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:

UKRAINIAN POLICY BRIEF

July 2012
This report was produced for review by the United States Agency for International Development (USAID). It was prepared by the Institute for Economics and Forecasting of Ukrainian National Academy of Sciences (IEF/UNAS) and International Resources Group (IRG).

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:

UKRAINIAN POLICY BRIEF

July 2012

TABLE OF CONTENTS

List of Figures

List of Tables

ACRONYMS

BAU	Business as Usual
CC	Combined cycle
CCGT	Combined-Cycle Gas Turbine
CFL	Compact fluorescent lamp
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)
EU	European Union
FEC	Final Energy Consumption
GDP	Gross Domestic Product
GFEC	Gross Final Energy Consumption
GHG	Greenhouse Gas
GT	Gas turbines
GW	Giga-watt
HP	Hydro Pumped
HFO	Heavy Fuel Oil
HV	High Voltage
IEA	International Energy Agency
IEF	Institute for Economics and Forecasting
IGCC	Integrated Gasification Combined Cycle
IRG	International Resources Group
Kt	Kilo-tons
Ktoe	Kilo-tons oil equivalent
kWh	Kilo-Watt hour(s)
LFO	Light Fuel Oil
LPG	Liquid Petroleum Gas
LV	Low Voltage
LWR	Light Water Reactor
MARKAL	MARKet ALlocation
Mcf	Million cubic feet

MECI	Ukrainian Ministry of Energy and Coal Industry
MRDCCL	Ukrainian Ministry of Regional Development, Construction, and Communal Living
Mt	Megaton
Mtoe	Megaton oil equivalent
MV	Medium Voltage
MW	Mega-Watt
NEEAPs	National Energy Efficiency Action Plans
NEEDS	New Energy Externalities Developments for Sustainability
NPV	Net Present Value
NSC	Ukrainian National Statistical Committee
O&M	Operation and maintenance
PC	Pulverized coal
PET	Pan-European TIMES model
RE	Renewable Energy
REACCESS	Risk of Energy Availability: Common Corridors for Europe Supply Security
REDP	Regional Energy Demand Planning
RESMD	Regional Energy Security and Market Development
RoR	Run-of-rRver
SF	Steam fossil
SSP	SYNENERGY Strategic Planning
TOE	tons of oil equivalent
TPP	Thermal Power Plant
TWh	Terawatt hour(s)
UK	United Kingdom
UNAS	Ukrainian National Academy of Sciences
US	United States
USAID	US Agency for International Development
WEO	World Energy Outlook

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 Ukrainian Planning Team using their national MARKAL (MARKet ALlocation)/TIMES integrated energy system model, TIMES-Ukraine. It examines 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 review of key sectoral assumptions, updated fuel prices, improved emissions accounting, more advanced approach to the energy efficiency, and renewables energy policy analysis, along with the revised analyses of national priorities – expanded domestic coal production and exploration of shale gas potential.

The analysis reflects several years of model development and use, jointly undertaken by the Institute for Economics and Forecasting of Ukrainian National Academy of Sciences (IEF/UNAS), Ukrainian Ministry of Energy and Coal Industry (MECI), and the Ukrainian Ministry of Regional Development, Construction, and Communal Living (MRDCCL), supported by International Resources Group (IRG) and the Centre for Renewable Energy Sources (CRES). The TIMES-Ukraine 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 Ukraine, 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 Ukraine, where model assumptions and policy scenarios may be readily changed and explored, that can provide analytic rigor and insight to underpin future national strategic planning and policy formulation.

The following supply and demand analyses have therefore been undertaken:

- Reference (Business-as-Usual or 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. The scenario assumes that 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 critical issues related to possible use of the domestically produced coal and shale gas in order to move towards energy independence, decreasing the trade balance deficit in Ukraine. The substitution of imported natural gas with the domestically produced coal/shale gas in electricity and heat production sectors, as well as in metallurgy, is examined in Section G.

B. KEY INSIGHTS FOR POLICY MAKERS

The analysis undertaken provides some important insights on how improving energy efficiency and promoting renewable energy impacts on the key policy areas of energy security and diversification, climate mitigation, and economic competitiveness. 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	Energy Efficiency	Renewables	EE&RE
Energy security and diversification	• Nuclear fuel imports stop in 2018 due to increased domestic production ◦ Total energy imports (not including nuclear) after 2010 stabilize (approximately 50-51M toe) • Gas imports decrease by 30.5% (from 59B m3 in 2005 to 41B m3 in 2030)	• Reduces fossil fuel imports by 168,484 Ktoe (10.4%) • Lowers primary energy supply by 215,617 Ktoe (5.5%)	• Reduces overall imports by 5.1% • Reduces gas imports by 56,812 Ktoe or 70.8 billion m^3 (6.2%) • Encourages more wind, solar and biofuels	• Increased use of wind, solar and biofuels (although the latter at much lower level than under RE case) • Cumulative total imports reduced by over 14.8%
Enhanced competitiveness[1]	• Energy intensity of economy decreases more than twofold • Energy consumption per capita grows by 29%	• Lower fuel costs, saving 12.4% in fuel expenditure (83,513€M) • Requires additional 31,024€M investment in more effective demand technologies while saving 9,617€M in power generation	• Stimulates additional 28,009€M investment in renewable market and additional 38,310€M investment in demand technology • Cuts expenditure on fuel by 33,212€M	• Final energy consumption reduced by 6.5% • Lower fuel costs, saving 16.1% in fuel expenditure (108,278€M)
CO_2 mitigation	• Emissions increase by 10.6% by 2030 owing to increased coal use	• Cumulative reduction of 7.2% due to lower total energy consumption	• Cumulative reduction of 6.5% due to use of less fossil energy (mainly natural gas)	• Cumulative reduction of 13.5% due to more RE and lower energy consumption

