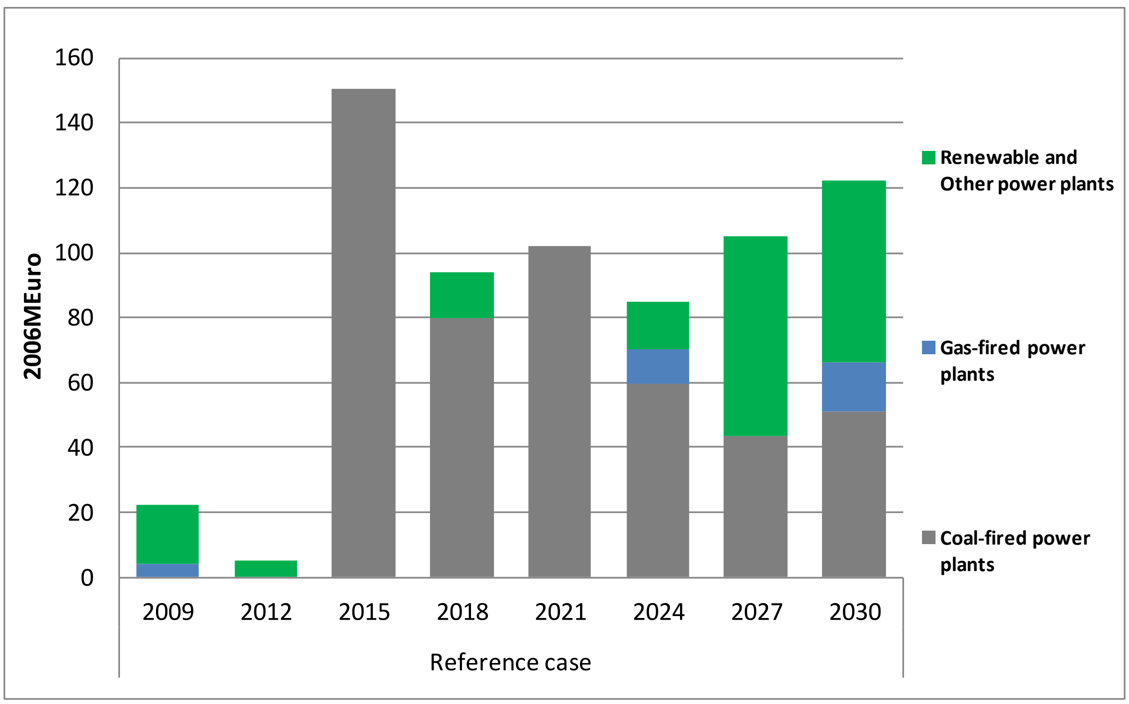


New power generation capacity is shown in Table 3 (aggregated for each three-year period). Cumulative additional capacity of 593 MW to 2030 is projected. Coal capacity comes online in 2015, making the most significant contribution (438 MW) while wind (20MW) and biomass plant (83 MW) make important contributions post-2020.[4]

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

Plant Type	2009	2012	2015	2018	2021	2024	2027	2030	Total
Coal	0	0	136	71	95	48	39	49	**438**
Gas	7	0	0	0	0	17	0	28	**53**
Renewables (Biomass / wind)	10	4	0	10	0	10	35	35	**103**
Total New Capacity	**17**	**4**	**136**	**81**	**95**	**75**	**74**	**111**	**593**
% of Installed Capacity	4.6%	0.9%	26.2%	13.6%	13.7%	9.8%	8.7%	11.7%	

Figure 5. Total Investment Cost of New Power Plants[5]



Growth in the energy system will require significant levels of new investment and increased payments for fuel. However, energy system expenditures are generally expected to absorb a smaller percentage of GDP in 2030 due to the reduced energy intensity per unit of economic output, as shown in Table 2. A breakdown of the energy system cost components is presented in Table 4, showing the growth in

[4] In reality, much of the capacity would not be built in the increments shown. However, a function of linear programming is that any size of increment can be built, irrespective of plant type (unless an alternative model formulation – lumpy investment – is used). Despite this, the model still provides a useful insight into the most cost-effective generation options.

[5] Investment levels are not annual but cumulative for a three-year period.

expenditure for fuel (extraction, import, and sector differential charges), operating and maintenance costs (fixed and variable), investments in new power plants, and the purchase of new end-use devices. The investment expenditures for new power plants and devices are incurred as demand rises and existing power plants and devices reach the end of their operational lifetimes.

Table 4. Annual Energy System Expenditure (€ Million)[6]

Expenditure Type	2009	2012	2015	2018	2021	2024	2027	2030
Fuel Costs	1,059	1,346	1,483	1,625	1,767	1,880	2,026	2,191
Operation and maintenance (O&M) Costs	380	410	444	483	521	553	590	629
Annualized Investment (Demand)	160	358	557	769	910	984	1,054	1,117
Annualized Investment (Power)	2	2	15	23	31	38	47	57
Total	**1,601**	**2,116**	**2,499**	**2,899**	**3,229**	**3,455**	**3,717**	**3,994**

Under the Reference scenario assumptions, to add the 593 MW of new generation capacity required by 2030, a total investment of 685€ million is required, which translates to average annual payments on the order of 85€ million. At the same time, by 2030 over 350€ million will be required to cover the cost of new demand devices, with the majority of this investment made by the private sector, including households. Fuel supply costs will also increase significantly, in fact doubling, driven by growing demand and increasing prices, from 1.1€ billion per year to 2.2€ billion per year.

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

D. EXAMINATION OF THE PROMOTION OF ENERGY EFFICIENCY IN MOLDOVA

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

The background to this EU Directive was highlighted in the *Green Paper on the Security of Energy Supply* (2000) which noted increasing dependence on external energy sources, and an increase from 50% to 70% by 2030. At the same time, the role of the energy sector as an emission source needed to be addressed, responsible for no less than 78% of EU greenhouse gas emissions. Therefore, efforts were required to focus on improving end-use energy efficiency and controlling energy demand.[7] The Directive notes that: *Improved energy end-use efficiency will make it possible to exploit potential cost-effective energy savings in an economically efficient way.*

For Moldova, the National Energy Efficiency Program (NEEP) 2010-2020[8] is developed in compliance with the Energy Strategy until 2020, Law on Renewables no. 160, EU-RM Action Plan, Law on joining the Energy Community Treaty, #117-VIII of 23.12.2009.

The Program has the following main objectives, comparing to base year – 2009:

- Improve energy efficiency by 20% of primary energy in 2020
- Increase use of renewable energy by 20% in year 2020
- A share of 10% of biofuels in total fuels by 2020
- Improve the environment by reducing CO2 emissions 25% by 2020 compared to 1990

The NEEP will be revised every three years according to the progress of the country and update of the EC and EU Directives.

In implementing policies and measures to increase energy efficiency, the focus is frequently on overcoming barriers to the take-up of different technologies, such as long payback periods, lack of familiarity with more efficient technology options, inconvenience, and high transaction costs. The costs of overcoming these barriers can be significant, and require strong policies and programs (e.g., appliance and building standards, information campaigns, low interest (subsidized) loans, "giveaway" programs for the low income groups). Such barriers and policy options are highlighted in the World Bank (2010) report *Status of Energy Efficiency in the Western Balkans*.[9] These costs are accounted for in this analysis by the

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[7] See European Commission website – http://europa.eu/legislation_summaries/energy/energy_efficiency/l27057_en.htm

[8] See "National Energy Efficiency Program 2011-2020" (NEEP), Gov.D. Nr. 833 of 10.11.2011, Published : 18.11.2011 in Official Monitor Nr. 197-202, art Nr : 914. http://lex.justice.md/index.php?action=view&view=doc&lang=1&id=340940

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

inclusion of so-called hurdle rates,[10] as discussed in Appendix II. As a result, such options are not invested in under the Reference case. However, it is assumed that when energy efficiency policies (e.g., setting a NEEP target) are pursued, programs aimed at reducing these impediments (or "hurdles") are also put in place, reducing those inherent added costs.

Under such a scenario (no NEEP target but reduced barriers to uptake), there is a 2.6% reduction in final energy consumption in 2018, with an overall savings to the energy system of 232€ million (or 0.76%), as shown in Table 5. However, simply removing some of these barriers is not enough to meet the reduction levels required by the NEEP target of 9%. So finding the balance between policies, programs, and targets is important to ensure that goals are achieved without undue burden on the economy or individuals.

Policies that promote increased energy efficiency have significant benefits with regard to competitiveness, energy security and climate change, as described below. Key insights include:

- A modest increase in discounted energy system costs of 0.18% (55€ million) is necessary to meet the NEEP target, however lowering cumulative fuel expenditure 989 € million in the process.
- Over 3.5% cumulative reductions in imports (2,275 ktoes) are observed under the NEEAP target, 52% of which is coal and 32% is gas. These import savings significantly contribute to the above fuel expenditure saving, reducing foreign exchange payments and enhancing energy security goals.
- Significant cumulative reductions in final energy of 6.3% are observed (4,138 ktoes).
- Strong synergies with low emission development, reducing CO_2 emissions by 4.4% (or 7,480 Kt).

The basis for the energy efficiency target is the Moldova NEEP, which has a 9% percentage reduction calculated based on the 2006-2009 average final energy consumption levels, which results in total reduction requirements from the Reference scenario levels of 187 ktoes (per annum). As the NEEP only extends out to 2018, it is assumed that the reductions under NEEP continue over the later years in the planning horizon, reflecting Government ambition to maintain improvements in energy efficiency over time.

Table 5 shows the key results as change between the Energy Efficiency and Reference 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 and the *Energy Efficiency + Target* reflects the former but also requires that the NEEP 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 to reduce barriers, resulting in overall energy system cost savings. In the second case, a target "forces" the energy system to go beyond this economically efficient level, and deploy additional higher cost technologies to meet the target level, but with ancillary benefits as discussed below.

The focus of this section is on the *Energy Efficiency + Target* case, as the NEEP is the main ongoing policy action in this area. As shown in the table, all of the key cumulative policy indicators (other than overall system cost) are improved due to efficiency induced savings. For example, imports drop by 3.5% and fuel expenditure goes down by 3.3%; saving 2,275 ktoe and 989€ million respectively. Such savings enhance economic competitiveness and energy security.

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[10] 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).

