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:

CROATIA POLICY BRIEF

July 2012
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by Croatian Ministry of Economy Trade, Energy and Hrvatska Elektroprivreda d.d. and International Resources Group (IRG).

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ACRONYMS

AEO	Annual Energy Outlook
BAU	Business as Usual
CC	Combined cycle
CHP	Combined Heat and Power
CRES	Centre for Renewable Energy Sources
EC	Energy Community
ECS	Energy Community Secretariat
EE	Energy Efficiency
EIA	Energy Information Association (US)
EKONERG	Energy and Environmental Protection Institute Ltd
ESD	Energy Services Directive
ESEC	Energy Strategy of the Energy Community
EU	European Union
GDP	Gross Domestic Product
GFEC	Gross Final Energy Consumption
GHG	Greenhouse Gas
GT	Gas turbines
HEP	Hrvatska Elektroprivreda d.d.
HGVs	Heavy Goods Vehicles
HPP	Hydro Power Plant
ICE	Internal Combustion Engine
IEA	International Energy Agency
IPA	International Policy Analysis
IRG	International Resources Group
LCVs	Light Commercial Vehicles
LDVs	Light Duty Vehicles
LPG	Liquid Petroleum Gas
LWR	Light Water Reactor
MARKAL	MARKet ALlocation
METE	Croatian Ministry of Economy Trade and Energy
NEEAPs	National Energy Efficiency Action Plans
NEED	New Energy Externalities Developments for Sustainability

NPV	Net Present Value
NREAPs	National Renewable Energy Action Plans
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
RoR	Run-of-River
RPS	Renewable Portfolio Standards
SF	Steam fossil
SSP	SYNENERGY Strategic Planning
UK	United Kingdom
UNDP	United Nations Development Program
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 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 Croatian Planning Team using their national MARKAL (MARKet ALlocation) integrated energy system model, MARKAL-Croatia, to examine the role of energy efficiency (EE) and renewable energy (RE) in meeting future requirements 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 Trade and Energy, Hrvatska Elektroprivreda d.d. (HEP), and EKONERG (Energy and Environmental Protection Institute Ltd.), supported by International Resources Group (IRG) and the Centre for Renewable Energy Sources (CRES). The MARKAL-Croatia 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 Croatia, as a Contracting Party under 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. Furthermore, what is important for decision-makers is that there is now a strategic planning platform available for Croatia, 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 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 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 some of the implications on the energy system of meeting CO_2 emission reduction targets by 2020, are discussed 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 undertaken 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. Summary Overview of the Impact of RE / EE Objectives on Key Energy Policy Issues

Policy issue / Scenario	Reference Scenario Trends	Renewables	Energy Efficiency	EE+RE
Energy security and diversification	• Increasing coal and oil imports	• Increased use of renewables • Reduced electricity production from coal	• Reduces imports by 11,703 Ktoe (13.5%) • Lowers final energy consumption by 10,821 Ktoe (5.9%)	• Increased use of renewables (although at lower level than under RE case) • Cumulative total imports reduced by over 34%
Enhanced competitiveness[1]	• Electricity system expansion at a total cost of 2,485 €M • 39% decrease in final energy intensity	• Stimulates investment in renewable market • Cuts cumulative expenditure on fuel by 4.9% (3,128€M)	• Lower fuel costs, saving 6.1% in cum. fuel expenditure (3,878€M)	• Lower fuel costs, saving 8.8% in fuel expenditure (5,552€M)
CO_2 mitigation	• Emissions increase by 40% by 2030 due to increased use of coal in power sector	• Cumulative reduction of 12.7% due to use of less fossil energy (mainly coal) and lower total energy consumption	• Cumulative reduction of 3.5% due to lower energy consumption	• Cumulative reduction of 15.3% 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 22% and 16% respectively, with a 36% 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 RE scenario, imported coal is reduced by half

[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.

cumulatively, while in the EE scenario, the reduction in gas and oil is 20%. In the combined scenario, there are reductions in coal as well as gas and oil imports.

The energy supply becomes more diversified under the RE case, with an increased role for hydro and wind generation, and a significant reduction in gas and coal supply. Large increases in investment in hydro capacity need to be balanced against issues of hydrological patterns change in future years (due to climate change) that could 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 actually an overall savings seen of 948€ million; however, only around a 6.6% 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 more than 6.1% (in the combined scenario case), or cumulative saving of 3.88€ billion, offsetting the cost of the more expensive efficient demand technologies. Once transformed, the energy system savings continue into the future, making the Croatia 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, particularly towards 2030, under the assumption that the RE share is to be sustained over time. To meet the target, an additional 2,000 MW of RE capacity will be required by 2020, and over 2,800 MW by 2030. Energy system costs are 0.27% higher (321€ million Net Present Value (NPV)[2]). If the RE target is implemented in coordination with policies to promote energy efficiency, the extra cost seen to meet the renewable targets is reduced to just 0.1% (118€ million). It is important to note that there is an increase in electricity prices owing to the more expensive power plants, so understanding the distribution of impacts and, where necessary, reducing competitiveness or social impacts will be important.

In addition, as already mentioned, a combined efficiency and renewables policy can substantially reduce imports, saving valuable foreign exchange funds, amounting to 2.0€ 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 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 Croatian energy economy. The combined EE & RE policy leads to cumulative reductions of 15.3% in CO_2 emissions. This is accomplished by increasing renewable generation from hydro and wind power on the order of 2,850 MW, compared to the Reference scenario, coupled with the overall reduction in demand for energy owing to the more efficient energy system.

[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.

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. The MARKAL-Croatia Reference scenario shows that rapid electricity demand growth requires a 30% increase in electricity generation capacity by 2030 to 5.5 GW at a cost of nearly 2.5€ billion. 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-Croatia analysis shows that a 3.6% reduction in final energy consumption can be achieved at a net savings of 950€ million (or 0.8%) by reducing barriers to the uptake of energy efficiency. Achieving the more ambitious NEEAP target of 9% still saves 0.2% (200€ million) over the baseline, while reducing imports by 13.5% and carbon emission savings of 3.5%. Achieving these goals does require a 4.5% increase in investment (or 1€ billion) for more efficient demand devices, resulting in an over 250€ million reduction in new power plant expenditures, as capacity growth is reduced by over 200 MW. The most cost effective areas for energy efficiency investment identified in this analysis include residential and commercial space heating, commercial cooling, and industrial process heat. The MARKAL-Croatia model is a readily available useful framework that, along with market analysis, can be used to identify key technology and building opportunities and develop targeted measures to achieve this potential.

Meeting RE targets without simultaneously promoting energy efficiency, increases energy system costs by a modest 0.3% (or 320€ million) driven by higher investments in the power sector of 3.7€ billion, increasing capacity compared to the Reference case by 1.5 GW. Capacity additions needed to reach the target by 2020 are approximately 1,000 MW (at a cost of 3.3€ billion), a very ambitious goal. Achieving the target does yield substantial benefits though: a more than 22% decrease in imports and a 5% decrease in both fuel expenditures (3.1€ billion) and a 13% 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 0.1% (or just over 100€ million). The savings are dramatic: a 9% decrease in fuel costs (5.5€ billion), a 15% decrease in carbon emissions, and a 34% 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 Croatia 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 tradeoffs regarding hydro versus other renewable capacity investments, designing feed-in tariffs to encourage renewables development, and developing targeted energy savings policies, including standards and appliance and retrofit subsidies.

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

C. CROATIA'S BUSINESS-AS-USUAL ENERGY PATHWAY

To assess the impact of different policies and programs on the evolution of the energy system in Croatia 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. In addition, all other available national data sources (national energy balances, etc.) as well as some international databases (e.g., International Energy Agency or IEA) were utilized. The full list of information sources is provided in Appendix I. 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.

Under the Reference scenario, energy consumption is projected to grow by 31% in terms of final energy by 2030, driven by Gross Domestic Product (GDP) growth and increasing per capita consumption. This will require increasing the electricity generation system from 4,200 to 5,500 MW and results in higher import levels, as well as growth in CO_2 emissions. Key indicators from the Reference scenario are shown in Table 2 and summarized subsequently.

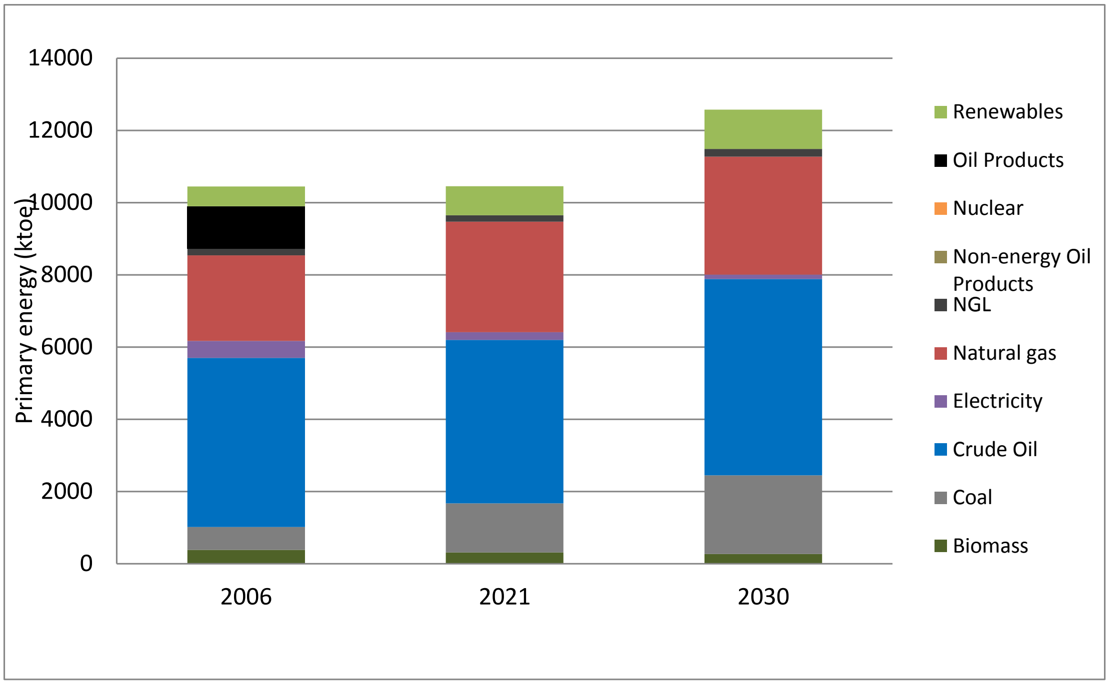
Table 2. Key Indicators for the Reference Scenario