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

ENERGY SECURITY AND DIVERSIFICATION

Under both RE and EE scenarios, import levels will be reduced by around 5.1% and 10.4% respectively, a 14.8% reduction under the combined scenario. This is due to increased use of indigenous renewable energy under an RE target, and lower energy demand resulting from increased energy efficiency. Gas imports are particularly affected. Under the RE scenario, imported gas is reduced by over 6.2% cumulatively, while in the EE scenario, the reduction is 13.9%. (In the combined scenario, following the reduction of gas demand over all sectors gas imports are reduced by 24.5% to 24.3 billion m^3.) The energy supply becomes more diversified under the combined scenario, with increased domestic production and a significant reduction in gas supply.

ENHANCED COMPETITIVENESS

An energy efficiency target with the right policies and programs has strong benefits for competitiveness by reducing payments for imports, 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 16.4€ billion. However, only around a 4% reduction is achieved – as opposed to the 9% called for by the Energy Community. With the target in place, total fuel expenditure savings (compared to the Reference case) amount to a cumulative saving of 108.3€ billion (in the combined scenario case), which partially offset the higher costs associated with the improved demand devices. Once transformed, these energy system savings will continue into the future such that in the long run, the Ukraine energy system will be more competitive.

The proposed 2020 RE target, in line with that proposed by the Energy Community, increases the cost of the energy system due to the additional renewable generation investment required, particularly as we near 2030, under the assumption that the RE share is to be sustained over time. To meet the target, an additional 12.8€ billion will be required by 2020, and over 11.4€ billion by 2030 compared with the Reference case. Overall energy system costs are 3.3% higher (31.3€ billion Net Present Value (NPV)[2]), but due to domestic investment rather than foreign fuel payments.

If the RE target is implemented in parallel with policies to promote energy efficient technologies, the combined cost of meeting renewable targets and energy efficiency targets are reduced, with additional costs of 1.9% compared to an aggregate increase (across both policy scenarios undertaken individually) of 5.2%. Since electricity prices increase under the RE target scenario, it will be important to understand the distribution of impacts, and, where necessary, to improve competitiveness or reduce social impacts redistribution of the savings due to less imports. To this end, a combined EE&RE policy can produce savings of valuable foreign exchange funds amounting to 108.3€ billion cumulatively, which can be redirected to support those people most vulnerable to the higher electricity prices.

It must 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 Ukrainian energy economy. The combined EE and RE policy leads to cumulative reductions of 13.5% in CO_2 emissions. This is accomplished by increasing renewable generation from solar and wind power by 13.366 MW along with the overall reduction in demand for through the deployment of more efficient power plants and demand devices.

---

[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

In recent years the availability of comparatively less expensive energy resources shaped the energy picture in Ukraine, increasing the critical dependence on gas, the negative effects of which were clearly felt after the rising cost of imported gas. Despite the goal of reducing Ukraine's dependency on gas, changing the trajectory of the evolution of the Ukraine energy system is challenging, requiring major investments and longer-term planning. As reflected in the new draft UESU2030, the Base scenario does not show radical change in the composition of the energy balance. Regardless however, large-scale investments, including a 100€ billion to expand generating capacities by 42% (19.2 GW), are going to be needed by 2030. The TIMES-Ukraine Reference scenario, using similar assumptions to the UESU2030 Base case, shows the need to introduce even more additional capacity – 25.8 GW. At the same time, costs to implement relevant energy and environmental policies increase the challenges and obviously require specific analysis of alternatives of energy supply.

An energy efficiency policy is recognized as one of the key priorities in Ukraine – energy intensity of national economy is still 2-3 times higher than developed countries, which dramatically reduces the competitiveness. The TIMES-Ukraine analysis shows that a 3.3% reduction in final energy consumption can be achieved at a net savings of 16,412€ million (or 1.7% of energy system costs) by removing barriers to the update of more energy efficient devices, while achieving the more ambitious National Energy Efficiency Action Plan (NEEAP) target of 9% until 2020 (in line with the Energy Community Contracting Party goal) requires only a modest cost increment of 0.08% (734€ million) over the baseline, while saving 83,513€ million in fuel expenditures and reducing imports by 10.4% (168.5 mtoe) and carbon emissions by 7.9% (684.1 Mt). Achieving these goals requires a 4.6% (31,024€ million) increased investment in more efficient demand devices, permitting a nearly 9,617€ million reduction in new power plant expenditures, as the need for capacity growth is reduced by nearly 5,292 MW. The most cost-effective areas for energy efficiency investment identified in this analysis include residential and commercial space and water heating, and technological transformations in metallurgy. The TIMES-Ukraine 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 target proposed by the Energy Community Secretariat (ECS) for Ukraine (12% of Gross Final Energy Consumption (GFEC) until 2020), on the other hand, increases energy system costs by 3.3% (31,271€ million) and requires 35% (8,566 MW) more power plant capacity additions, and over 16€ billion in increased investment costs. Meanwhile, achieving the target yields substantial benefits: a more than 5.1% (81,723 ktoe) decrease in imports, an 4.9% (33,212 € million) decrease in fuel expenditures and 6.5% (564 Mt) carbon emissions, while demand for final energy increases only by 0.6% as a result of increased use of solar energy for heating and water heating in residential and commercial sectors and increase of biofuels. The cumulative capacity addition needed to reach the target by 2020 is approximately 6,101 MW (12.8€ billion). This suggests that meeting the target and critically sustaining it beyond 2030 will require strong policies to stimulate investment and attract high levels of capital in the end-use and power generation sectors. Further analysis using the stochastic formulation of TIMES-Ukraine together with an additional dispatching model can explore uncertainty associated with future water/wind/solar availability and help formulate more robust hedging strategies for electricity transportation, export, and supply.