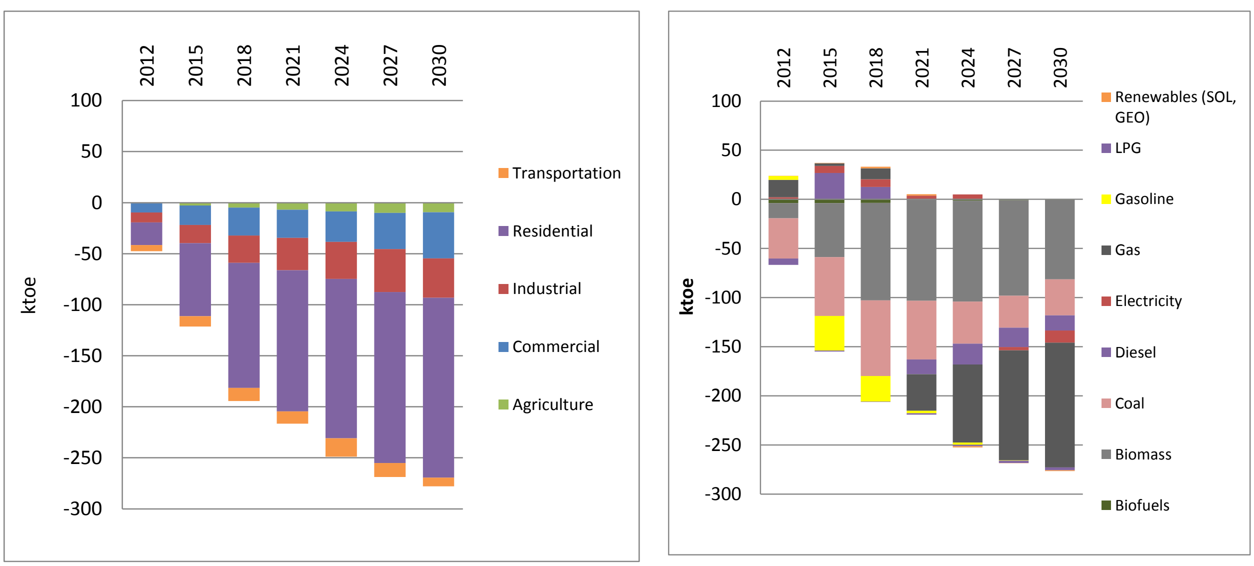
The slightly higher overall cost of the energy system is due to the increased expenditure for better performing demand devices that, despite policies and programs, still command a premium over conventional devices, though this is lower than would otherwise be the case in the absebce of such actions.

Table 5. Cumulative Impacts of the EE Target on the Energy System (Change Compared to Reference Scenario)

Indicator	Units	Reference	Energy Efficiency Promotion		Energy Efficiency + Target	
Total Discounted Energy System Cost	2006M€	30,507	-232	-0.8%	55	0.2%
Primary Energy Supply	Ktoe	77,692	-2,077	-2.7%	-4,159	-5.4%
Imports	Ktoe	65,530	-1,620	-2.5%	-2,275	-3.5%
Fuel Expenditure	2006M€	29,746	-673	-2.3%	-989	-3.3%
Power Plant New Capacity	MW	593	-31	-5.2%	6	1.1%
Power Plant Investment Cost	2006M€	685	-38	-5.5%	-45	-6.5%
Demand Technology Investments	2006M€	5,908	85	1.4%	497	8.4%
Final Energy	Ktoe	65,483	-1,897	-2.9%	-4,138	-6.3%
CO_2 Emissions	Kt	171,500	-3,843	-2.2%	-7,480	-4.4%

The contribution of different sectors to the targets is shown in Figure 6, indicating that energy saving potential is economy wide, and that all sectors provide a significant contribution. Under the energy efficiency target, the residential sector provides the largest savings (62% of total savings), followed by the industry (15%) and commercial sectors (14%).

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

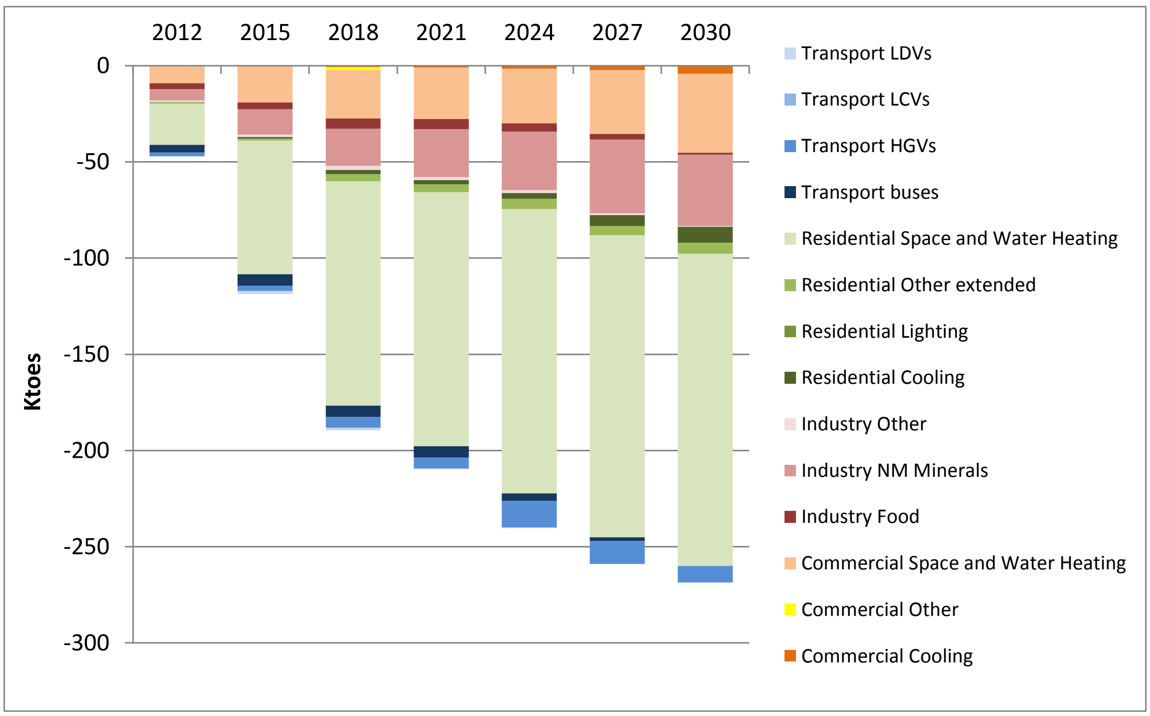


In terms of fuels, the largest near-term reductions come from biomass (residential, replaced by electricity/gas) and coal (commercial, replaced by gas). Post-2020, there are also significant reductions in gas, again primarily in the residential sector, due to more efficient space and water heating appliances.

A more detailed overview of the savings by energy service demands are shown in Figure 7. The most cost-effective reductions occur by deploying more efficient space and water heating systems, with a strong uptake of heat pumps (using electricity). Other more efficient appliances lead to a strong reduction in gas and biomass consumption in the residential sector. For the transport sector, there is an increasing purchase of hybrid vehicles across light duty vehicles (LDVs), light commercial vehicles (LCV)s, and heavy goods vehicles (HGVs).

In industry, savings are most prevalent in the food and non-metallic mineral industries, where efficiency savings from process heat are realized. Much of the commercial savings are in cooling and heating, where most of the savings are from more increased uptake of insulation (reducing cooling / heating demand), efficient appliances and some increased penetration of heat pumps. Lighting does not feature significantly as much of the efficiency savings are realized in the Reference case due to assumed market restrictions on the sale of incandescent bulbs.

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. This is highlighted in the World Bank (2010) report *Status of Energy Efficiency in the Western Balkans*. This particularly relates to understanding different appliance types in the building stock and potential for conservation measures (insulation, improved glazing, etc.). Therefore, it is important to continually review the data in the model for use in future analyses, assessing new data available in Moldova to further improve the robustness of the analysis.

Under the NEEAP target, costs are shown to increase overall despite significant reductions in fuel expenditure. This is because the advanced devices have a higher upfront cost, on top of which, despite policies and programs, not all the barriers to foster their uptake are fully overcome (as described earlier and more fully in Appendix II). However, the cost increases are modest, at 0.2% higher than the Reference case. In addition, the analysis does not reflect the wider economic benefits that could come from energy efficiency promotion, in terms of export competitiveness or stimulating new industries, e.g.

for solar water heaters. At the same time, there are significant co-benefits arise from pursuing energy efficiency goals, including energy security through reduced imports (3.5% reduction) and CO_2 reductions (4.4% reductions).

The modest costs to achieve the NEEP target would be significantly higher if policies and programs were not introduced to reduce the barriers to uptake of energy efficient technologies, rising 1.6% compared to 0.2%. Conversely, a more aggressive NEEP target post-2018 can be achieved at only modest additional cost. A 15% reduction by 2024 results in additional costs of 0.5% compared to the Reference case, highlighting scope for additional action. And under such an aggressive policy, the barriers would likely also be reduced resulting in more less overall cost for achieving the more ambitious target.

Such insights are useful in the context of the EU ambition to reduce primary energy by 20% by 2020 (relative to projected primary energy consumption). In fact, the EU is proposing a new Directive (*Proposal for a Directive of the European Parliament and of the Council on energy efficiency and repealing Directives 2004/8/EC and 2006/32/EC. EC draft 12046/2011, COM(2011)370, Issued 22 June 2011*) that is seeking to ensure that the 20% energy efficiency target can be met by 2020 – as current legislation will not achieve this goal.

E. ASSESSMENT OF A RENEWABLE ENERGY STRATEGY FOR MOLDOVA

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

The Energy Community Secretariat (ECS) commissioned a study in 2009 examining illustrative RE targets for the contracting parties,[11] 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 estimated targets.[12] A 2020 renewables target of 19% of Gross Final Energy Consumption (GFEC) for Moldova has been proposed by the ECS. However, a target value of 20% of Total Primary Energy Supply was used for consistency with the current national strategy.

The main highlights are noted below, with key insights summarized in Table 6 and elaborated upon in the rest of this section.

- Cumulative energy system costs (2005-2030) are 0.65% higher than under the Reference scenario. While this is a relatively modest increase it is important to highlight that significant additional investment is needed in the energy system, for example, in the power sector , increasing capacity by 18.9% (112 MW), requiring an additional 97€ million.
- Energy security is enhanced with a 2.8% cumulative decrease in the imports required as a result of increased use of indigenous biomass resources and renewable electricity.
- This policy contributes towards moving to a lower emissions pathway, with cumulative CO_2 reduction reaching 3.7%.

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

Indicator	Units	Reference	RE Target Change	
Total Discounted Energy System Cost	M€2006	30,507	199	0.65%
Primary Energy Supply	Ktoe	77,692	228	0.29%
Imports	Ktoe	65,530	-1,824	-2.78%
Fuel Expenditure	M€2006	29,746	32	0.11%
Power Plant New Capacity	MW	593	112	18.94%
Power Plant Investment Cost	M€2006	685	97	14.08%
Demand Technology Investments	M€2006	5908	227	3.83%

11 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.