Indicator	2006	2030	Annual Growth Rate (%)	Overall Growth (%)
Primary Energy (Ktoe)	10,447	12,330	0.7%	18%
Final Energy (Ktoe)	6,179	8,110	1.1%	31%
Power plant capacity (MW)	4,212	5,490	1.1%	30%
Imports (Ktoe)	3,226	5,185	2.0%	61%
CO_2 emissions (Kt)	17,932	25,714	1.5%	43%
GDP (€ Mill.)	39,102	81,202	3.1%	108%
Population (000s)	4,494	4,810	0.3%	7.0%
Final Energy intensity (toe/€000 GDP)	0.158	0.097	-2.0%	-39%
Final Energy intensity (toe/Capita)	1.37	1.64	0.7%	19%

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 significantly lower than observed in 2006 – estimated to be 0.097 toe/1000€, a reduction of around 39%. This is a result of the continuation of current structural changes in the Croatian economy and natural technological progress underway throughout the world.

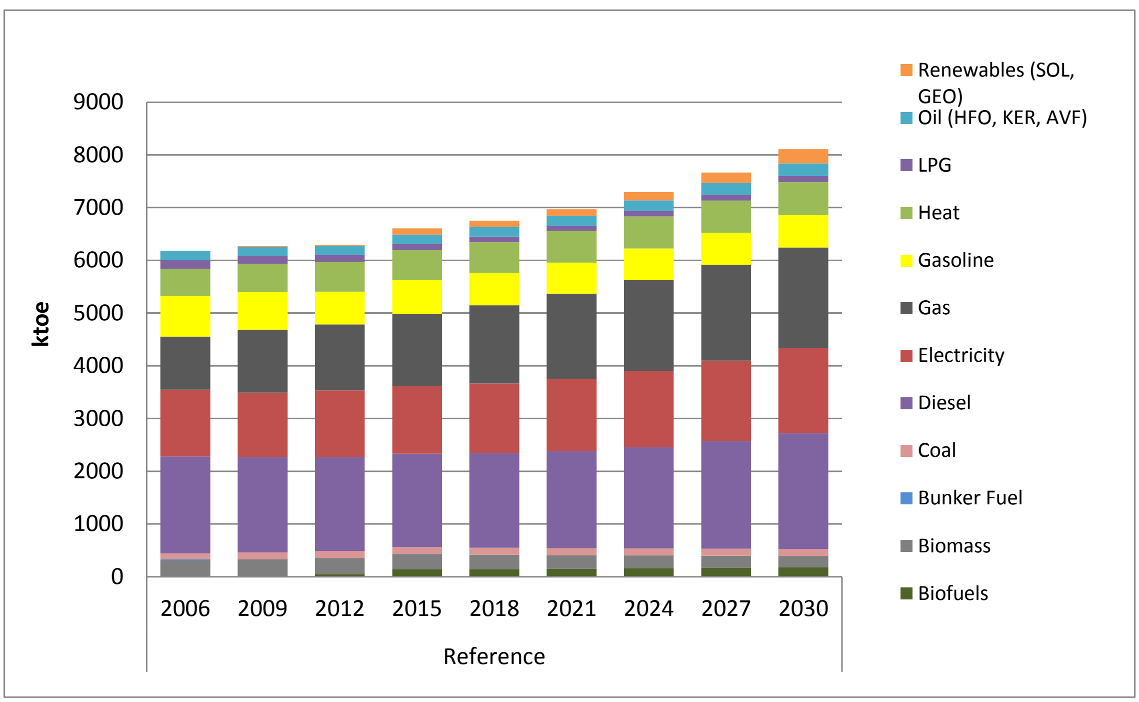
As shown in Figure 1, primary energy supply increases by 18%, with the growth occurring after 2021. Imported oil products are expected to diminish, given the expansion of refining capacity. Electricity imports are also expected to drop due to increased generation capacity. The contribution of renewable energy sources (excluding biomass) to total primary energy during this period increases from 5% to 9%. The biomass contribution drops from 3.6% to 2.2%, as households switch to more modern forms of energy.

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



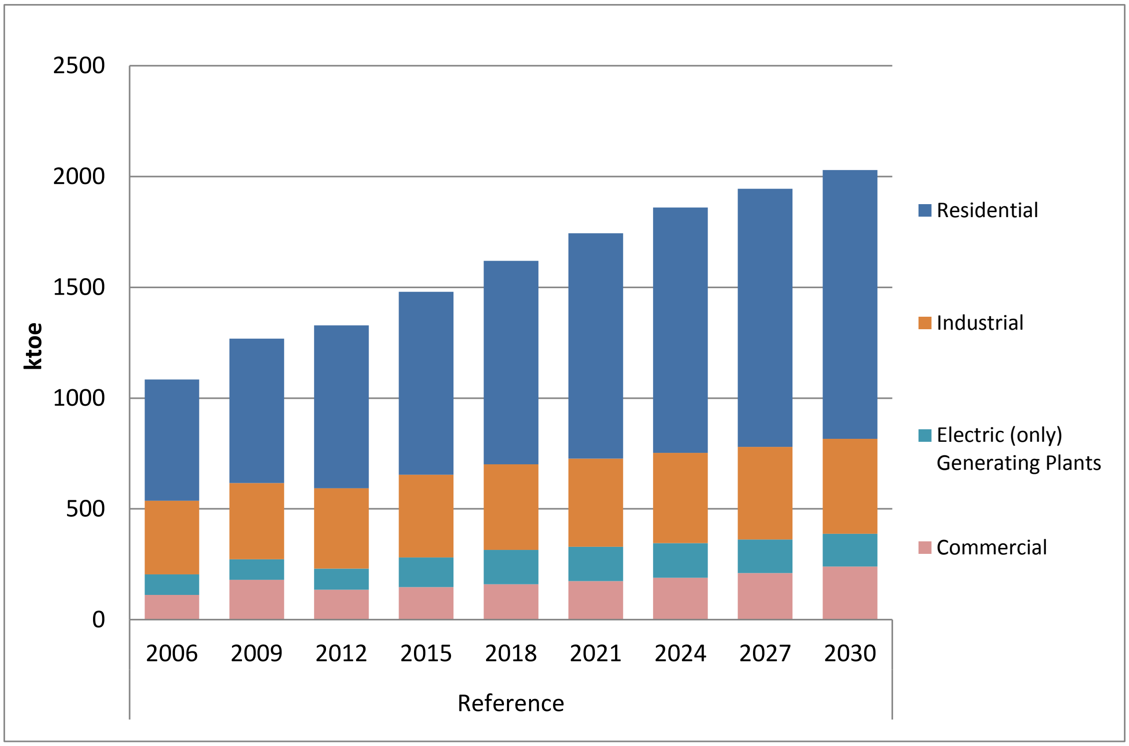
Total final energy consumption grows by over 31% over the planning horizon, with the most significant change being natural gas, increasing from an initial level of 16% to 24% by 2030, as shown in Figure 2.

Figure 2. Final Energy Consumption by Energy Type



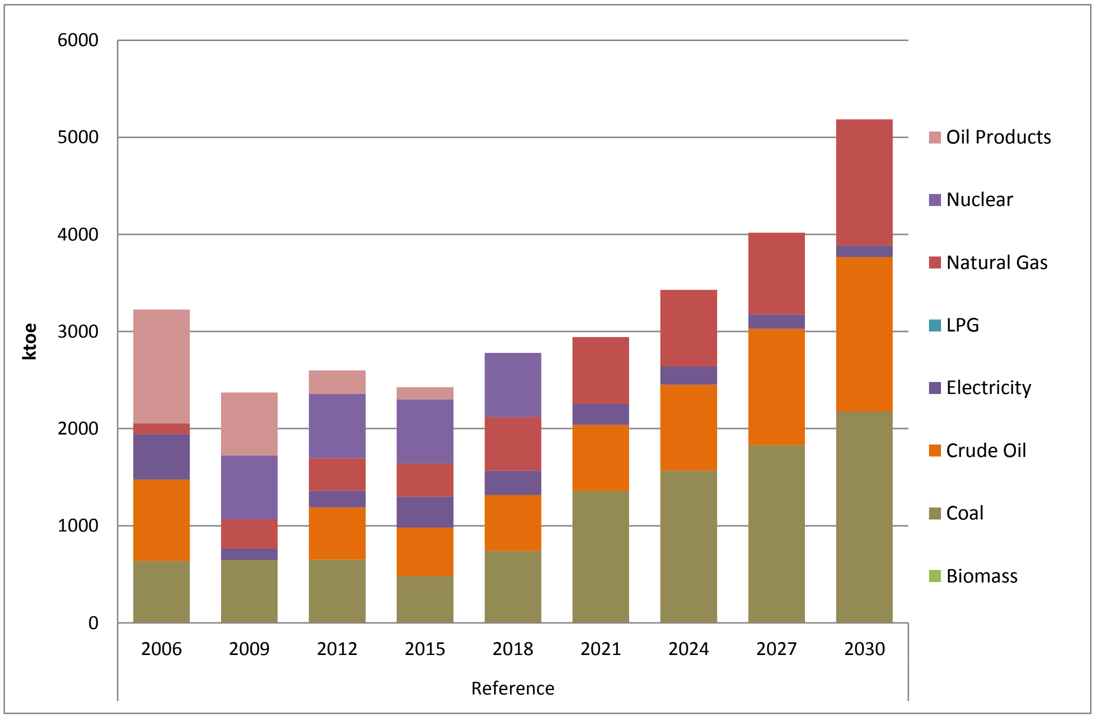
A more detailed view of gas consumption by sector is shown in Figure 3. It shows that the majority of gas is used in the residential and industry sectors but with significant take-up for power generation. In the residential sector, gas is used primarily for cooking and space/water heating, while in the commercial sector the main uses are for cooking and space heating. Note that at this stage, the cost of expanding the domestic gas network is only partially reflected in the model. This is an area that needs a closer look. It is possible that if costs were fully reflected, the penetration could be lower than presented here. Gas is used across most industry sectors for the production of high temperature heat for a number of different processes.