Although the investment challenges are significant, pursuing the EE and RE strategies simultaneously leads to important synergies. The increase in system cost is limited to 1.9% (18,093€ million) or 1.5% (64,364€ million) less than the sum of the two strategies separately. The savings are dramatic: a 16.1% (108,278€ million) decrease in fuel costs, 13.5% (1,163 Mt) decrease in carbon emissions, and nearly 15% (239,419 ktoe) decrease in energy 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 of other alternative scenarios described herein make it clear that Ukraine now has a fully operational integrated energy system planning model that can be used to examine in more detail various energy and environmental policy scenarios and their combination to achieve these and other policy goals. Key areas for future analysis include assessing tradeoffs regarding domestic versus imported energy resources considering relevant economic and environmental impacts, designing EE&RE development policies with a view to adequate multiplicative effect, and identification of low emission development strategies in order to keep the role of Ukraine as a key player on international carbon markets.

C. UKRAINE BUSINESS-AS-USUAL ENERGY PATHWAY

To assess the impact of different strategies or policies on the energy system in Ukraine, the Planning Team developed a Reference scenario, which takes into account specific characteristics of the national energy system, such as existing technology stock, domestic resource availability and import options, and near-term policy interventions. The results obtained will provide insights to facilitate achieving the goals established by Cabinet of Minister of Ukraine Approval of Energy Strategy of Ukraine until 2030 (decree March 15, 2006 145-p) and by the State Program of Economic and Social Development of Ukraine for 2010, adopted by Law (May 20, 2010 # 2278–V) regarding strategic planning for the fuels and energy sector. In order to formulate the Reference scenario, all available national data sources (National Statistical Committee (NSC), National energy balances, etc.) as well as some international databases (including the International Energy Agency (IEA)) were utilized. The full list of information sources is provided in Appendix I.

Reference scenario energy growth is driven by the assumption regarding economic growth, averaging around 3.8% per year during 2005-2030, although for 2012-2030 this figure averages 4.3%. This is in line with assumed economic growth for the revised Energy Strategy of Ukraine until 2030 (UESU2030),[3] falling between the Pessimistic and Base scenarios of the Strategy. Final energy consumption is projected to grow only 18% by 2030 compared with 19% in the UESU2030.[4] While growing Gross Domestic Product (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 2005 – it is estimated to be 0.61 toe/1000€ (GDP), a reduction of around 52%. This is a result of the continuation of current structural changes in the Ukrainian economy and natural technological progress underway throughout the world.

To support this growth, an expansion of the electricity generation system capacity is required, from 46,000 MW to 70,808 MW (a nearly 55% increase by 2030). Key indicators from the Reference scenario are shown in Table 2.

Table 2. Key Indicators for the Reference Scenario

Indicator	2005	2030	Annual Growth Rate (%)	Overall Growth (%)
Primary Energy (Ktoe)	139,992	158,764	0.5%	13.4%
Final Energy (Ktoe)	87,858	103,390	0.7%	17.7%
Power plant capacity (MW)	46,000	70,808	1.7%	54.6%
Imports (Ktoe)	86,337	51,167	-1.8%	-40.7%
CO_2 emissions (Kt)	321	354	0.5%	10.6%
GDP (€ Mill.)	69,086	170,784	3.8%	147.2%
Population (000s)	47,281	43,034	-0.4%	-9.0%

---

3 The new draft UESU2030 was released on June 11, 2012, after the analysis for this report was completed. The TIMES-Ukraine model could be used to explore more deeply the implications of what the UESU2030 proposes against the integrated least-cost perspective presented here.