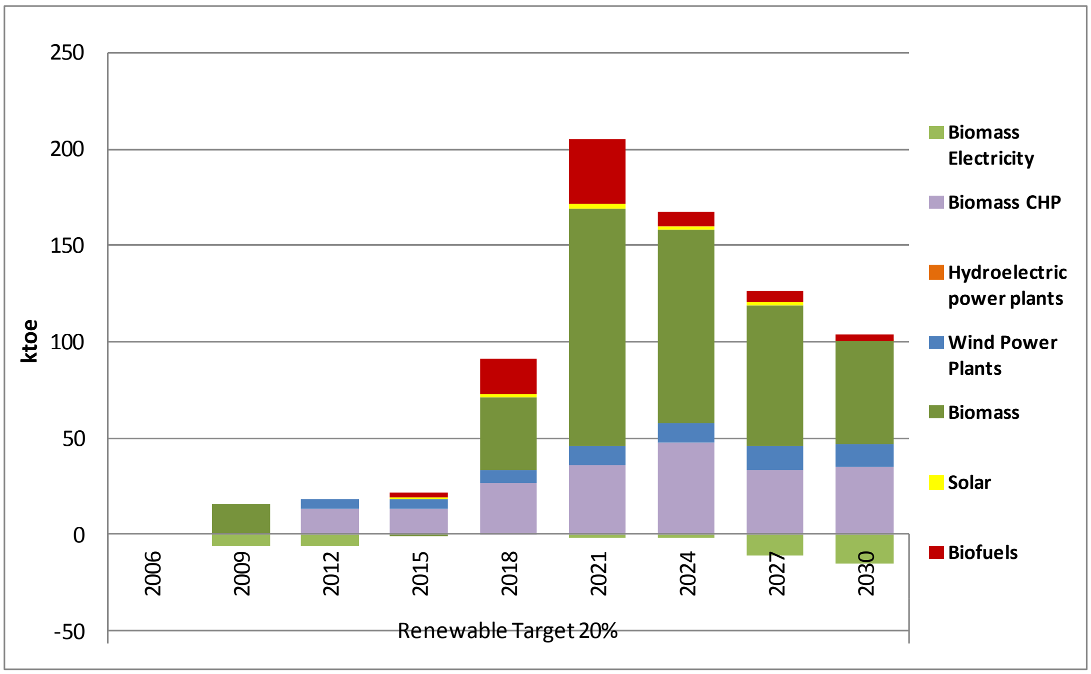
12 Updated Calculation of the 2020 RES Targets for the Contracting Parties of the Energy Community, Presentation by ECS to 8th Renewable Energy Task Force meeting, 06 March 2012.

Indicator	Units	Reference	RE Target Change	
Final Energy	Ktoe	65,483	465	0.71%
CO_2 Emissions	Kt	171,500	-6,364	-3.71%

In the Reference scenario, the main contribution to renewable energy in 2009 was biomass (232 ktoes), 11% of total final energy, primarily used in the residential sector for heating. By 2020, the share of renewables has increased to 13.4%, with the biomass use level at 320 ktoe.

The introduction of a target requires that renewable energy contributes 20% of GFEC, by 2020, with a sub-target of 10% of transport fuels from biofuels, so further action is necessary. A summary of the change in renewable energy use for centralized electricity and direct use compared with the Reference scenario is provided in Figure 8.

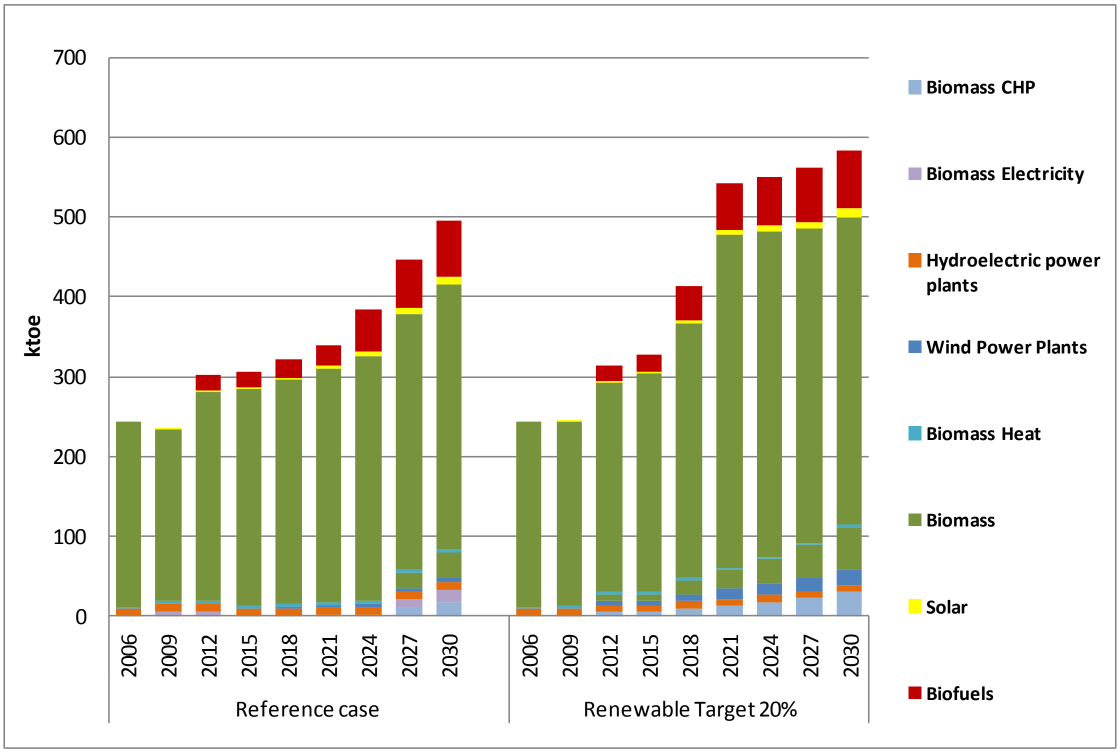
Figure 8. Additional Renewable Energy under RE Target (Compared to the Reference Scenario)



The main additional renewable energy contribution comes from biomass (primarily for residential heating), biomass CHP, wind, and biofuels (in the transport sector). In 2021, the amount of additional renewable energy is greatest but then decreases, due to the growing use of biofuels under the Reference case. It is primarily the shift to more energy efficient appliances, necessary to keep overall renewable requirements at a minimum due to the uptake of less efficient biomass, that drives increasing costs but the required investment in new biomass CHP and wind plant is also significant, cumulatively an additional 97€ million. This suggests that meeting the target will require strong policies to stimulate investment and attract significant levels of capital.

The strong role for biomass in the energy system in terms of renewable energy contribution is illustrated in Figure 9. But there is some uncertainty as to the extent to which biomass energy would increase in the future, particularly as a fuel of choice in the residential sector, and due to limited data on overall potential. In the absence of additional biomass, other renewable energy types would have to play a stronger role, including wind energy. However, due to the low cost of coal generation, adopting additional biomass is an attractive option, ensuring take-up in end use sectors rather than power generation.

Figure 9. Total Renewable Energy under Reference and RE Target Cases



Overall, adapting the energy system to meet the target increases total energy system costs by 0.65%, or 199€ million relative to the Reference scenario over the entire planning horizon. And, 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 2.8% and CO_2 emissions are reduced (cumulatively) by almost 3.7% relative to the Reference scenario. This suggests strong synergies between an ambitious renewable policy and other policies relating to low emission strategies, energy security, and competiveness. Furthermore, as discussed in Section F, coordinating policies that encourage energy efficiency can dramatically enhance the benefits and lower the cost of meeting a renewables target.

F. COORDINATED RENEWABLES AND ENERGY EFFICIENCY POLICIES FOR MOLDOVA

Promoting both energy efficiency and renewable energy goals in parallel has strong policy synergies. In the case of Moldova, the NEEP and draft National Renewable Energy Action Plan (NREAP) will be implemented in parallel; therefore, this analysis reflects the policy reality and challenges facing Moldova in order to meet these goals. Key insights arising from the analysis of these coordinated policies and programs are noted here, reflected in Table 7, and discussed in the rest of this section.

- Energy system costs increase by 303€ million (0.99%). Despite this increase, there are co-benefits with respect to reduction of total primary energy and lower import dependency, leading to a reduction in fuel expenditure of 965€ million, much of which is payments for imports.
- Final energy reductions of 6.1% are the same as those observed in the EE target case, because the of increase use of biomass energy but lower overall final energy demand.
- CO_2 emissions and imports are each reduced by 10.5% and 7.3%, illustrating important synergies and co-benefits arising from the implementing efficiency and renewable energy policies together.

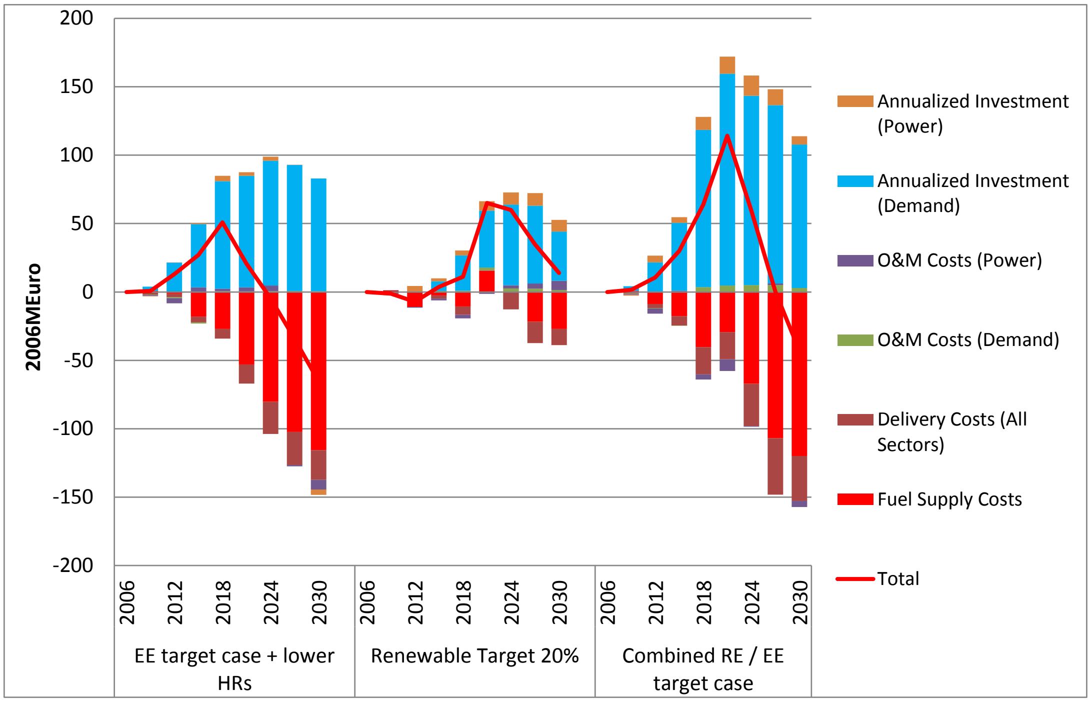
Table 7 shows the key result changes between the combined RE & EE scenario and the Reference scenario.