Figure 3. Gas Consumption by Sector and Power Plant Type



A large share of Croatia's fossil energy requirements are imported, and these imports are expected to increase by 61% by 2030 (relative to current levels), as shown in Figure 4. Import dependency thus still remains an important issue, with Croatia relying on imports for 42% of its Primary Energy in 2030.

Figure 4. Imports by Type



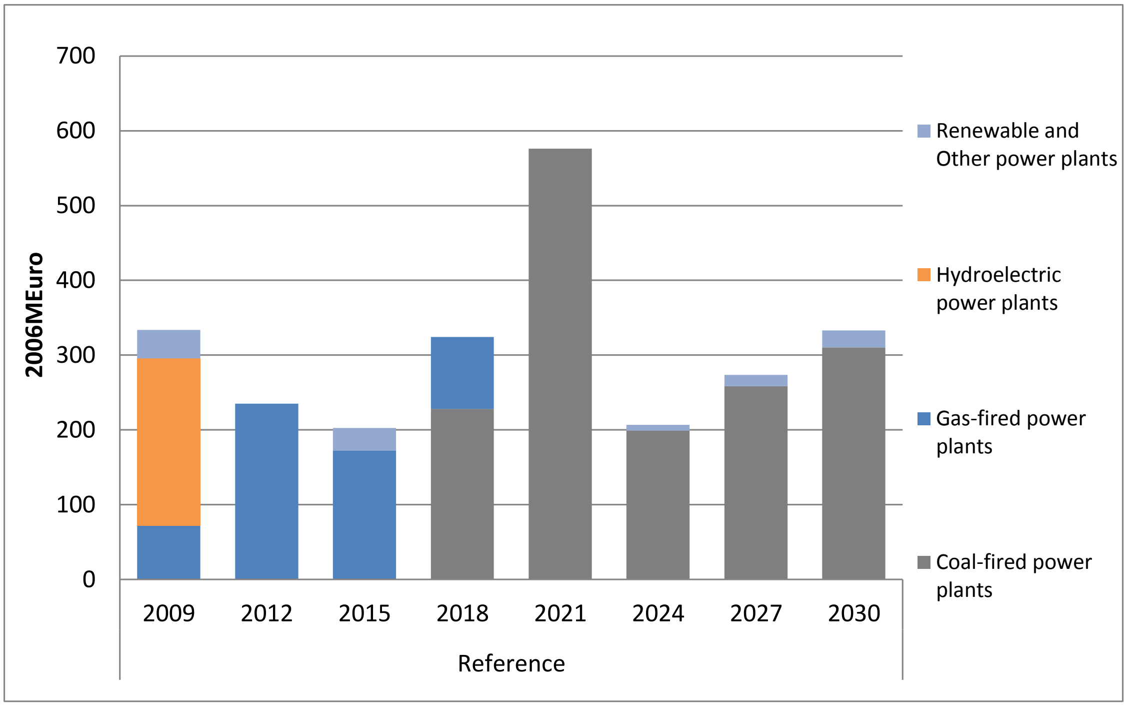
New power generation capacity additions needed are shown in Table 3. About 500 MW of committed gas power and combined heat and power (CHP) plants are forced in 2009 and 2012. This is followed by a need for more gas plants in 2015 and 2018 to meet the increasing demand and the objective of reducing electricity imports. The retiring nuclear power plant after 2018 is replaced by new baseload coal plants. Afterwards, new additions are mainly coal plants as electricity demand rises 1.7%/year (340 GWh/year). This move from gas to coal is due to the escalating gas price, which rises faster than that of coal. In the later years some renewables in the form of wind enter as the cost of those plants is assumed to drop over time.

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

Plant Type	2009	2012	2015	2018	2021	2024	2027	2030	Total
Coal	0	0	0	194	489	169	220	264	1,136
Gas	115	382	419	233	0	0	0	0	1,149
Hydro	73	0	0	0	0	0	0	0	73
Wind	32	0	20	0	0	5	10	15	82
Total New Capacity	220	382	439	427	489	174	230	279	2,640
% of Installed Capacity	5.0%	8.3%	9.5%	9.1%	10.1%	3.5%	4.4%	5.1%	

Figure 5 shows the investments required in new power plants. About 2,500€ million is required in total over the study horizon, with 600€ million needed in the 2021 period to replace the retiring nuclear plant.

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

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

Expenditure Type	2009	2012	2015	2018	2021	2024	2027	2030
Fuel Costs	2,856	3,166	3,942	4,274	4,762	5,245	5,787	6,585
Operation and maintenance (O&M) Costs	2,026	1,927	1,972	2,047	2,137	2,318	2,478	2,660
Annualized Investment (Demand)	1,819	2,212	3,407	3,309	3,433	2,902	2,872	1,584
Annualized Investment (Power)	103	72	58	84	130	39	38	25
Total	**6,705**	**7,421**	**9,455**	**9,804**	**10,642**	**10,663**	**11,357**	**11,048**

[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.

Under the Reference scenario assumptions, to add the 2,640 MW of new generation capacity required by 2030, a total investment of 2,485€ million is required, which translates to average annual payments of the order of 120€ million. At the same time, by 2030 over 1,580€ 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 households. Fuel supply costs will also increase significantly, driven by growing demand and increasing prices, from 5,560€ million per year to 6,590€ million per year.

D. EXAMINATION OF THE PROMOTION OF ENERGY EFFICIENCY IN CROATIA

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, responsible for no less than 78% of EU greenhouse gas (GHG) emissions, needed to be addressed. Therefore, efforts were required to focus on improving end-use energy efficiency and controlling energy demand.[5] 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.*

This analysis provides insights into the cost-effective technologies that would be required to meet the NEEAP target. It is difficult to compare the outputs of this analysis with the measures listed in the NEEAP, as those measures tend to be related to policies and programs rather than technologies per se. It is also difficult to compare costs, as the NEEAP only cites implementation costs required in the public budget, not the costs of the actual technologies net of fuel savings (which MARKAL provides).[6]

It is also clear that the costs of overcoming barriers to take-up of different technologies can be significant, and require strong policies and programs. Such barriers are highlighted in the World Bank (2010) report *Status of Energy Efficiency in the Western Balkans*.[7]

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,[8] 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 NEEAP 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 EE target but reduced barriers to uptake), there is only a 3.6% reduction in final energy consumption, though with an overall savings to the energy system of 948€ million (or 0.8%, as shown in Table 6). However, simply removing some of these barriers is

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

6 In addition, no impact assessment is available against which to cross-compare the MARKAL analysis.

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

8 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).

not enough to meet the reduction levels required by the target in the NEEAP 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, as described below. Key insights include:

- A modest increase in discounted energy system costs of 0.17% (197€ million) is observed under the NEEAP target, where without programs and policies to reduce barriers to uptake the cost to meet the same target would potentially increase nearly three times that.
- Over 13.5% cumulative reductions (11,703 ktoes) in imports are observed under the NEEAP target, enhancing energy security goals.
- Significant cumulative reductions in final energy of 5.9 % are observed (10,821 ktoes), as are synergies with low emission development, reducing CO_2 emissions by 3.5% (or 18,913 Kt).

The basis for the energy efficiency target is the Croatian NEEAP, which has a percentage reduction calculated from the 2006-2009 average final energy consumption levels, which results in total reduction requirements from the Reference scenario levels as shown below in Table 5. As the NEEAP only extends out to 2018, it is assumed that the reductions under NEEAP continue over the later years in the planning horizon, reflecting Government ambition to maintain improvements in energy efficiency over time.

Table 5. Energy Efficiency Targets

	2012	2015	2018	2021	2024	2027	2030
NEEAP target	4.2%	6.4%	8.5%	9.0%	9.0%	9.0%	9.0%
Reduction totals* (ktoes)	262	419	577	559	559	559	559

* Reduction totals are relative to average across 2006/2009 consumption levels

Table 6 shows the key results as change between the EE 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* represents the former but also requires that the NEEAP consumption reduction target be met. In the first case, this represents a situation where only the most cost-effective technologies are taken up, incentivised 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.

The focus of this section is on the *Energy Efficiency + Target* case, as the NEEAP is the main on-going policy action in this area. As shown in the table, all of the key cumulative metrics (other than overall system cost and investment in new demand technologies) are reduced due to efficiency savings. For example, imports drop by 13.5% and fuel expenditure goes down by 6.1%; saving 11.5 Mtoe and 3,878€ million respectively. Such savings enhance economic competitiveness and energy security.