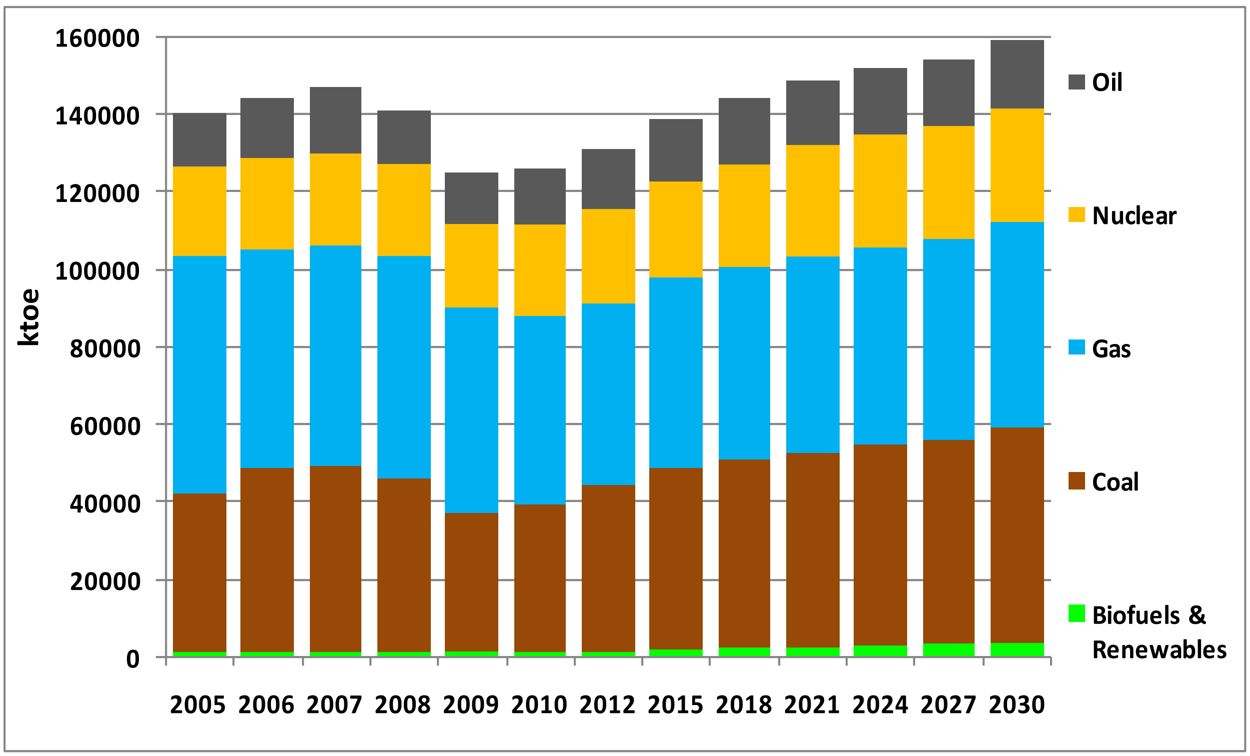
4 In UESU2030 Energy balance of Ukraine is presented in internal format and primary supply and final consumption are not reported. The comparison was done on total consumption indicator.

Indicator	2005	2030	Annual Growth Rate (%)	Overall Growth (%)
Final Energy intensity (toe/€000 GDP)	1.272	0.605	-2.7%	-52.4%
Final Energy intensity (toe/Capita)	1.858	2.403	1.1%	29.3%

Primary energy consumption in 2030 is projected to be 159 Mtoe, up from 2005 levels by 13%. An important point in the Reference scenario is the assumption of full utilization of the existing domestic uranium ore deposits in the country reactor fuel fabrication, which leads to zero nuclear fuel imports by 2018.

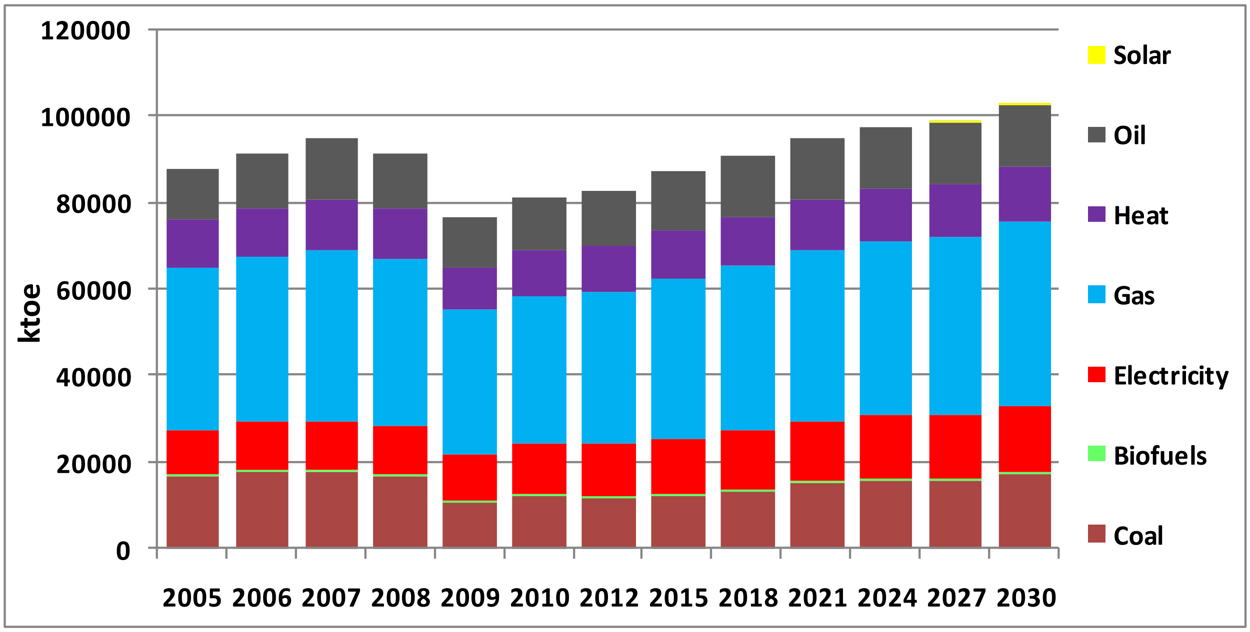
As shown in Figure 1, the primary energy supply mix does not change much between 2005 and 2030. The share of natural gas decreases from 43.6% in 2005 to 33.3% in 2030 and coal increases from 29.1% in 2005 to 34.9% in 2030; the difference is taken up by nuclear and oil. The contribution of renewable energy sources to total primary energy during this period will increase from 0.8% to 2.3%.