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	2006M€	30,507	303	0.99%
Primary Energy Supply	Ktoe	77,692	-3,913	-5.04%
Imports	Ktoe	65,530	-4,760	-7.26%
Fuel Expenditure	2006M€	29,746	-965	-3.25%
Power Plant New Capacity	MW	593	116	19.48%
Power Plant Investment Cost	2006M€	685	73	10.68%
Demand Technology Investments	2006M€	5908	718	12.15%
Final Energy	Ktoe	65,483	-3,971	-6.06%
CO_2 Emissions	Kt	171,500	-17,917	-10.45%

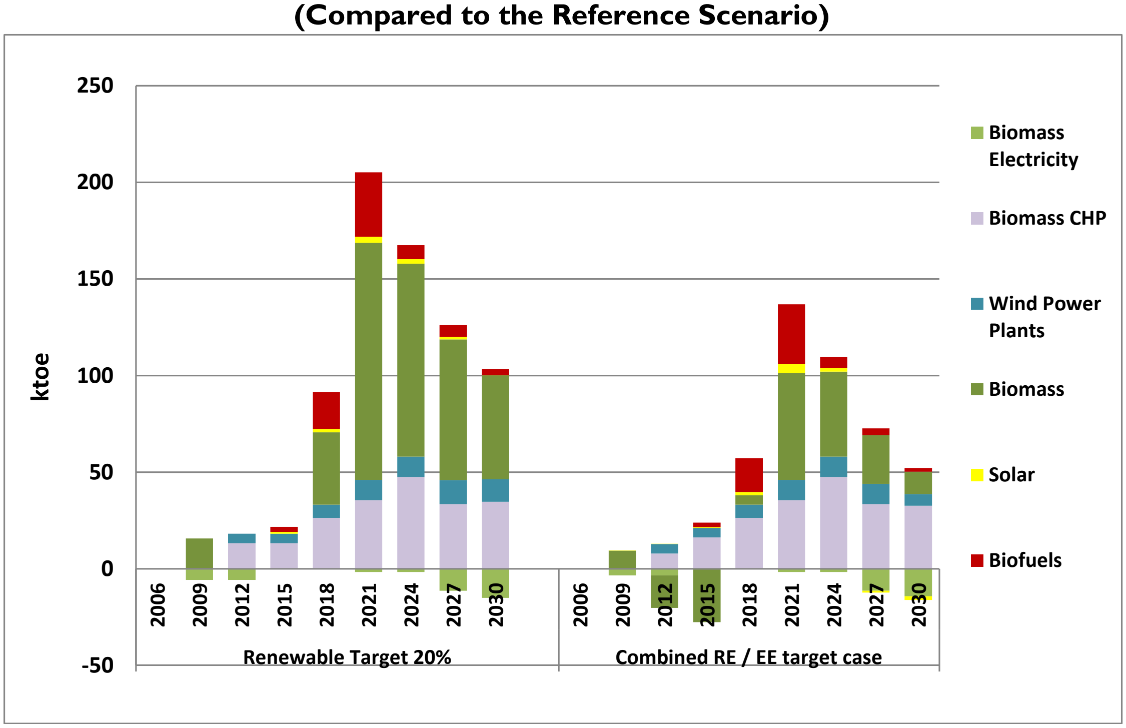
Figure 10 shows the change in annual energy system costs for the three policy scenarios relative to the Reference scenario. The bars show the increases (positive) and decreases (negative) in annual system cost components, and the change in net costs over time is shown as the red line. Overall, costs increase due to the additional investment needs for renewable generation capacity, and the additional costs of energy efficient demand devices. Fuel savings (in dark blue) can be seen in all scenarios, reaching 115€ million per annum in the combined scenario by 2030, and thereby saving a cumulative 965€ million over the planning horizon.

Figure 10. Costs and Savings from Renewable and Energy Efficiency Policies



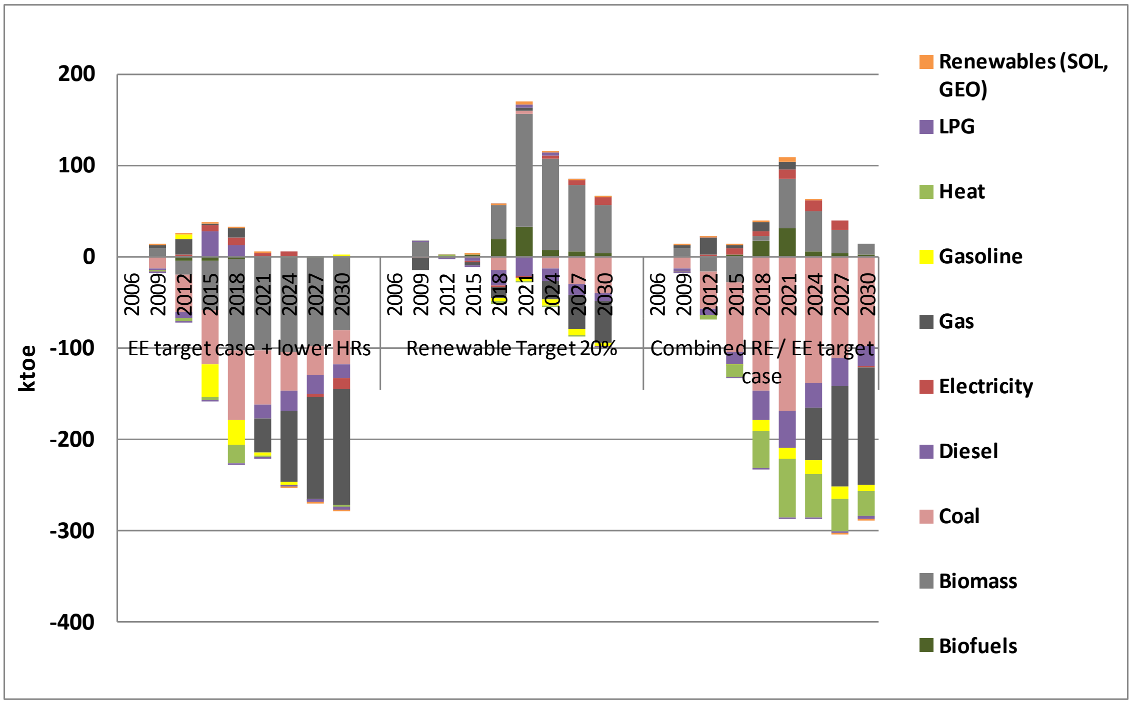
The synergies of meeting both targets by reducing RE requirements are illustrated in Figure 11 below. Energy efficiency action results in lower levels of renewable energy being required, as the renewable target is relative to (gross) final energy consumption. Due to a lower RE requirement, it is direct biomass consumption that drops but with similar levels of contribution from other renewable energy types (as observed in the RE case).

Figure 11. Additional Renewable Energy under the RE and RE+EE Combined Cases (Compared to the Reference Scenario)



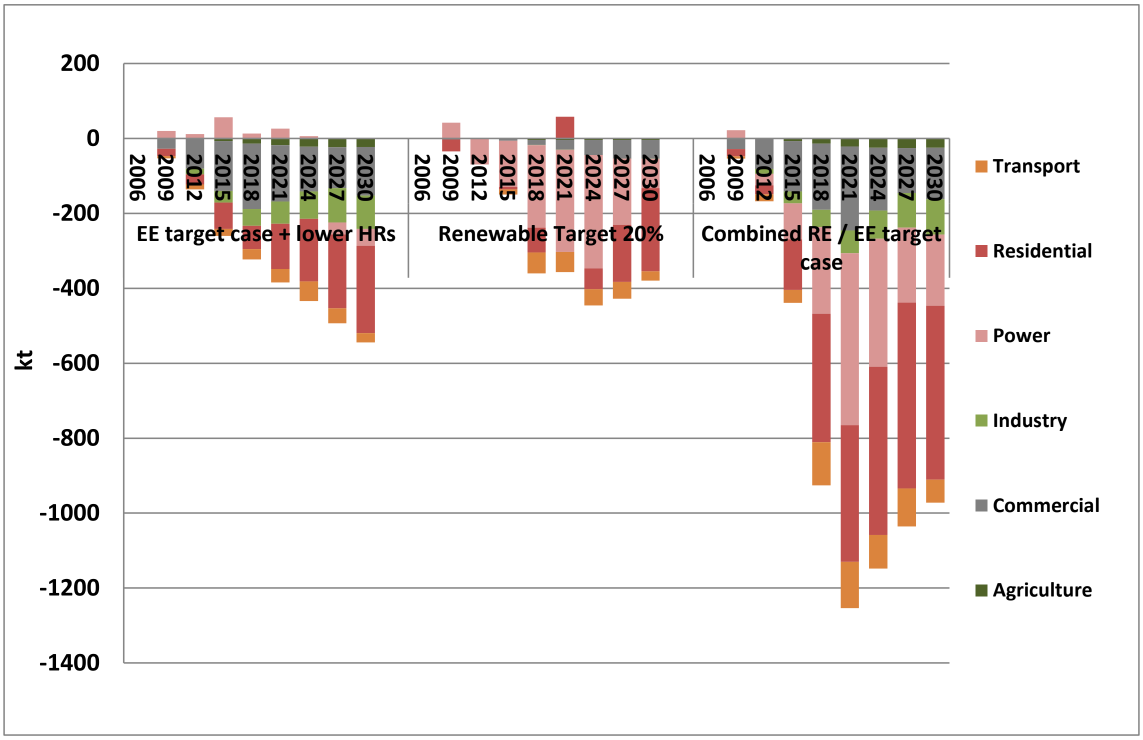
However, as illustrated in Figure 12, the level of reductions in biomass cannot be achieved in the combined case as observed in the EE case. This is because biomass remains an important option for meeting the overall RE target; therefore, more reductions in coal use are observed. The reduction in coal rather than biomass means increased costs, resulting in the cost reductions not being as significant under the combined case.

Figure 12. Final Energy reductions from Renewable and Energy Efficiency Policies



CO_2 emission reductions are shown in Figure 13, illustrating the significant additional reduction associated with the combined energy efficiency and renewable policy. In cumulative terms, CO_2 emissions are reduced by 10.5%, compared to the Reference case.