The slightly higher overall cost of the energy system is due to the increased expenditure (4.5% cumulatively) 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 absent of such actions. At the end of the section we briefly discuss variants of the EE analysis to look more at energy efficiency policy in Croatia.

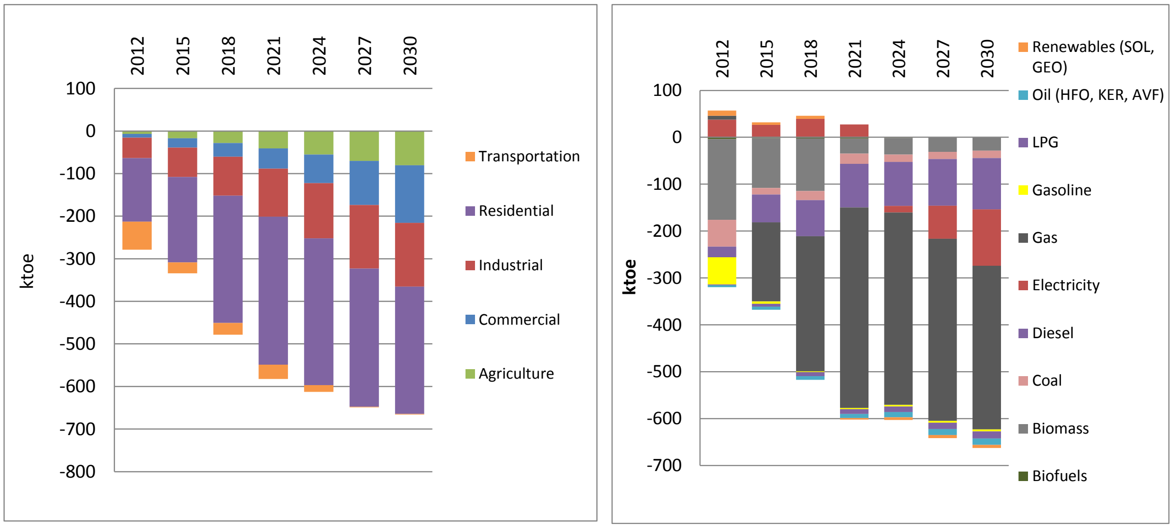
The less than expected CO_2 reductions in the *Energy Efficiency + Target* case is explained by the fact that a gas plays an important role in achieving the final energy reduction target with more efficient gas-fired space and water heaters coming into play.

Table 6. 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€	119,334	-948	-0.79%	-197	-0.17%
Primary Energy Supply	Mtoe	285	-9.72	-3.4%	-13.5	-4.7%
Imports	Mtoe	86.9	-9.54	-11.0	-11.7	-13.5%
Fuel Expenditure	2006M€	63,490	-2,746	-4.3%	-3,878	-6.1%
Power Plant New Capacity	MW	2,640	-272	-10.3	-213	-8.0%
Power Plant Investment Cost	2006M€	2,485	-274	-11%	-248	-10%
Demand Technology Investments	2006M€	64,611	2883	1.8%	960	4.5%
Final Energy	Mtoe	184	-6.6	-3.6%	-10.8	-5.6%
CO_2 Emissions	Mt	543	-22.2	-4.1%	-18.9	-3.5%

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 (59% of total savings), followed by the industry sector (18%), and commerce (11%).

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

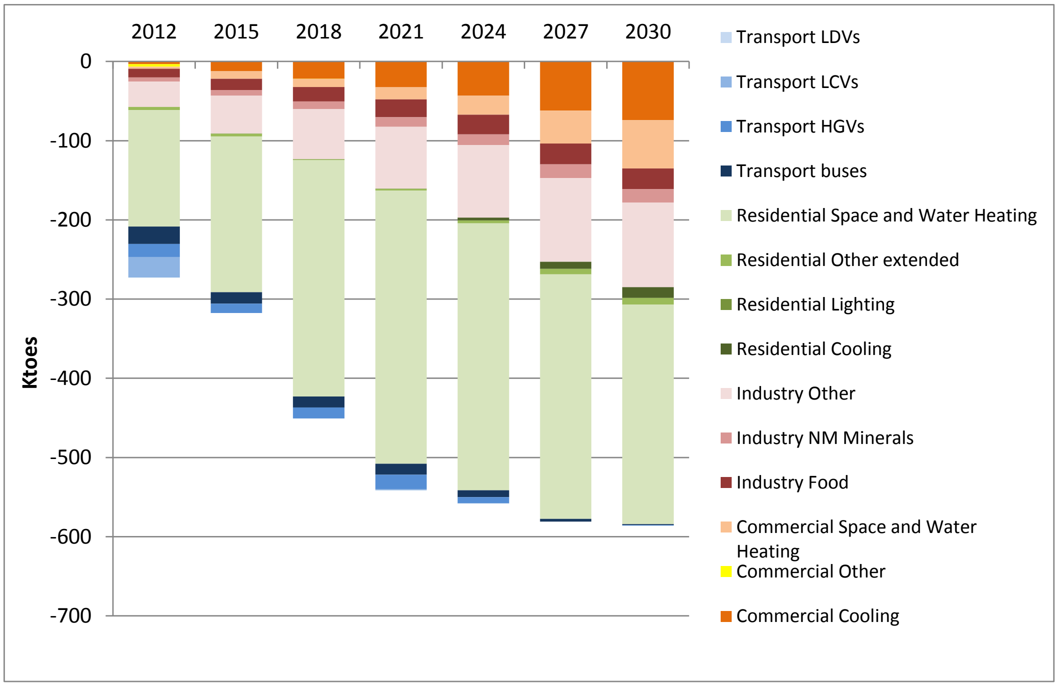


In terms of fuels, the largest near-term reductions come from biomass (residential), coal (industry), and gasoline (transport). Later in the time horizon, large reductions in gas for space heating in the residential sector are observed due to switching to more efficient appliances, as described below.

A more detailed overview of savings by energy service demands are shown in Figure 7. The most cost-effective reductions occur in the more efficient provision of space and water heating, with a strong uptake of heat pumps (using electricity) and more efficient use of appliances. This leads to a fairly strong reduction in gas consumption while electricity consumption levels increase by a small percentage. For the transport sector, there is an increasing uptake of hybrid vehicles across light duty vehicles (LDVs), light commercial vehicles (LCV)s, and heavy goods vehicles (HGVs). There is also some penetration of plug-in hybrid electric vehicles in the LDV stock from 2018. The bus fleet moves towards more advanced internal combustion engine (ICE) technology.

In industry, savings are most prevalent in the "industry other" sector and 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 efficient appliance uptake 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*. Therefore, it is important to continually review the data in the model for use in future analyses, assessing new data available in Croatia to further improve the robustness of the analysis.

Under the EE target, costs are shown to decrease by a small percentage compared to the large final energy savings. This is because the model uses higher discount rates for more advanced appliances (as described earlier and more fully in Appendix II) to reflect the market barriers and costs of policies to overcome them. 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 (11% reduction) and CO_2 reductions (3.5% reductions).

The costs observed for the EE target case are significantly higher if policies and programs are not introduced to reduce the barriers to uptake of energy efficient technologies, at 1.1% compared to -0.17%. Conversely, the modeling also suggests that a more aggressive NEEAP target post-2018 can be achieved at only modest additional cost. A 15% reduction by 2024 results in additional costs of 0.52% compared to the Reference case, highlighting scope for additional action.

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 (including the ESD) will not achieve this goal.

E. ASSESSMENT OF A RENEWABLE ENERGY STRATEGY FOR CROATIA

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 industry, further encouraging technological innovation and employment.

The Energy Community Secretariat (ECS) commissioned a study in 2009 examining illustrative RE targets for the contracting parties,[9] 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 estimated.[10] A 2020 renewables target of 25% of Gross Final Energy Consumption (GFEC) for Croatia has been proposed by the ECS and was used in the analysis presented below.

Key insights are summarized in Table 7 and elaborated upon in the rest of this section.

- Cumulative energy system costs (to 2030) are 0.27% higher. While this is a relatively modest increase it is important to highlight significant additional power sector investment is needed out to 2030 increasing by 59%, or 1,560 MW. The cumulative capacity addition by 2020 is approximately 1,000 MW (2.6€ billion), a capacity increase consistent with Croatia's own draft RE Strategy.
- Energy security is enhanced with a 16.5% cumulative decrease in imports, while demand for final energy reduces by 3.8% as a result of increased use of indigenous electricity and increase biofuel use in the transport sector.
- This policy contributes towards moving to a lower emissions pathway, with cumulative CO_2 reduction reaching almost 10.7% (between 2009-2030).

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

Indicator	Units	Reference	RE Target Change	
Total Discounted Energy System Cost	M€2006	119,334	321	0.27%
Primary Energy Supply	Mtoe	285	-8.90	-3.1%
Imports	Mtoe	86.9	-3.13	-22.3%
Fuel Expenditure	M€2006	63,490	-3,128	-4.93%
Power Plant New Capacity	MW	2,640	1,560	59%
Power Plant Investment Cost	M€2006	3,485	3,700	149%
Final Energy	Mtoe	184	-1,14	-4.9%
CO_2 Emissions	Mt	543	-68.9	-12.7%

[9] 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.

[10] 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.