Figure 1. Primary Energy Supply — 2005/2030



Total final energy consumption grows by 17.7% over the planning horizon, with the most significant change being natural gas decreasing from 42.8% of the mix in 2005 to 41.2% in 2030 and coal consumption decreasing from 19.2% in 2005 to 16.6% in 2030, with electricity increasing from 12.0% in 2005 to 14.9% in 2030, and renewable energy and biofuels appearing at 0.7%, as shown in Figure 2.

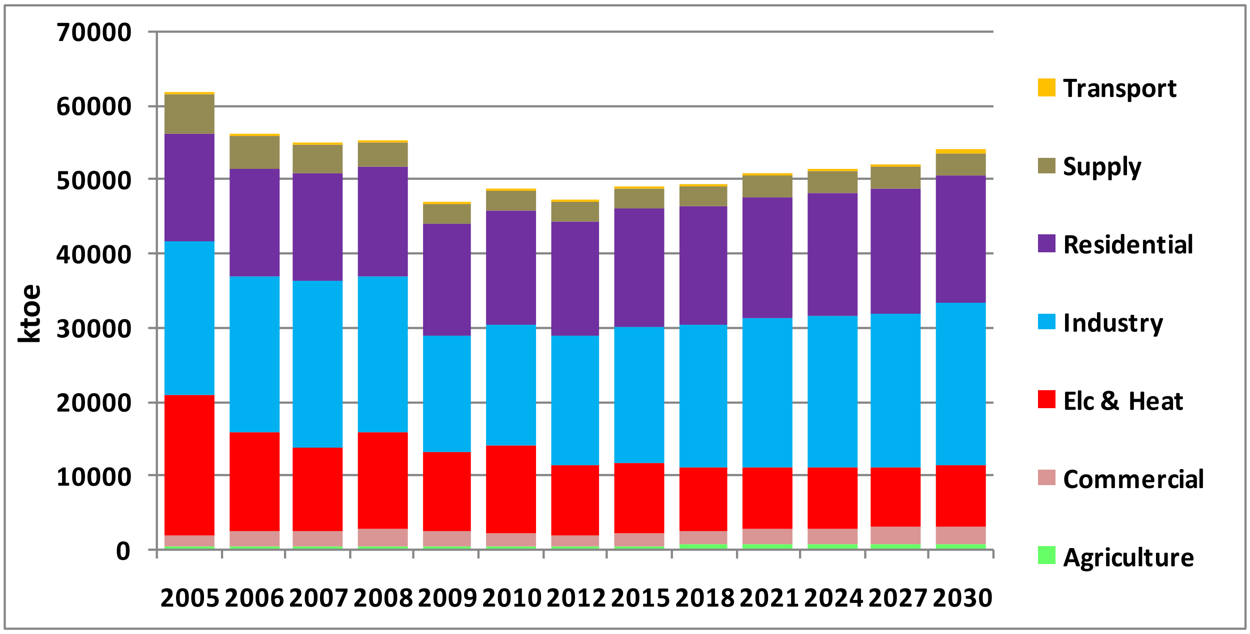
Figure 2. Final Energy Consumption by Energy Type



A more detailed view of gas consumption by sectors is shown in Figure 3. Gas consumption decreased abruptly in 2006 and 2009 primarily due to the sharp gas price increase by Russia and the (financial) crisis in 2008-2009. In 2006, the natural gas price grew from \$50 to \$95 per 1000 m^3 and from \$180 to \$230 per 1000 m^3 in 2009. Currently the price of Russian gas for Ukraine is \$425 per 1000 m^3. In the future, the total direct consumption of gas is not expected to rise, while in the electricity and heat production sector, gas use decreases substantially.

As shown below, the main natural gas consumers in 2005 were industry (33.8%), the electricity and heat production sector (30.8%), and households (23.7%). Due to the significant rise in gas prices, and the relevant government policy, the electricity and heat production sector's share decreased to 24.2% in 2010 (the decrease primarily by electricity producers) and could decrease to 15.4% in 2030. Industry's consumption was reduced similarly; however, with the renewal of industrial output, the gas demand approaches pre-crisis level. The share of industrial gas consumption will increase from 33.8% in 2005 to 40.3% in 2030. However, due to gas substituting for other fuels in some industries (particularly in blast furnaces), the absolute values remain close to the 2005 level. Overall, household gas consumption changed little. As a result of continued large-scale gasification, households' share of gas consumption grew to 32.1% in 2010, and is projected to remain at that level until 2030.