Figure 13. Sectoral CO_2 Emission Reductions under RE, EE and RE+EE Combined Cases



G. LOW EMISSION DEVELOPMENT PATHWAYS IN MOLDOVA

A Draft "Low Emissions Development Strategy of the Republic of Moldova to the Year 2020"[13] has the objective of providing a general policy framework focused on national sustainable development that is likely to lead to lower GHG emissions and will help to:

- Reach and if possible increase the level of reduction commitment
- Propose mitigation solutions, which will provide economic opportunities
- Highlight the barriers to the conversion to the low carbon emissions economy development
- Reinforce and build on existing projects/investments

The Draft "National Climate Change Adaptation Strategy"[14] (NCCAS) of the Republic of Moldova has been developed within the United Nations Development Program (UNDP) Project "Support to Environmental Protection and Sustainable Use of Natural Resources" implemented by the Climate Change Office (CCO) of the Ministry of Environment (MoEN) with financial support of the UNDP Regional Bureau for Europe and the Commonwealth of Independent States (RBEC) and UNDP Moldova. The low carbon pathway investigated in this scenario analysis is a 45% reduction in CO_2 emissions by 2020, relative to 1990, and maintained to 2030, consistent with the Low Carbon Development Strategy (LCDS). This is equivalent to 8.5% reduction relative to the Reference scenario level in 2020, and 23% in 2030. Three approaches to achieving this goal were examined; firstly an annual limit was imposed, second an equivalent cumulative constraint (instead of a annual limit) was imposed to explore the cost-optimal timing of abatement, and lastly the annual limit case was assessed in conjunction with EE /RE targets to explore synergies.

The key findings are summarized below, and reflected in Table 8 and figures that follow.

- The 45% reduction requirement from 2020 onwards raises overall energy system costs by 0.75%, or 229€ million. Marginal abatement costs in 2020 are estimated at 10€/tCO_2 and in 2030, at 190€/tCO_2 for this aggressive reduction target. These costs are associated with reductions equivalent to 8.5% and 23% in 2021 and 2030, compared to the Reference scenario.

- The majority of reduction occurs in the power sector through a shift from coal to gas. Increased efficiency in the power and end use sectors reduces import and primary energy requirements by 3.6% and 3.9% respectively.

- Applying the constraint as a cumulative constraint across the model horizon results in lower cost increase of 0.54%, compared to 0.75% in the annual limits case (shown in Table 8). The marginal

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[13] Low Emissions Development Strategy of the Republic Of Moldova to the Year 2020 www.clima.md%2Fdoc.php%3Fl%3Den%26idc%3D236%26id%3D2527&ei=8bswUNjNGcrrsgayhYGIBQ&usg=AFQjCNHH9_ojLWSmZ2z0RL3FMkVHtQUf2Q

[14] National Climate Change Adaptation Strategy http://www.clima.md/download.php?file=cHVibGljL3B1YmxpY2F0aW9ucy8yNTI5MjM3X2VuX21vbGRvdmFfbmF0aW9uLnBkZg%3D%3D . Note that the LCDS for Moldova does not include the Trannistria region.

abatement costs in 2020 are higher, at 80 €/tCO_2, but lower in 2030, at 150 €/tCO_2. This illustrates the change in timing of mitigation action, with relatively more action earlier in the time horizon.

- Adding the annual CO_2 target to the combined RE/EE case only increases additional discounted system costs by a limited amount, to 1.2% compared to 1% under the combined RE/EE case. Given the CO_2 target cost an additional 0.75%, this illustrates the strong low carbon synergies associated with EE / RE strategies.

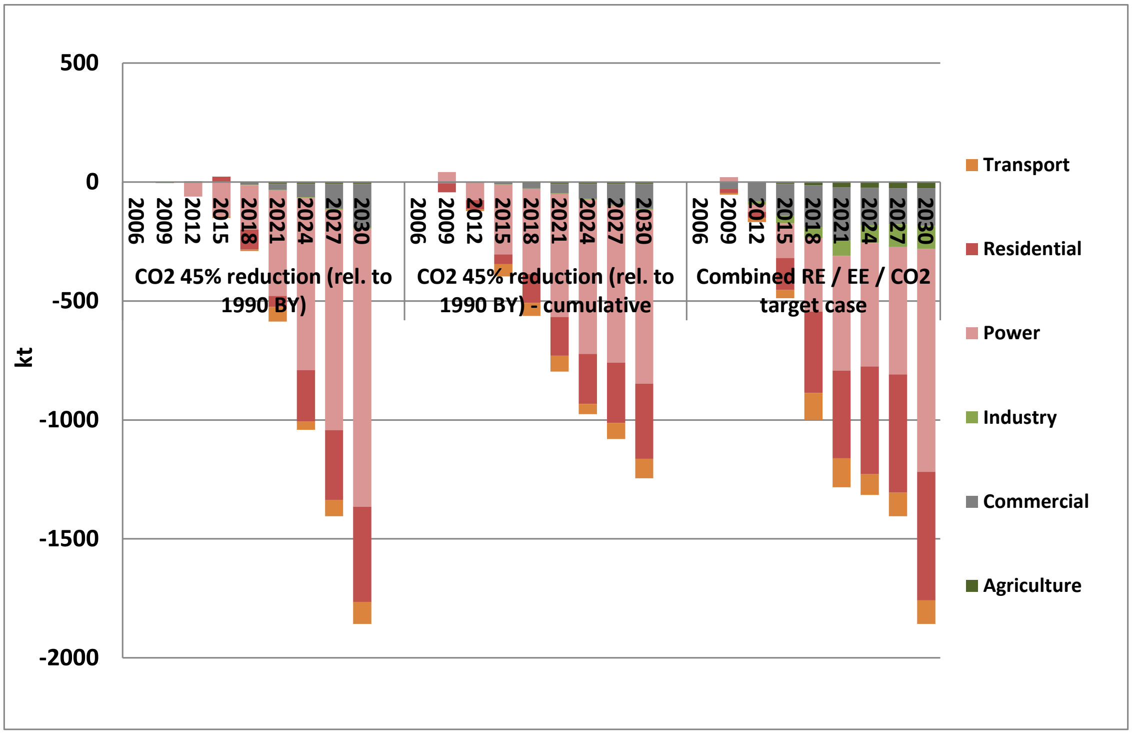
Table 8. Key Results: Low Carbon Emission Pathway (Compared to the Reference Scenario)

Indicator	Units	Ref. Case	Annual Limit Case		Cumulative Limit Case		Combined Case	
Total Discounted Energy System Cost	2006M€	30,507	229	0.75%	165	0.54%	369	1.21%
Primary Energy Supply	Ktoe	77,692	-3,007	-3.87%	-3,045	-3.92%	-5,028	-6.47%
Imports	Ktoe	65,530	-2,344	-3.58%	-2,706	-4.13%	-4,708	-7.18%
Fuel Expenditure	2006M€	29,746	423	1.42%	-46	-0.16%	-667	-2.24%
Power Plant New Capacity	MW	593	110	18.60%	43	7.29%	91	15.26%
Power Plant Investment Cost	2006M€	685	-8	-1.21%	-26	-3.76%	20	2.96%
Demand Technology Investments	2006M€	5908	382	6.47%	434	7.34%	802	13.58%
Final Energy	Ktoe	65,483	-1,361	-2.08%	-1,465	-2.24%	-4,185	-6.39%
CO_2 Emissions	Kt	171,500	-16,093	-9.38%	-15,535	-9.06%	-17,601	-10.26%

CO_2 emission reductions are shown in Figure 14 for both the annual limit and cumulative limit cases. The power sector is the primary driver of emission reductions in the two CO_2 target cases although there are also important contributions in the end use sectors, particularly from the residential sector, through reductions in coal and gas use. The difference in reduction profile in the cumulative case highlights that it is more cost-effective to mitigate more in the nearer term rather than focusing mitigation primarily in the later periods.

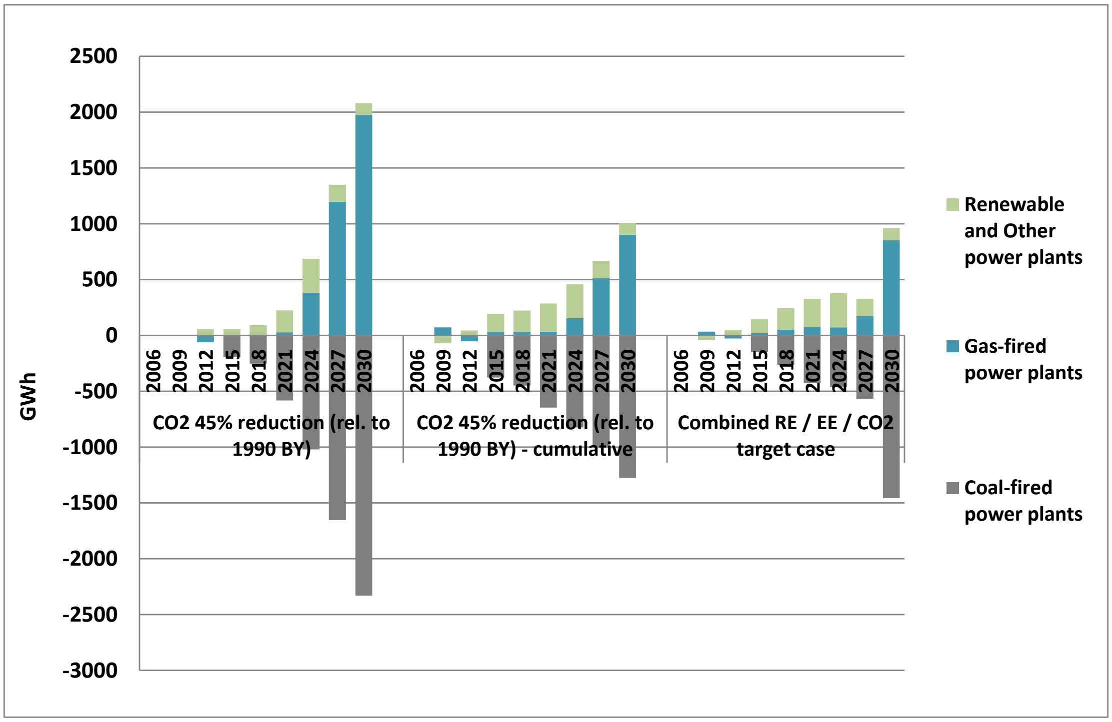
In the combined case, other sources make a more significant contribution due to the energy efficiency measures and increasing use of biomass (under the RE target).

Figure 14. Change in CO_2 emission under the Low Carbon Emission Pathway cases



The change in electricity generation profile is shown in Figure 15, illustrating the switch to gas and renewables, away from coal in the annual limits case. However, in the cumulative case, a switch to more expensive gas generation is avoided due to the more flexible timing of reductions, with wind and biomass CHP displacing coal generation. The combined case sees less change in generation mix due to more CO_2 emission reductions coming in end use sectors, as a result of the impact of EE/RE targets. EE target reduces final energy consumption in end use sectors while RE increases the role of biomass.