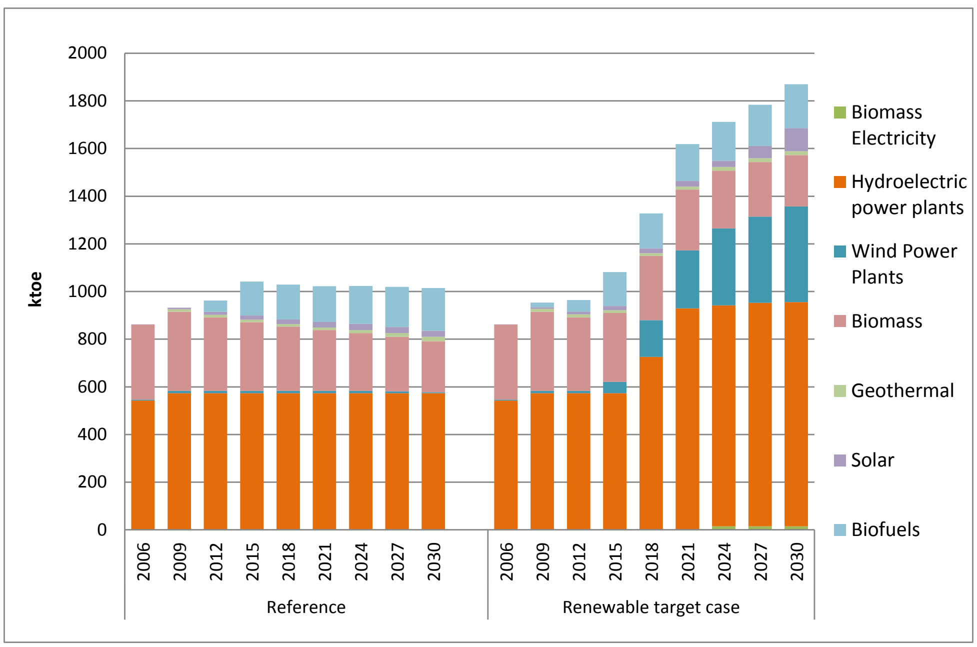
Under the RE target, cumulative additions in RE capacity (between 2009-2030) total 3,015 MW out of total new capacity of 4,200 MW. Comparing this to the Reference case, this means an additional 2,860 MW of RE capacity, two-thirds of which is wind generation capacity. This suggests that meeting the target and critically sustaining it beyond 2020 will require strong policies to stimulate investment and attract high levels of capital in the power generation sector, particularly wind. The additional capital required under the RE target in the power generation sector is estimated at 3.27€ billion. The large increases in capacity above the Reference case are well illustrated in Figure 8.

A consequence of this substantial increase in renewable generation is a model increase of 10% in the average marginal electricity price. 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 is important, as discussed in the next Section.

The other main contributor to the renewable energy target is biofuels, which are required to contribute a minimum of 10% of transport fuels by 2020. This level of contribution is maintained to 2030.

A summary of the change in renewable energy use for centralized electricity and direct use can be seen compared with the Reference scenario in Figure 8.

Figure 8. Total Renewable Energy under Reference and RE Target Cases



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 increased investment in wind. The uptake of solar towards the end of the horizon, and some biomass for electricity generation is a result of all hydro potential being deployed by 2021. This suggests that it is critical for decision-makers to take into consideration the post-2020 regime and plan for even steeper investment if the RE target share is to be maintained.

Adapting the energy system to meet the target increases total energy system costs by 0.27%, or 321€ million relative to the Reference scenario over the entire planning horizon, or on average only 12.8€ million annually. However, power sector investments increase by 150% in cumulative terms (undiscounted), with 3.7€ billion needed in addition to what is required in the Reference scenario.

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 22.3% and CO_2 emissions are reduced (cumulatively) by 12.7% 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.

It is also worth highlighting the issue of the system's climate resilience. Increasing investment in hydro generation, which limits diversification of generation sources, could leave Croatia more vulnerable to climate change impacts, particularly reduced precipitation levels.[11] Further sensitivity analysis should therefore be undertaken to explore how Croatia can achieve the RE target if it reduces its reliance on a hydro-dominated system. Hydro generation is relatively high due to the RE target. An area for future analysis can be to use the stochastic formulation of MARKAL to explore uncertainty associated with future water availability to help with formulating more robust hedging strategies.

[11] ESMAP (2009), Climate Vulnerability Assessments, An Assessment of Climate Change Vulnerability, Risk, and Adaptation in Croatia's Energy Sector, Energy Sector Management Assistance Program, November 2009, World Bank, Washington DC.

F. COORDINATED RENEWABLES AND ENERGY EFFICIENCY POLICIES FOR CROATIA

Promoting both energy efficiency and renewable energy goals in parallel may have strong policy synergies. This analysis looked at assessing both objectives at the same time. In the case of Croatia, the NEEAP and draft Renewable Strategy will be implemented in parallel; therefore, this analysis is a better reflection of the policy reality. What the analysis highlights is that this is more cost-effective due to the synergies between these policy areas.

Key insights include:

- Energy system costs increase by 118€ million or 0.1%. In isolation, the RE target case increases system costs by 0.27% and decreases the EE case costs by 0.17%.
- The efforts to reduce final energy through energy efficiency (reduces by 5.9%) means a lower level of renewable energy required, resulting in lower overall costs.
- CO_2 emissions and imports are each reduced by 15.3% and 34.0%, illustrating important synergies and co-benefits arising from the implementing efficiency and renewable energy policies together.

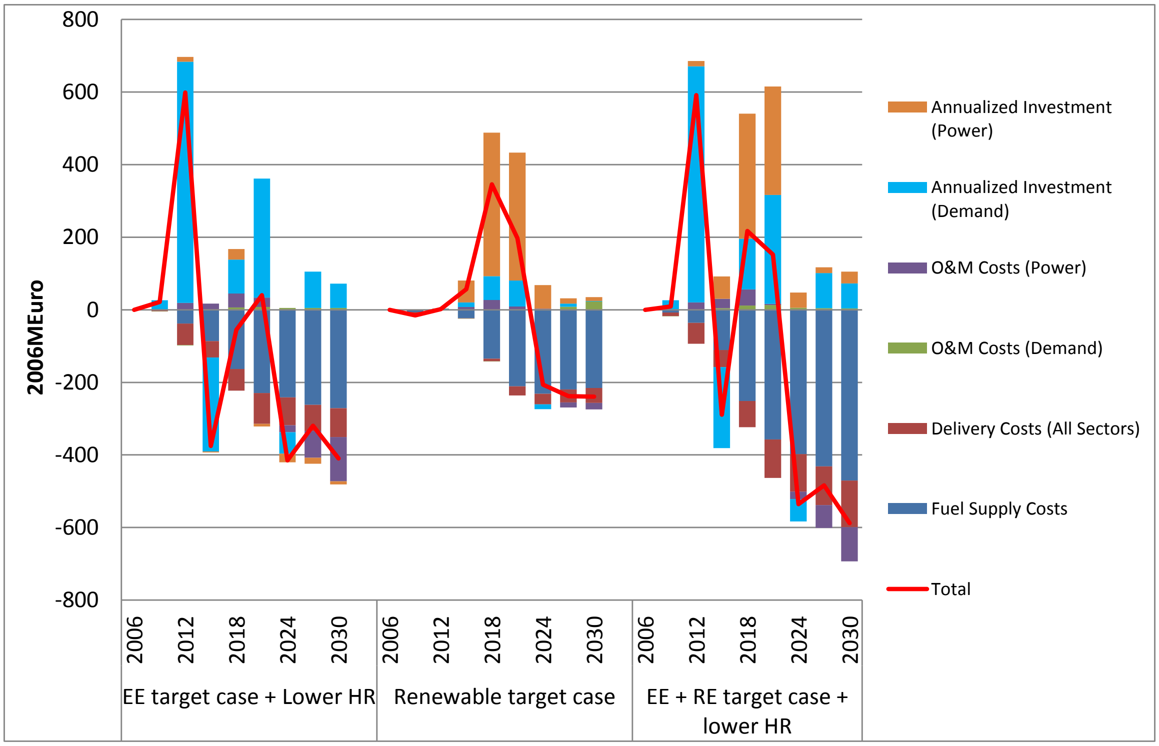
Table 8 shows the key result changes between the combined RE & EE scenario and the Reference scenario.

Table 8. Cumulative Impacts of Combined RE/EE Targets on the Energy System (Change Compared to Reference Scenario)

Indicator	Units	Reference	EE + RE Targets Change	
Total Discounted Energy System Cost	2006M€	119,334	118	0.10%
Primary Energy Supply	Mtoe	285	-20.5	-7.2%
Imports	Mtoe	86.9	-29.5	-34.0%
Fuel Expenditure	2006M€	63,490	-5,552	-8.75%
Power Plant New Capacity	MW	2,640	1,378	52.2%
Power Plant Investment Cost	2006M€	2,485	3,452	139%
Demand Technology Investments	2006M€	64,611	2,991	0.7%
Final Energy	Mtoe	184	-11.0	-6.0%
CO_2 Emissions	Mt	543	-82.9	-15.3%