Figure 3. Gas Consumption by Sectors

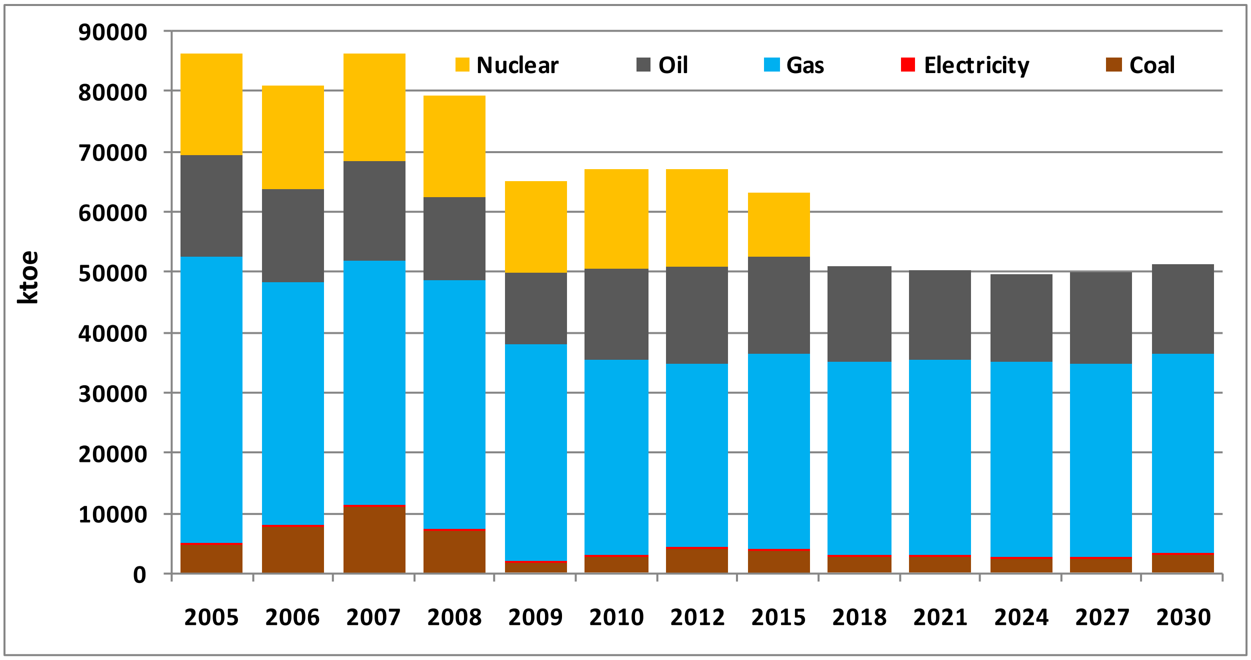


The use of gas in electricity-only production in Ukraine is modest, just 550 ktoe/19,437 Mcf per year, while municipal and industrial cogeneration installations consume about 15% of total gas consumption. The main use is for heat production, either in district heating plants, industry or the residential and commercial sectors.

The issue of imported gas substitution with domestically produced coal and shale gas is extremely important for Ukraine to improve its energy security. The substitution of natural gas in blast furnaces in the combined heat and power (CHP) by coal is promising. In addition, there is a possibility to re-equip urban boilers to shift them from gas to coal (see Section G for the More Coal and Shale Gas scenario analysis).

Due to the elimination of imported nuclear fuel, the share of natural gas in imports increases from 50% in 2005 to 64% in 2030, as shown in Figure 4. But in absolute terms, the level in 2030 is 31% lower. That is, the need to import natural gas will be reduced from 59 billion m^3 in 2005 to 41 billion m^3 in 2030. The supply of imported oil and petroleum products may also slightly decrease due to domestic extraction and production. Similarly, domestic nuclear production will push out all imports as of 2018. The combination results in total imports going from 62% of total primary energy supply in 2005 to 32% by 2030, saving some 710€ million/year in foreign payments for these energy sources, greatly enhancing energy security and competiveness.