Figure 15. Change in Electricity Generation under the Low Carbon Emission Pathway cases



Interestingly, the main increase in costs comes from mitigation action undertaken in the end-use sectors, as illustrated in Figure 16. This is due to a move towards more efficient devices, particularly in the residential sector. Note that in these two limit cases we are not assuming any additional energy efficiency programs to reduce the associated cost barriers to uptake, as done in the EE cases. The analysis also highlights the role played by undertaking a cumulative reduction approach, as described earlier, by switching more mitigation to earlier in the model horizon.

The costs in the combined CO_2/RE/EE case are not significantly higher than those observed in the combined EE/RE only case (shown in Figure 10). This is because there are strong synergies between all three policy objectives. The small increase in costs is mainly observed later in the time horizon, due to the pressure on the system to meet the CO_2 targets.

A range of insights can be gained from reviewing the marginal cost of carbon, which is an output of the model (see Figure 17). The first observation is the different between the annual and cumulative cases, where under the cumulative case, a more gradual increase in costs is observed over time. In addition, the marginal cost increases dramatically in 2024, under the annual limit case, suggesting that abatement action is becoming increasingly expensive (at the margin). Further work is needed to explore what other options could be considered in the Moldova model, or if there is more potential for existing options.

Interestingly, in the combined case (with annual target), the marginal cost implies that it is only in 2027 at the earliest that the CO_2 target actually makes any difference, because the reductions resulting from the RE/EE targets already meet the annual limits between 2015-2024. This reflects the very strong synergies between these different policy areas.

Figure 16. Change in annual costs under Low Carbon Emission Pathway cases

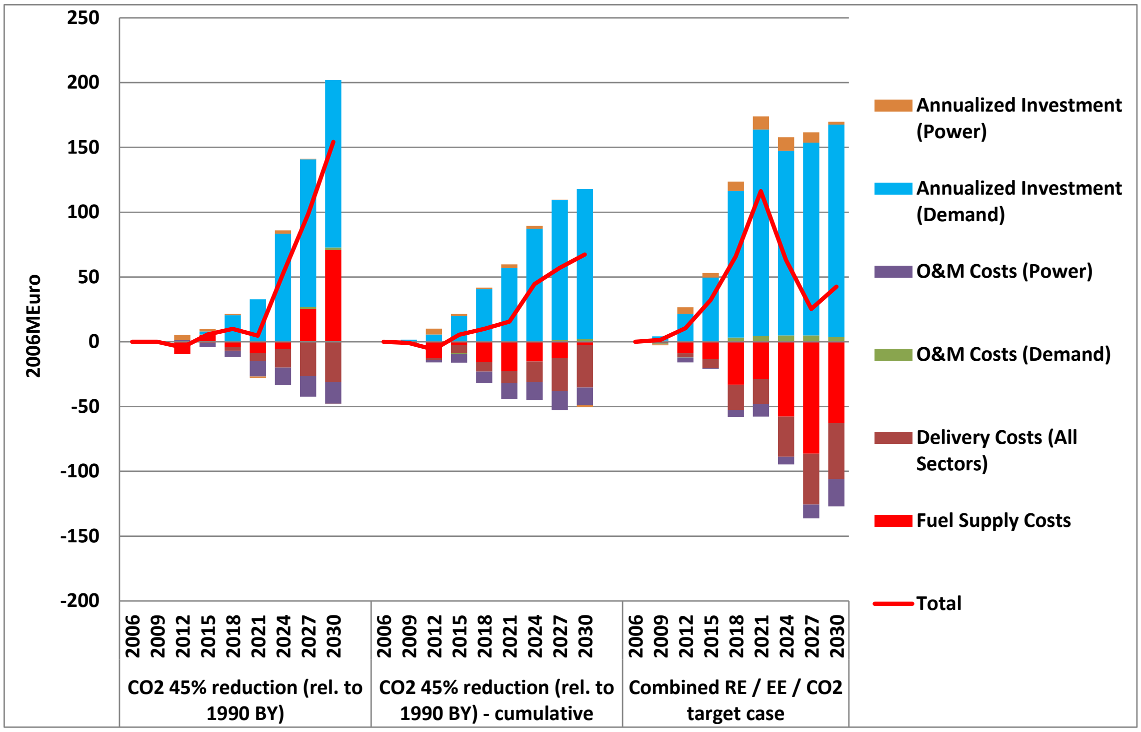
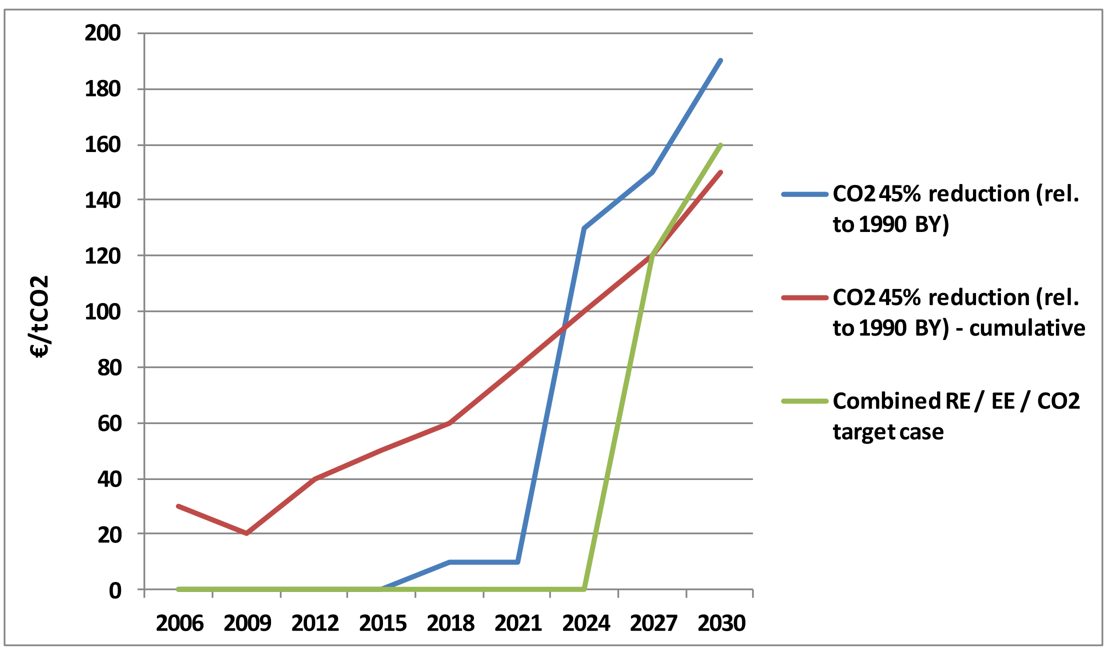


Figure 17. Marginal cost of carbon under Low Carbon Emission Pathway cases



APPENDIX I: DATA SOURCES AND KEY ASSUMPTIONS

The Moldova analysis is based on numerous data inputs and assumptions, and therefore requires a set of key national data sources. The sources of this information are listed by data requirement in Table 9 below.

Table 9. Key Data Sources

Data Requirement	Source
2006 Energy Balance	IEA Online Database: Energy Balances of Non-OECD and Energy Statistics of Non-OECD [2008] Energy balance of the Republic of Moldova[15]
Domestic Energy Prices	Statistical yearbook of the Republic of Moldova
Resource Potential, including imports/exports	Energy balance of the Republic of Moldova
Installed capacity and characterization of existing electricity, heating and CHP plants	Energy balance of the Republic of Moldova ACTIVITY REPORT 2008 of National Agency for Energy Regulation[16]. Centralized heat supply Company[17] of Chisinau
Electricity generation plants (adjustment to the SSP plant characterizations)	Energy balance of the Republic of Moldova ACTIVITY REPORT 2008 of National Agency for Energy Regulation
Timing of demands for energy services	Hour-by-hour load curve of energy system of Moldova[18]
Fuel consumption patterns by energy service	Expert estimations based on Energy balance of the Republic of Moldova
Demand Drivers	Expert evaluation of Value Added by economic activity sector and of GDP based on Statistical yearbook of the Republic of Moldova
Known energy policies	Energy Strategy of the Republic of Moldova to the year 2020[19] National Energy Efficiency Program to the year 2020

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

The Planning Team has ensured (to the extent possible) that current or planned policy is reflected in the Reference scenario. They have also consulted with different sector experts to ensure that the Reference scenario in the model is reasonable, and does not diverge significantly from other analyses undertaken,

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15 Energy balance of the Republic of Moldova. Available from National Bureau of Statistics of the Republic of Moldova: http://www.statistica.md

16 ACTIVITY REPORT 2008 of National Agency for Energy Regulation.

Available from National Agency for Energy Regulation http://www.anre.md

17 http://termocom.md/en/

18 Available from the National Energy Dispatching Company “Moldelectrica”.

19 Energy Strategy of the Republic of Moldova to the year 2020

e.g. for the Energy Strategy, draft National Renewable Energy Action Plan, National Energy Efficiency Program.

Some of the key resulting assumptions are listed in the table below.

Table 10. Key Assumptions in Reference Scenario

Category	Assumption
GDP growth rate	5% annual
Sectoral growth rates[20]	
Residential	2.7% Average Annual (Av.An.)
Commercial	3.0% (Av.An.)
Industry	2.2% (Av.An.) up to 2015, 1.6% (Av.An.) 2015 onwards
Agriculture	1.6% (Av.An.)
Population growth rate	0.4% (Av.An.)up to 2015, 0.2% (Av.An.)2015 onwards
HH number growth rate	1.2% (Av.An.)up to 2015, 0.9% (Av.An.)2015 onwards
Key policies modelled	
	Feed-in Tariffs (FIT) for small hydro (100 €/MWh), wind (97 €/MWh) and PV (420 €/MWh), with associated potential.

The basic parameters for the existing electricity and heat generation plants are given in Table 11 below.

Table 11. Existing Heat and Power plants

Plant Type/Fuel	Capacity (GW)	Efficiency	Availability
Power Plant/ N. Gas	0.33	~25%	80%
Power plant/ Hydro	0.016	100%	70%
Heating plant (centralized)/ Natural gas	0.365	83 %	90%
Heating plant (centralized)/ Oil	0.014	80%	90%
Heating plants (decentralized)/ Oil	0.026	80%	90%
Heating plants (cen/zed+dec/zed)/ Coal	0.012	73%	90%
Heating plants (cen/zed+dec/zed)/ Biomass	0.014	57.9%	85%

A series of constraints have been introduced to ensure that the Reference case is plausible, and properly reflects the situation in Moldova (see Table 12 below).