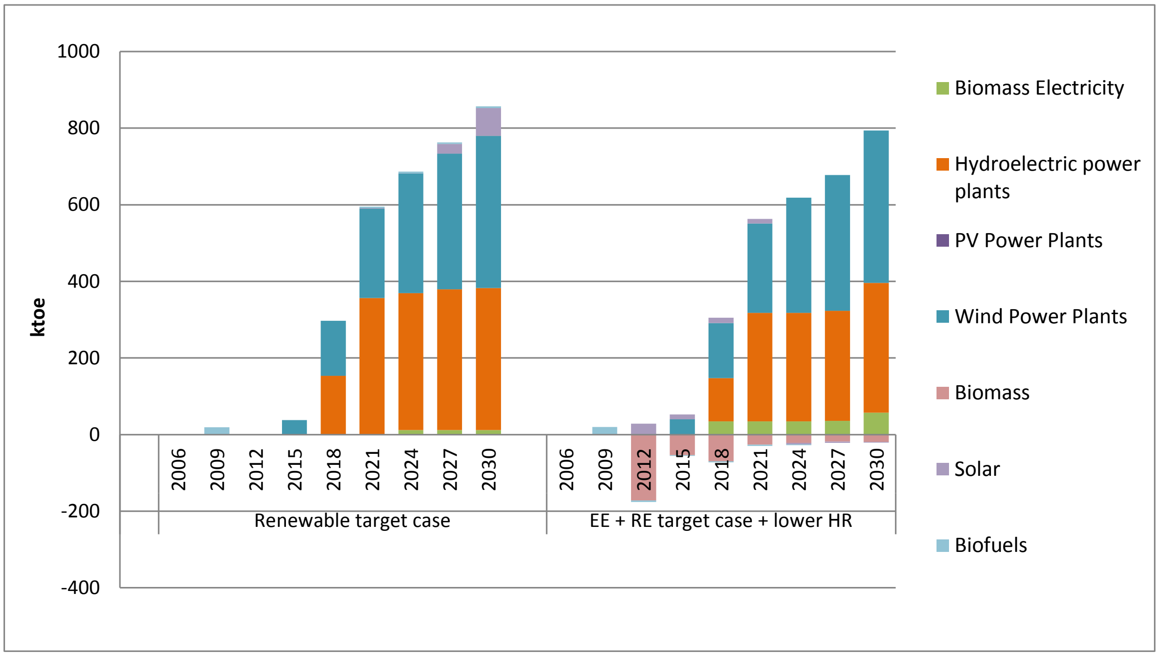
Figure 9 shows the change in annual energy system costs for the three policy scenarios relative to the Reference scenario. The bars show the increases (positive) and decreases (negative) in annual system cost components, and the change in net costs over time is shown as the red line. Overall, costs increase 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 over 470€ million per annum in the combined scenario by 2030.

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



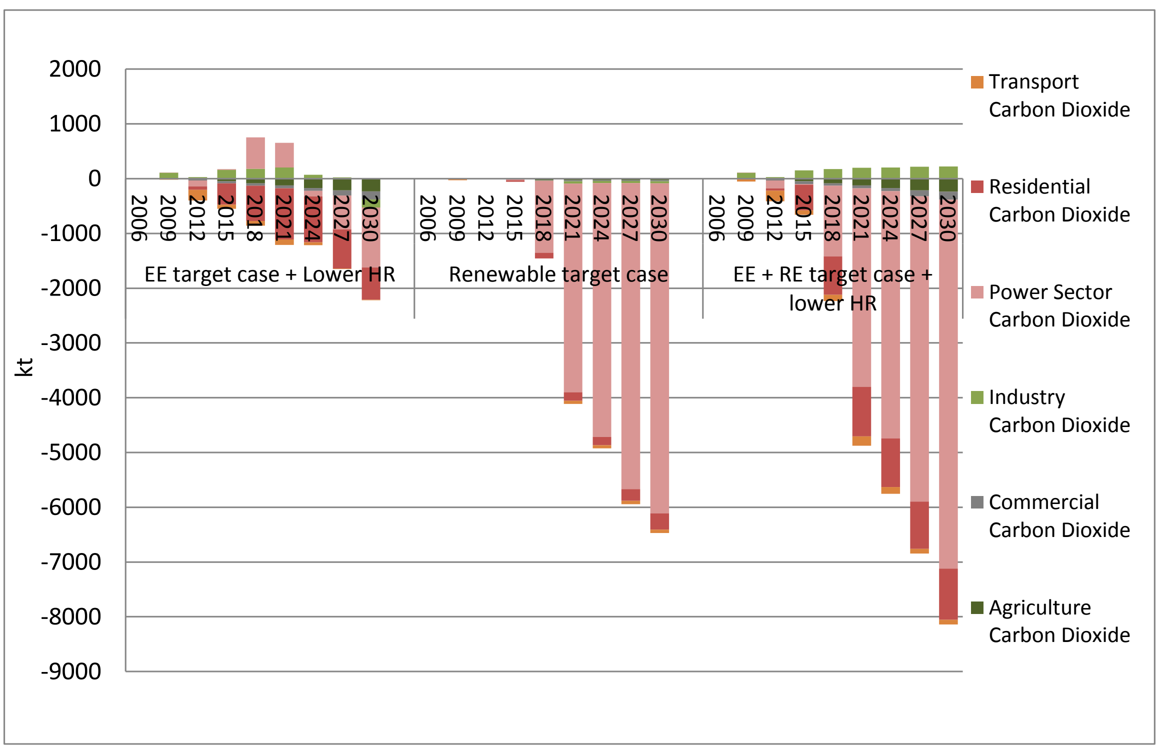
The synergies of meeting both targets at an overall lower cost are illustrated in Figure 10 below. Energy efficiency results in lower levels of renewable energy being required, as the renewable target is relative to (gross) final energy consumption.

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



CO_2 emission reductions are shown in Figure 11, illustrating the significant savings associated with energy efficiency and renewable policy.

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



G. EXPLORING ADDITIONAL NATIONAL PRIORITIES – CO_2 PRICE AND CAP

Other than the role of energy efficiency and renewable energy in meeting future requirements through 2030, another consideration regarding Energy Community commitments and European Union accession directives, is the commitment to a CO_2 reduction. In 2008, the EU put in place the Climate and Energy Package to achieve its 2020 targets of reducing greenhouse gas emissions to 20% below their 1990 levels and increasing the share of renewable energy to 20%. In May 2010, the Commission presented its analysis of options to move beyond 20% GHG emission reductions and assessing the risk of carbon leakage.

This Communication explored the options for, and related costs and benefits of, moving towards a 30% reduction, which the EU had committed to do provided other developed countries committed themselves to comparable emission reductions and more advanced developing countries contributed adequately according to their responsibilities and respective capabilities. This 30% target is based on a 25% GHG reduction through domestic measures, with the remaining 5% reduction met through the use of international emission reduction credits. As the Commission has shown in its Roadmap for moving to a competitive low carbon economy in 2050, for a cost-efficient transition to a low carbon economy as a contribution to global efforts in line with the 2°C objective, that avoids carbon lock-in, domestic emissions reductions of the order of 40%, 60% and 80% below 1990 levels by 2030, 2040 and 2050 respectively should be considered as milestones.[12]

The combined EE&RE targets are sufficient to meet the 20% CO_2 emission reduction target over the study horizon. Some additional analysis was conducted to explore the implications for the energy system of Croatia of some of the more ambitious CO_2 reduction targets contemplated by the EU, and can be summarized as follows:

A. EE&RE_Relaxed_Fossil_Operation: In the scenarios presented in the previous sections, a large share of existing coal, gas power and CHP plants were constrained to run until the end of their lifetime which extends beyond the modeling horizon. Given CO_2 considerations, it may make sense to relax this constraint and to allow early retirement of these plants should it be economical to do so.
B. EE&RE_RFO_25pCO2CAP: The same as scenario A with the more ambitious CO_2 reduction target starting at 25% below 1990 levels in 2021 and 33% below 1990 levels in 2030 in line with the 30%, 40% reduction milestone where the difference is met through the use of international emission reduction credits.
C. EE&RE_RFO_25CO2PRICE: The combined EE&RE with relaxed fossil plant operation scenario with a 25 Euro/ton CO_2 price imposed from 2015 onwards, to see how far from the 33% target Croatia would get given this level of CO_2 pricing.

[12] European Commission Staff Working Paper: Analysis of options beyond 20% GHG emission reductions: Member State results, Brussels, 1.2.2012,SWD(2012) 5 final.

Figure 12. CO_2 Emissions relative to the 1990 levels for Croatia

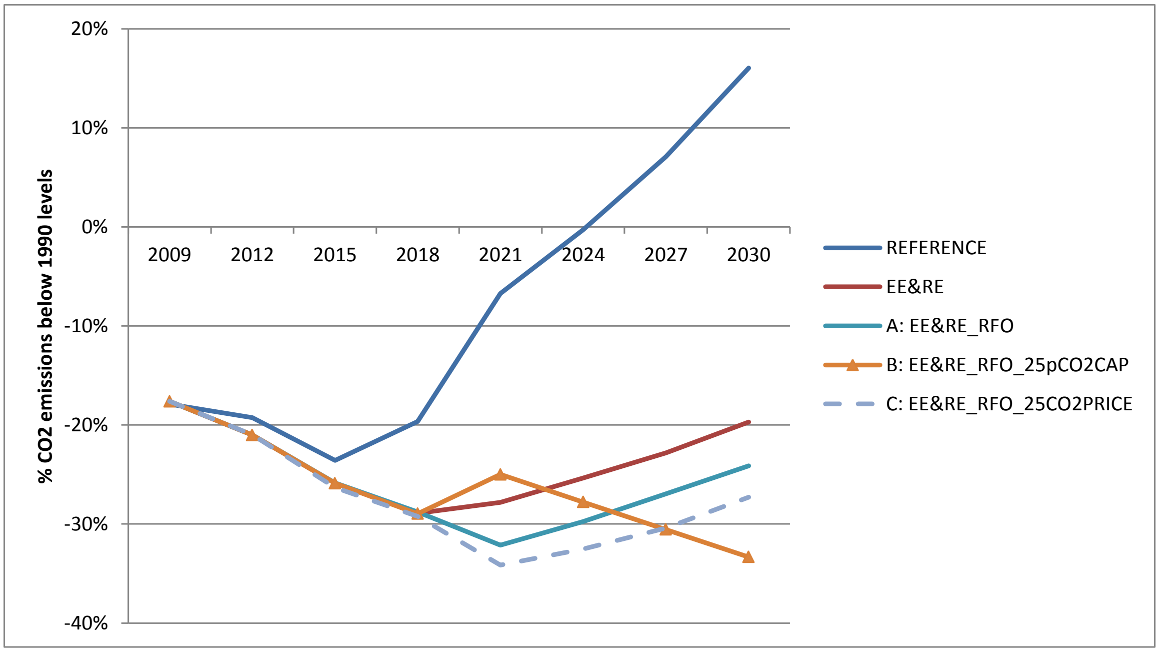


Figure 12 shows the CO_2 emission for Croatia relative to its 1990 emission levels for their Reference Scenario, the combined EE&RE scenario, and the three additional scenarios described above. It shows that in the Reference scenario, the CO_2 emission levels rise to around 15% above the 1990 level, and as mentioned above, in the combined EE&RE scenario emissions stay below the -20% level over the planning horizon. When the constraint on the existing fossil plants is removed the CO_2 emission levels drop to almost 25% below 1990 levels in 2030. Interestingly, the EE&RE targets are also met at a slightly lower cost, the system cost dropping 0.1% relative to the reference, as opposed to the 0.03% increase observed when the constraint is in place. The more ambitious constraint shifts some of the emissions to earlier years in order to meet the 2030 -33% target. This scenario costs 0.07% more than the reference when the fossil plants are allowed to retire early, and requires an investment in 1 unit of nuclear (1000MW) in 2030. The CO_2 margin in this scenario peaks at 40 Euro/ton in 2027.