Figure 4. Imports by Type

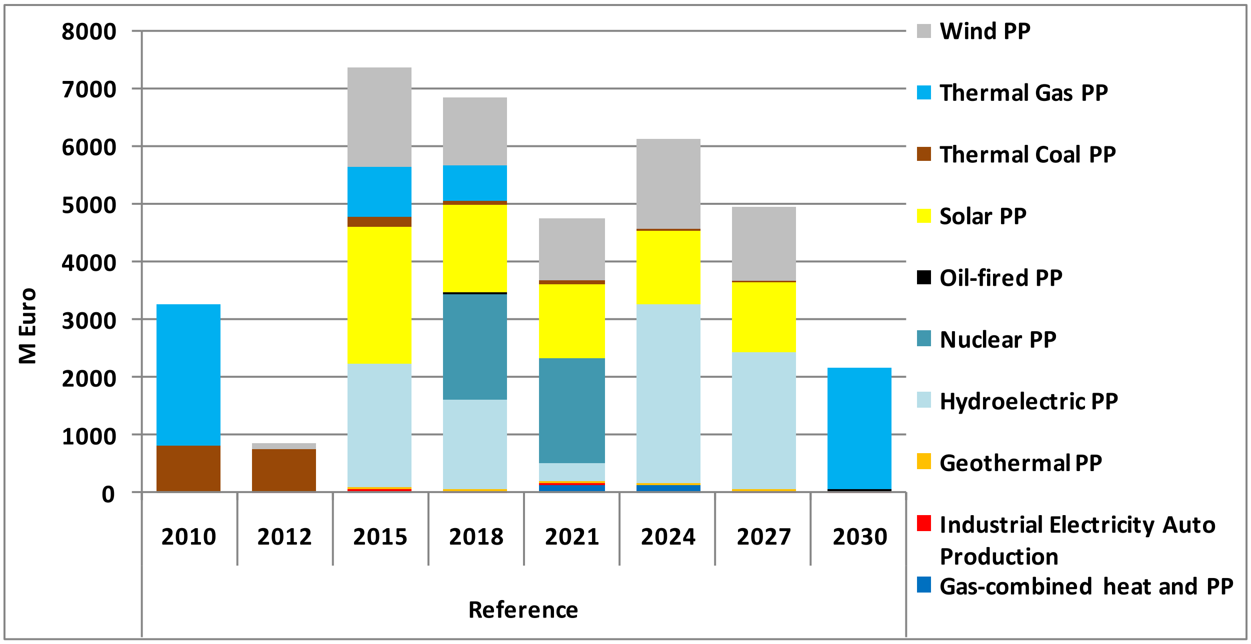


Currently, almost half of the electricity supply (46%) is provided by the nuclear power plants; 36% by the coal-fired plants; and the remaining by the gas-fired plants (10%), hydro (7%), and renewables and other sources (2%). Future additions in generation capacity are allocated primarily to coal-fired, renewables (among which 49% are wind power plants, 21% solar power plants, and 30% are big hydro power plants), nuclear, and gas-fired power plants, as shown in Table 3. New gas-fired power plants are mostly the modernized existing plants with improved performance and somewhat increased capacity. Figure 5 shows the timing and total capital investment requirements associated with the capacity additions in each three-year period. Total needs for investments during 2010-2030 will be around 29€ billion. Overall, 68.5TWh/year more electricity is required in 2030 compared to 2005.

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

Plant Type	2010	2012	2015	2018	2021	2024	2027	2030	Total
Coal	742	2,551	684	259	313	45	35	0	**4,629**
Natural Gas	2,637	70	1,087	792	575	419	140	2,307	**8,026**
Oil	5	0	0	5	0	0	0	41	**50**
Nuclear	0	0	0	1,000	1,005	0	0	0	**2,000**
Renewables (and other)	0	62	2,615	1,735	1,164	2,307	1,890	12	**9,786**
Total New Capacity	**3,383**	**2,683**	**4,387**	**3,796**	**3,051**	**2,771**	**2,065**	**2,359**	**24,496**
% of Installed Capacity	*6.8%*	*5.1%*	*7.7%*	*6.2%*	*4.8%*	*4.2%*	*3.0%*	*3.3%*	

Figure 5. Total Investment Cost of New Power Plants



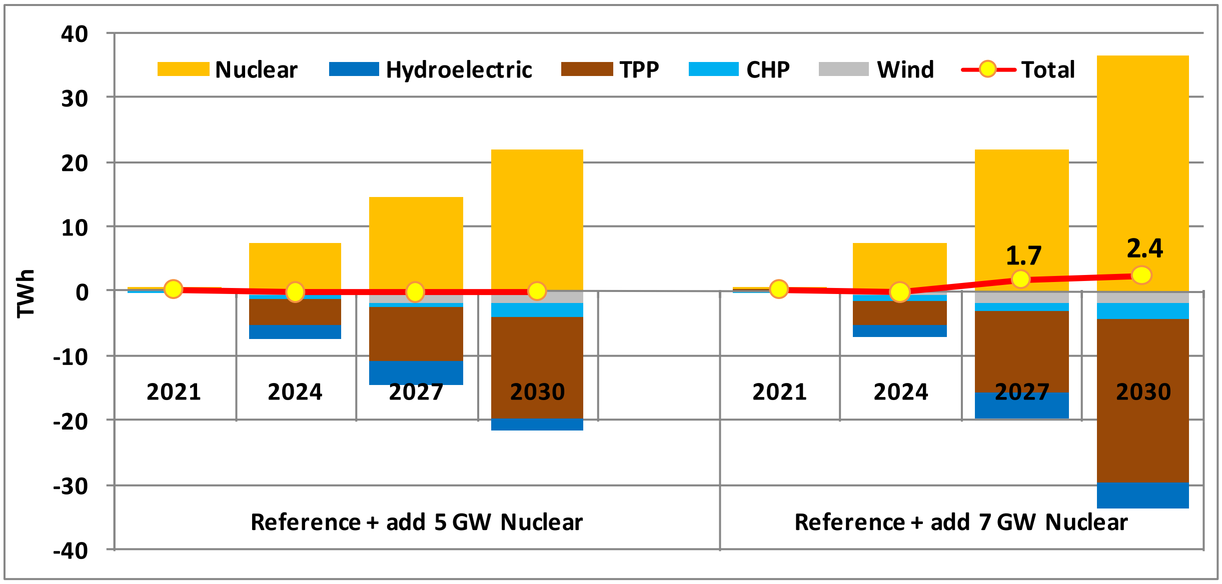
In the Reference and other scenarios examined here, construction of only two additional nuclear power plants (1,000 MW each) is permitted, installed in 2018 and 2020, while existing nuclear plants are not decommissioned until 2030. Under the revised UESU2030, installation of an additional 2,000 MW-7,000 MW of generation capacities was assumed under various economic growth scenarios (5,000 MW under the baseline scenario), while also keeping the existing nuclear units in service. This is an important difference in assumptions between UESU2030 and this study.