Table 12. Key Constraints in the Reference Scenario

Sector / Issue	Constraint
Resource supply	All fossil fuels are imported
Domestic resources	No domestic resources
RES potential:	
Hydro	No hydro potential
Wind	Limited potential for wind power plants (up to 120 MW by 2030)
Solar	Limited potential for PV installation (up to 40 MW)
Imports/Exports	Limit on electricity imports, price in the range 36-47 €/MWh
Electricity generation	
Technology availability	Same Electricity and CHP technologies available in all scenarios

[20] Overall growth rate for useful energy based on projections for the different energy services in each sector

Sector / Issue	Constraint
End use sectors	Limited penetration of advanced technologies (max 15% of new devices purchased by 2030)
	Limited fuel switching allowed (max 15% fuel share deviation from base year by 2030), in addition if a fuel share (Sh) is ~2% switching allowed can lead to values between 0% and Sh+2%

All of the national models draw on a set of common assumptions for future energy prices and technology characterizations. In terms of the energy prices each country model uses its 2006 "border/mine-mouth" price for energy sources (see the country sections in this Appendix), and any sectoral adjustments to these (for delivery and mark-up (but not taxes)). Then there is an overriding assumption that regardless of the 2006 prices by 2015 all countries will be competing on the global energy market using world prices. With this in mind, the IEA WEO 2009 energy price projections for each fuel are adopted, as shown in the table below.

Table 13. Energy Price Trajectory Assumptions (2006Euro/GJ)

Energy Carrier	2015	2018	2021	2024	2027	2030
Coal	2.78	2.91	3.03	3.09	3.14	3.20
Coke	3.53	3.70	3.84	3.92	3.99	4.06
Brown coal	2.78	2.91	3.03	3.09	3.14	3.20
Lignite	2.04	2.14	2.22	2.27	2.31	2.35
Crude	10.97	12.06	13.06	13.77	14.46	15.17
Heavy Distillate Oil	10.50	11.54	12.50	13.17	13.84	14.52
Light Distilate Oil	14.26	15.67	16.98	17.89	18.80	19.73
LPG	12.07	13.26	14.37	15.14	15.91	16.69
Gasoline	15.36	16.88	18.29	19.27	20.25	21.24
Kerosene	15.36	16.88	18.29	19.27	20.25	21.24
other oil products	13.17	14.47	15.68	16.52	17.35	18.21
Naphta	12.07	13.26	14.37	15.14	15.91	16.69
Feedstock	12.07	13.26	14.37	15.14	15.91	16.69
Non energy use	12.07	13.26	14.37	15.14	15.91	16.69
Natural Gas	10.02	10.79	11.48	11.93	12.45	13.02
LWR Fabricated Fuel	0.80	0.80	0.80	0.80	0.80	0.80

Note that individual country experts may choose to adjust these price trajectories using the flexible mechanism built into the fuel price Excel workbook which prepares this information for the model.

The other two datasets that start from a common point for all the national models are repositories for the characterization of future power plants and demand devices. Tables 17, 18, and 19 present these assumptions for electricity, coupled heat and power and heating plants respectively (with centralize/decentralized distinguished in the model). There are nearly 100 instances of the various plant type available for selection by the national expert to include as options for consideration by the model.[21] These are organized by fuel and plant type, and cover new construction and estimated costs for refurbishment/life extension options for existing plants (which need to be tailored by the analyst for the individual plants under consideration for rehabilitation). Additional options may also be easily added should the national situation dictate.

Table 14: Future Electric Power Plant Characterization*

Power Plant Type	Start Date	Life-time	Efficiency ***	Availability Factor	Investment Cost (M€/GW)**	Fixed O&M (M€/GW)	Variable O&M (€/MWh)
Coal Steam Turbine	2009 - 2015	35	0.46	0.85	920 - 985	40.50 - 43.0	9.20
Lignite Fired	2009	40	0.40	0.80	1000 - 1250	25.00 - 35.00	4.32
Coal IGCC	2010	35	0.51	0.85	1200	52.50	11.04
Natural Gas Steam Turbine	2009	25	0.34 - 0.58	0.80	350 - 375	7.00	2.52 - 2.7
Natural Gas CCGT	2009 - 2015	35	0.58	0.85	385 - 471	18.00 - 2`.00	5.52 - 5.91
Nuclear	2009	40	0.36	0.90	1550	38.55	3.53
Hydro	2009	60 - 80	1.00	0.27 - 0.60	3000 - 3500	45.00 - 59.00	0.72 - 1.44
Wind	2009 - 2012	20 - 30	1.00	0.06 - 0.22	1000 - 1070	40.00 -43.00	0.00
PV	2009 - 2012	30	1.00	0.10	2000 - 2950	29.40	0.00
Geothermal (dry steam)	2009	30	1.00	0.85	5000	275.00	4.32
Biomass	2009	30	0.37	0.80	1800 - 1820	43.00 - 46.00	6.84 - 7.32

* All of the assumptions above are subject to revision by Planning Teams. For example, this is particularly true of hydro investment costs and wind availability factor which depend on the site in question, therefore may differ significantly between national models.
** In some cases a range for investment costs reflects country differences, or in some cases the higher value is the current cost and the lower value that in 2030.
*** Efficiency for hydro, wind, solar and geothermal are effectively 1.0 for the model as no actual fuel is consumed.

[21] The complete set of power plant characterizations as used in each national model is managed in the SSP_<country>_NEWTCH-PP Excel template, and is available for review and consideration from the national Planning Teams.

Table 15. Future Coupled Heat and Power Plant Characterization

Power Plant Type	Start Date	Life-time	Heat / Electric Ratio	Efficiency	Avail-ability Factor	Investment Cost (M€/GW)	Fixed O&M (M€/GW)	Variable O&M (€/MWh)
Biomass	2009	25	1.74	0.31	0.85	1600 - 1873	71.75 - 77.0	6.48
Hard coal	2009	35	1.43	0.35	0.85	1200	54.50	9.20
Lignite	2009	30	1.25	0.29	0.80	1400	28.00	4.75
Natural gas	2009	30 - 35	1.00 - 2.59	0.23 - 0.45	0.80 - 0.85	585 - 650	13.00 - 30.00	2.77 - 5.52
Heavy fuel oil	2009	18 - 25	0.88 - 1.93	0.30 - 0.42	0.85	750 - 850	35.00 - 65.00	27.0 - 50.4*

* These values seem extremely high and will be adjusted in the next phase. However fuel oil based power plants are not generally competing to enter the models.

Table 16. Future Heating Plant Characterization

Power Plant Type	Start Date	Life-time	Efficiency	Avail-ability Factor	Investment Cost (M€/PJa)	Fixed O&M (M€/PJa)	Variable O&M (M€/PJ)
Biomass	2012	30	0.78	0.80	8	0.16	1.52
Brown coal	2009	30	0.78	0.80	8	0.16	0.88
Lignite	2009	30	0.78	0.80	8	0.16	0.96
Distillate	2009	30	0.78 - 0.85	0.80	7	0.13	0.56
Natural Gas	2009	30	0.78 - 0.85	0.80	6	0.12	0.56
Geothermal	2009	30	1.00	0.80	10	0.20	1.20
Heavy fuel oil	2009	30	0.78 - 0.85	0.80	7	0.13	0.56
LPG	2009	30	0.78	0.80	7	0.14	0.56

For Moldova the characteristics of the key new power plants that are chosen by the model are shown in Table 17. The characteristics of the existing power plants are shown in Table 11.

Table 17. Characterization of Key Power Plant Options

Power Plant Type	Start Date	Life	Efficiency (n_e, n)	Avail-ability Factor	Investment Cost (M€/GW)	Fixed O&M (M€/GW)	Variable O&M (€/MWh)
Natural Gas Steam Turbine	2009	25	0.34	0.80	375	7.5	2.70
Natural Gas CCGT	2015	35	0.58	0.85	471	21.4	5.91
Coal Steam Turbine	2015	35	0.46	0.85	985	43	9.9
Wind	2012	20	1.00	0.22	1070	42.8	0.0
Biomass CHP	2012	25	0.31/0.85	0.85	1873	76.8	6.95
Hard coal CHP	2015	35	0.35/0.85	0.85	1284	58.3	9.86

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

Technology characterizations depict the current typical technology available in 2009, and then assumptions are made that reflect the cost and performance improvement of more efficient alternatives. There are more than 300 instances of these core technologies, and then up to three levels of improved devices available to the analyst to include in their model. The cost (M€/PJa) and performance characteristics for a subset of the key base devices are shown in Table 18.

Table 18. 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
	Solar heat pump	16.78	4.00

Energy Service Demand	Demand Device	Investment Cost (€/GJ)	Efficiency (Fraction)
	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	Incandescent light bulbs	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 percent, the base purchase price may increase a corresponding 0.74/1.34/2 times. All these assumptions may be adjusted for national circumstances, though most use this standard approach as described.

Note that due to lack on data on the process details of Moldova industry, an approach that calibrates to the current energy intensity of each industrial demand, with then 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 19) 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 Annual Energy Outlook (AEO) 2011.[22] Only the relative efficiency numbers are used and applied to information from the Sultan Tool mentioned above. Relative cost values are applied to user provided information on standard gasoline/diesel vehicles. LDV costs and efficiencies are shown in Table 19.

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[22] 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/

- Marine and aviation estimates are from the best available data from the US/UK National MARKAL models. This approach is satisfactory as these subsectors in the model are not subject to technology choice.

Table 19. 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 18. LDV Efficiency by Type in Moldova MARKAL Model