When a 25€/ton CO_2 price is imposed, the CO_2 emissions drop to 34% below 1990 levels in 2024 before climbing back up to 27% below 1990 levels.

The main conclusion of this analysis is that given the EE&RE targets in place, Croatia would easily meet the 20% reduction targets, and the additional effort to meet the more ambitious target is relatively modest, needing CO_2 price levels somewhere between 25 and 40€/ton CO_2.

APPENDIX I: DATA SOURCES AND KEY ASSUMPTIONS

The Croatia 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	• Energy in Croatia yearbook
Domestic Energy Prices	• Energy in Croatia yearbook
Resource Potential, including imports/exports	• Energy in Croatia yearbook
Installed capacity and characterization of existing electricity, heating and CHP plants	• HEP d.d. reports: • HEP, Annual Report 2006
Electricity generation plants (adjustment to the SSP plant characterizations)	• HEP d.d. reports: • HEP, Realized Energy Balance 2006 • OIEKPP Registry
Timing of demands for energy services	• Hour-by-hour load curve of energy system of Croatia[13]
Fuel consumption patterns by energy service	• Expert estimations based on Energy balance of the Republic of Croatia
Demand Drivers	• Statistical Bureau
Known energy policies	• Strategy of the Energy Development of the Republic of Croatia

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

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

A set of key assumptions provide the basis for developing the Reference case, which properly reflects the situation in Croatia (see Table 10). 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 centralized/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. 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

[13] Available from HEP trading Company – HEP Trgovina d.o.o.

the analyst for the individual plants under consideration for rehabilitation). Additional options may also be easily added should the national situation dictate.

A series of constraints have been introduced to ensure that the Reference case is plausible, and properly reflects the situation in Croatia (see Table 10 below).

Table 10. Key Constraints in the Reference Scenario

Sector / Issue	Constraint
Resource supply	
Domestic energy resources	
RES potential	
Hydro	No more than 800 MW of new large hydro small hydro constrained to about 120 MW in total until 2030.
Wind	Wind capacities gradually constrained up to 2GW in 2030.
Solar	Solar capacities gradually constrained up to 420MW.
Biomass	Biomass capacities gradually constrained up to 1200MW.
Imports/Exports	Biomass import constrained throughout the whole analyzed period.
	Net imports of electricity constrained to the base year level.
Electricity generation / supply	
Technology availability	Nuclear generation is not available in the Reference scenario until 2020. There are limits on other technologies, in particular forced known build (one large hydro power plant (HPP), small HPPs, wind and biomass).
Functioning profile of existing power plants	Stable production of existing power plants.
End use sectors	Limited penetration of advanced technologies (<10% share by 2030).
	Smoothening of the fuel switching to the end-use sectors compared to the BY mix by increasing upper bounds and decreasing lower bounds respectively.
	Limited penetration of thermal insulation technologies in the residential sector (about 10%).

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 centralized/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.[14] 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.

[14] 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 11. Future Electric Power Plant Characterization*

Power Plant Type	Start Date	Lifetime	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	2020	40	0.36	0.90	3000	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.

Table 12. 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 13. Future Heating Plant Characterization

Power Plant Type	Start Date	Life-time	Efficiency	Availability 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 Croatia the characteristics of the key new power and coupled heat power plants that are chosen by the model are shown in Table 14.

Table 14: Characterization of Key Power Plant Options

Power Plant Type	Start Date	Life	Efficiency (n_e , n)	Availability Factor	Investment Cost (M€/GW)	Fixed O&M (M€/GW)	Variable O&M (€/MWh)
Nuclear	2009	40	0.36	0.9	4816	41	1.05
Natural Gas Steam Turbine	2009	25	0.34	0.80	375	7.5	2.70
Hard Coal IGCC	2010	35	0.51	0.85	1200	53	11
Wind	2012	20	1.00	0.22	1070	42.8	0.0
Biomass Electricity decentralized	2009	30	0.37	0.8	1700	43	6.8
Dual Cogen (Natural Gas + Geothermal)	2012	25	0.14/0.67	0.8	1500	80	54**
Natural gas CHP	2009	35	0.45/0.9	0.75	585	30	5.5

** These values seem extremely high and will be adjusted in the next phase. However the basic fuel for this technology is geothermal heat power (90%) which is supplied in zero costs.

In terms of demand devices, the approach taken involves drawing on the technology characterizations that were employed in the EU NEEDS model, 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/).

Table 15. Key Assumptions in the Reference Scenario: Energy Prices / Infrastructure

Import Commodity Price Assumptions (11)									
	Units	**2006**	**2009**	**2012**	**2015**	**2018**	**2021**	**2024**	**2027**	**2030**
Gas	(€/MBTU)	5.82	5.03	6.05	7.27	7.83	8.33	8.66	9.03	9.45
Coal	(€/ton)	50.07	66.12	66.29	66.46	69.67	72.40	73.90	7.22	76.45
Oil (crude)	(€boe)	49.16	41.05	51.21	63.88	70.20	76.07	80.14	84.20	88.35
Electricity (12) (13)	cents€/kWh)	4.78	4.87	5.13	5.39	5.65	5.91	6.17	6.43	6.69

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 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 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 light 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
	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

Energy Service Demand	Demand Device	Investment Cost (€/GJ)	Efficiency (Fraction)
	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 adjusted for national circumstances, though most use this standard approach as described.

Note that due to lack on data on the process details of Croatia 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 17) 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.[15] Only the relative efficiency numbers are used and applied to information from the Sultan Tool mentioned earlier. Relative cost values are applied to user-provided information on standard gasoline/diesel vehicles. LDV costs and efficiencies are shown in Table 17.
- 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.

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

Table 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 13. LDV Efficiency by Type in Croatia MARKAL Model

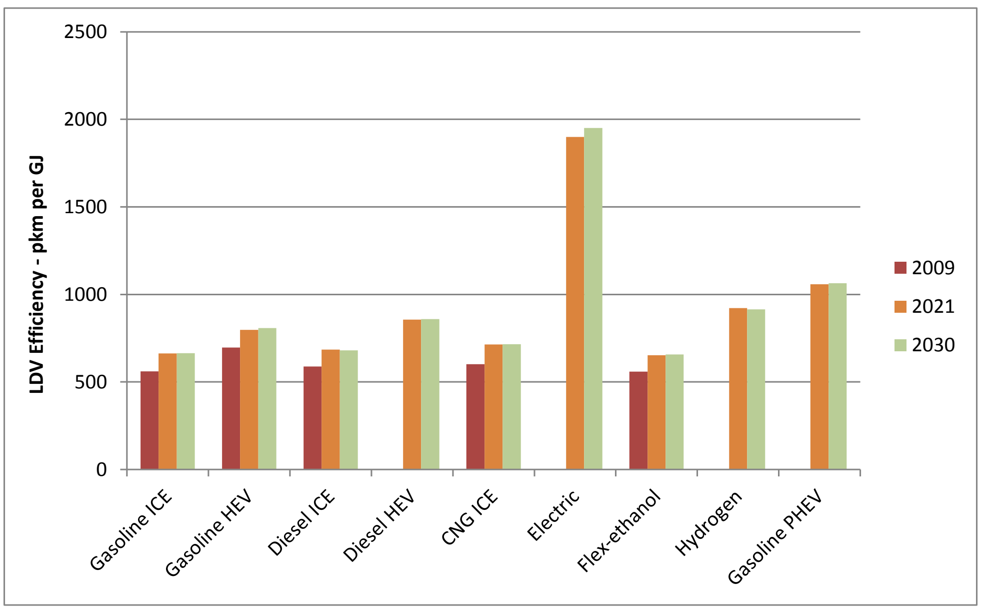
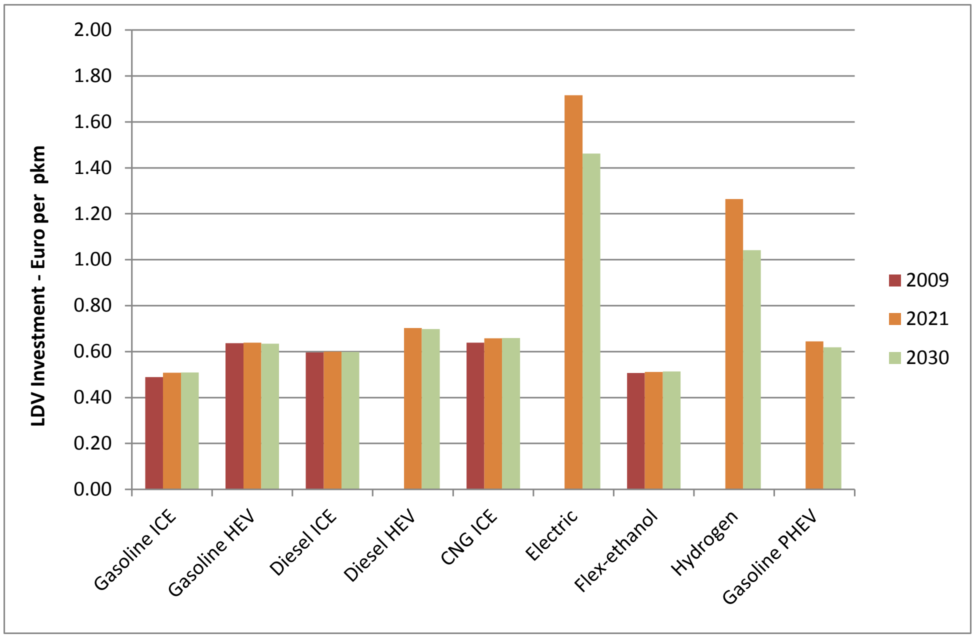


Figure 14. LDV Efficiency by Type in Croatia MARKAL Model



For the year 2006, the transport sector is calibrated to the national energy balance. The transport sector energy totals have been disaggregated using Croatia 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 projection 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 and United Kingdom 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 in the 20-40% range to achieve the dampening of the new device updates to the original Reference scenario level. This reflects the fact that in the absence of policy it is highly unlikely that (most) people will recognize the cost savings over the lifetime of an advanced improved device and overcome the higher upfront cost. Then, as EE policies and programs incentivize uptake, these hurdle rates are reduced. Under the EE target case, hurdle rates are reduced to the range of 10-20%, reflecting the impact of policies (e.g., appliance standard – that eliminates inefficient options from the market place) and programs (e.g., low interest loans for building shell improvements and the purchase of efficient appliances).

CONDUCTING EE ANALYSIS

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

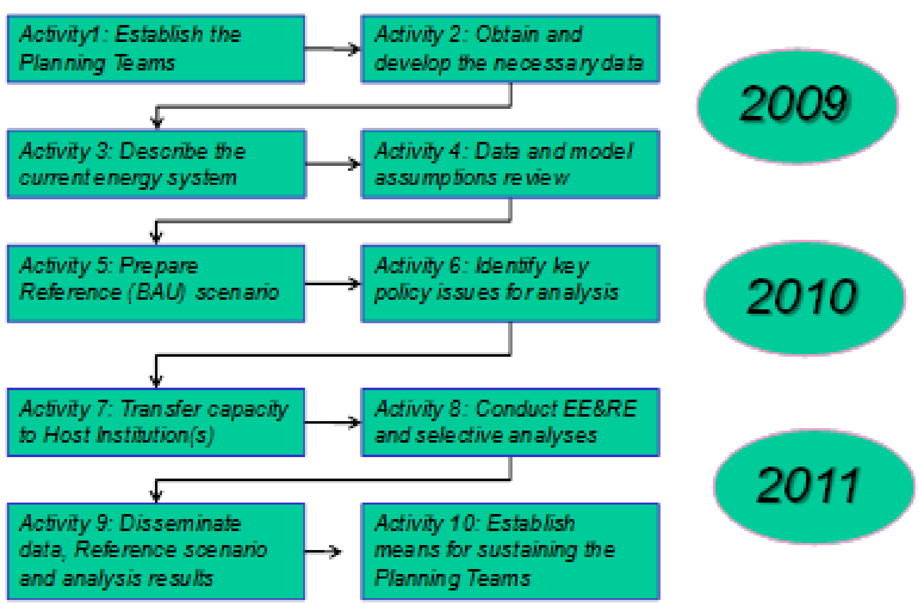
APPENDIX III: PROJECT ACTIVITIES AND METHODOLOGY EMPLOYED

MAJOR PROJECT ACTIVITIES

The consultant teams for International Resource Group (IRG) and the Centre for Renewable Energy Sources (CRES) worked with key personnel from the Croatian Ministry of Economy Trade and Energy (METE) and the Energy and Environmental Protection Institute Ltd. (EKONERG) to establish a credible MARKAL-Croatia 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 14). 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 15. 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.

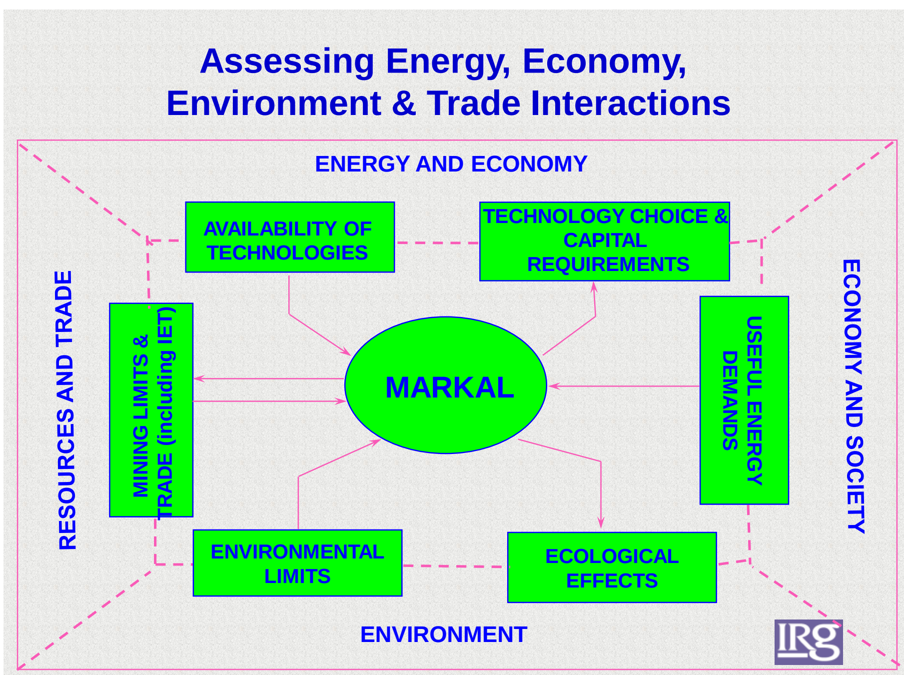
At least as important as the energy balances themselves, and the accompanying information systems, is the process of building a team of professionals in each country that can work with the data, maintain the information systems, and support higher level analytical approaches. This team building should 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 15).

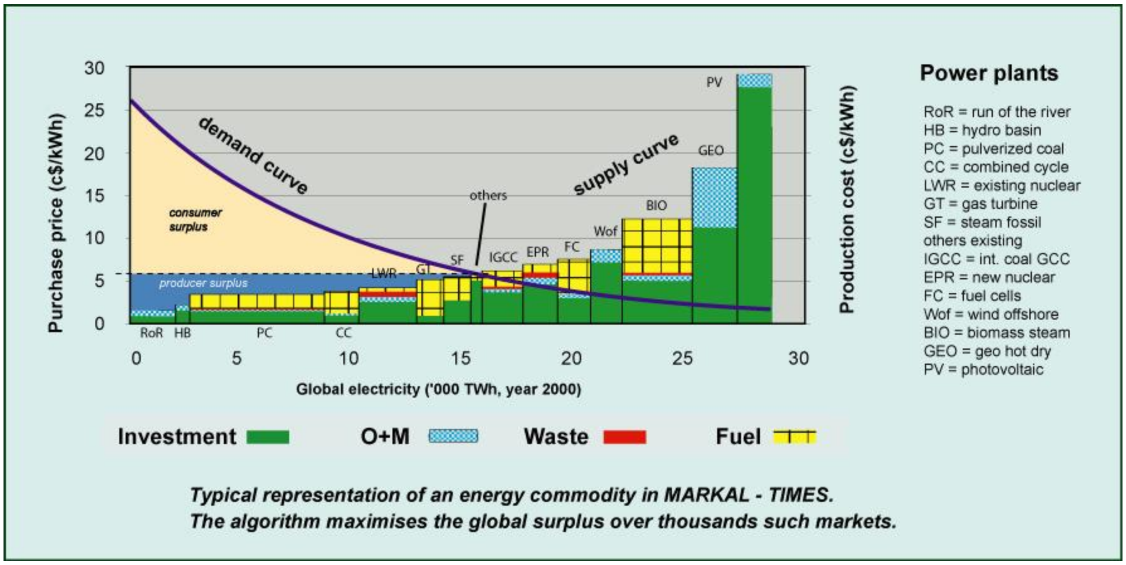
Figure 16. Interactions in the MARKAL/TIMES Model



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 17) 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 17. Power Plant Dispatch in the MARKAL/TIMES Model



One of the most relevant suite of studies conducted recently are those sponsored by the European Union, which 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)[16] undertaking. The Pan-European TIMES model (PET)[17] evolved from the original NEEDS model and has been employed for series of high profile EU projects, including RES2020[18] examining the EU renewables directive,[19] REALISEGRID[20] 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).[21] Another pair of high-profile uses of MARKAL/TIMES is the IEA Energy Technology Perspectives[22] and UK Climate Change Policy "White Paper."[23]

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16 http://www.isis-it.net/needs/

17 http://www.res2020.eu/files/fs_inferior01_h_files/pdf/deliver/The_PET_model_For_RES2020-110209.pdf

18 http://www.res20202.eu

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

20 http://realisegrid.rse-web.it/

21 http://reaccess.epu.ntua.gr/TheProject/ProjectObjectives.aspx

22 http://www.iea.org/techno/etp/index.asp.

23 http://www.ukerc.ac.uk/ResearchProgrammes/EnergySystemsandModelling/ESM.aspx.

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