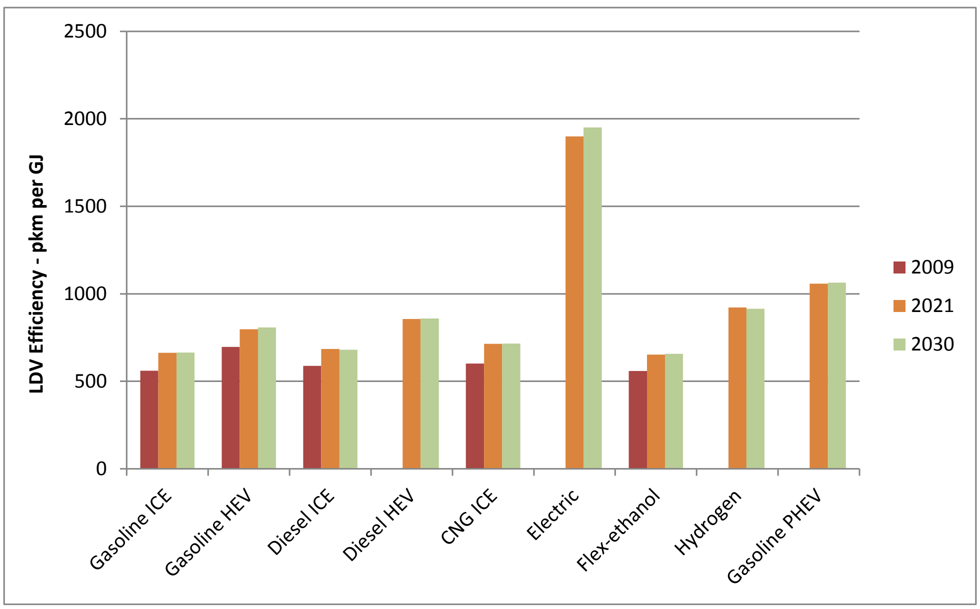
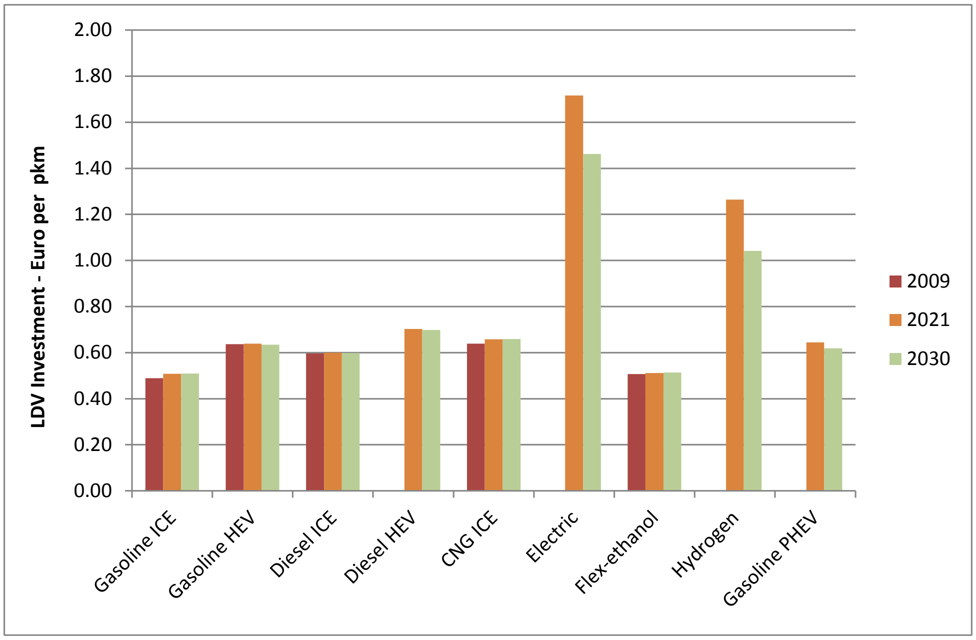


Figure 19. LDV Investment Cost by Type in Moldova MARKAL Model



For year 2006, the transport sector is calibrated to the national energy balance. The transport sector energy totals have been disaggregated using Albania 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 own (even if past performance lifetime), buy only what 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.

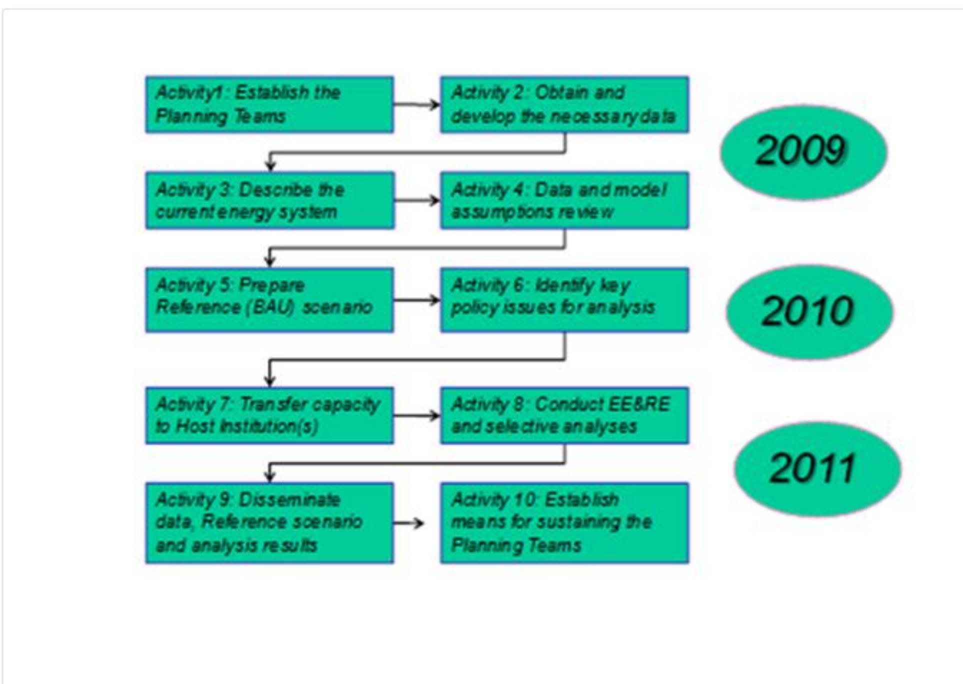
APPENDIX III: PROJECT ACTIVITIES AND METHODOLOGY EMPLOYED

MAJOR PROJECT ACTIVITIES

The consultant teams for International Resource Group (IRG) and the Centre for Renewable Energy Sources (CRES) worked with key personnel from the Ministry of Economy of Moldova (MoE) and the Institute of Power Engineering of Academy of Sciences of Moldova (IE ASM) to establish a credible MARKAL-Moldova model, and guide this Planning Team's use of the model to assess and analyze several policy alternatives aimed at improving energy efficiency and increasing the use of renewable energy resources.

Over the course of two years, the joint SYNENERGY Strategic Planning (SSP) effort undertaken by the US Agency for International Development (USAID) and Greece Hellenic Aid was able to introduce new methods, implement these methods and transfer the capabilities to the national counterparts in a sustainable manner (see Figure 20). 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 20. 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.

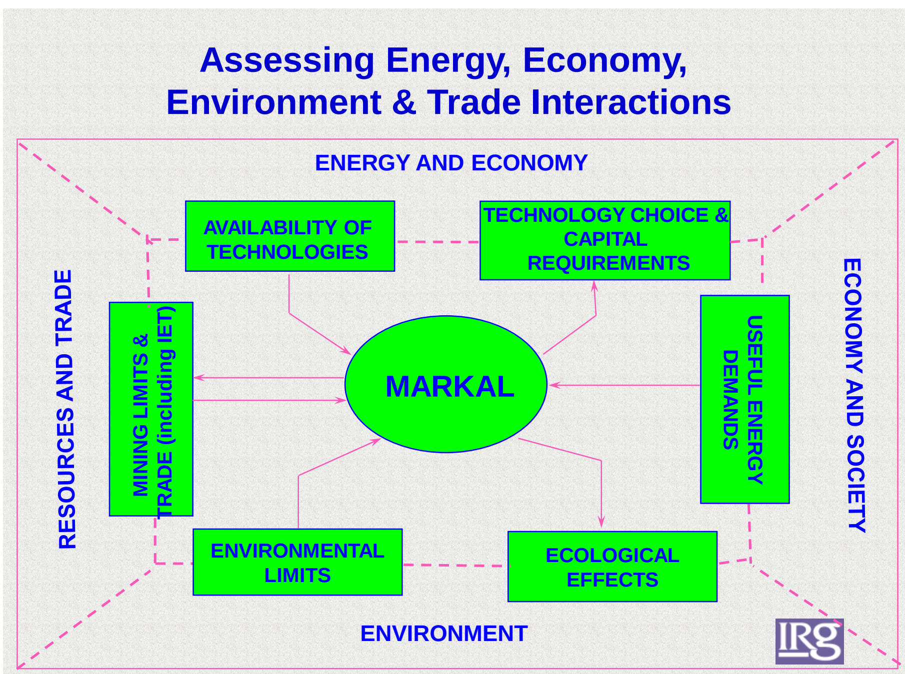
At least as important as the energy balances themselves, and the accompanying information systems, is the process of building a team of professionals in each country who can work with the data, maintain the information systems, and support higher level analytical approaches. This team building should 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 21).

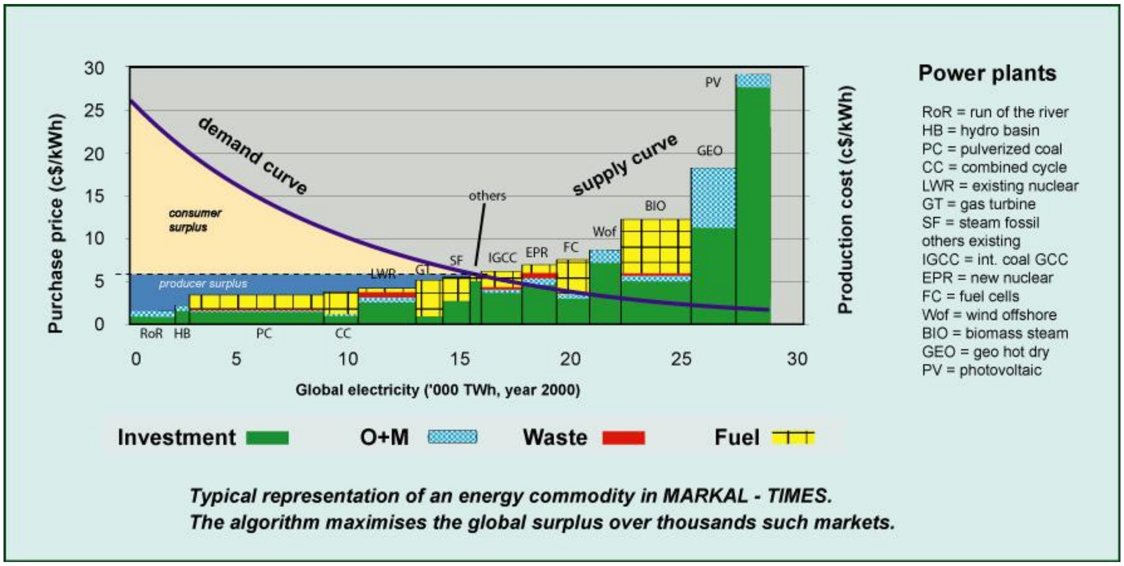
Figure 21. Interactions in the MARKAL/TIMES Model



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

Figure 22. Power Plant Dispatch in the MARKAL/TIMES Model



One of the most relevant suite of studies conducted recently using are those sponsored by the European Union that employ MARKAL/TIMES to represent the pan-European energy picture as a closely tied integration of the national energy systems. The initial incarnation of this was realized as part of the New Energy Externalities Developments for Sustainability (NEEDS)[23] undertaking. The Pan-European TIMES model (PET)[24] evolved from the original NEEDS model and has been employed for series of high profile EU projects, including RES2020[25] examining the EU renewables directive,[26] REALISEGRID[27] 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).[28] Another pair of high-profile uses of MARKAL/TIMES is the IEA Energy Technology Perspectives[29] and UK Climate Change Policy "White Paper."[30]

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

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

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

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

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

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

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

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

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