For this Baseline scenario of UESU2030, the share of nuclear plant capacity in 2030 is around 28%, compared with 22% in this analysis. This means that the share of electricity production from nuclear will amount to about 45%, while electricity from renewable sources will be only 5-7%. These nuclear and renewable additions meet most of the increase in demand, with the coal power plants continuing to produce about 30% of total generation in 2030.

Depending upon the economic growth assumptions, the range of the projected electricity production in 2030 under UESU2030 is quite wide – within 244-314 Terawatt hours (TWh), while this study predicts about 252 TWh under the Reference scenario. As mentioned earlier, because of assumptions regarding technology improvements and the interrelationship between supply-demand actions, being on the lower end of the consumption levels reported in the UESU2030 is to be expected.

Allowing an additional 5 gigawatts (GW) of nuclear to be built after 2020 (similar to the UESU2030 Baseline scenario), there is a reduction of electricity generation from coal, wind, and big hydro power plants, while the total electricity production in 2030 is only slightly higher (see Figure 6). Permitting an additional 7 GW of nuclear to be built after 2020 results in total electricity production of 2.4 TWh, with most of the additional electricity going to the commercial sector.

Figure 6. Generation Structure under the Reference and Nuclear Scenarios



Building more nuclear plants reduces the need for fossil fuel, including the reduction of coal imports by about 24%, gas by more than 2.5%, and oil by up to 5%. Domestic coal production will also decrease by up to 10% stabilizing at about 100 million tons.

Growth in the energy system will require significant levels of new supply and demand side investment and expanded payments for fuels. However, energy system expenditures are generally expected to absorb a smaller percentage of GDP in 2030 due to the reduced energy intensity per unit of economic output, as shown in Table 2. A breakdown of the energy system cost components is presented in Table 4, showing the growth in expenditure for fuel, operating and maintenance costs, investments in new power plants, and the purchase of new end-use devices. The investment expenditures for new power plants and devices are incurred as demand rises and existing power plants and devices reach the end of their operational lifetimes.

Table 4. Annual Energy System Expenditure (€ Million)[5]

Expenditure Type	2010	2012	2015	2018	2021	2024	2027	2030
Fuel Costs	18,372	21,726	25,267	26,743	28,176	29,477	30,957	33,008
Annualized Investment (Demand)	11,816	16,551	21,776	26,534	31,173	35,944	38,296	40,035
Annualized Investment (Power)	322	385	868	1,289	1,601	1,985	2,297	2,435
Annualized Investment (Process)	1,297	1,389	1,860	2,418	2,971	3,652	4,175	4,742
O&M Costs	3,028	3,327	3,916	4,547	5,157	5,771	6,262	6,860
Total	44,556	53,515	64,659	73,428	81,834	90,541	96,325	102,155

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

5 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.

payments, operating and maintenance (O&M) costs and fuel expenditures constitute the overall energy system cost. To add the 24,496 MW of new generation capacity needed by 2030, a total investment of 29,178€ million is required, which corresponds to annual payments of 2,233€ million from 2030 onward. At the same time, 40,035€ million annually will be required to cover the cost of new demand devices and 4,742€ million for energy processes in industry and infrastructure development. Meanwhile, payments for primary fuels will rise to 33€ billion per year in 2030, more than four times the 2005 level.

D. EXAMINATION OF THE PROMOTION OF ENERGY EFFICIENCY IN UKRAINE

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

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, 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 (GHG) emissions. Therefore, efforts were required to focus on improving end-use energy efficiency and controlling energy demand.[6] 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.*

A National Energy Efficiency Plan for Ukraine is currently being developed, planned to be ready by the end of 2012. It is expected to include a national indicative energy savings target of 9% (of current consumption levels) by 2020, with interim targets of 2% in 2014 and of 5% in 2017. The target was based on the methodology outlined in Annex 1 of the Directive, and is in line with the EC goal. The possibilities to achieve such a reduction of final energy consumption in Ukraine are discussed in the rest of the chapter.

Key insights include:

- Over 10.4% cumulative reductions (around 168 Mtoes) in imports are observed under the EE-target, enhancing energy security goals.
- Significant cumulative reductions in final energy of 7.2% are observed (around 181 Mtoes), reducing expenditures on fuel and thereby increasing competitiveness.
- There are strong synergies with low emission development, reducing CO_2 emissions by 7.9% (or 684 Mt).
- Only a modest increase in the discounted energy system costs of 0.1% (734€ million) is observed as more expensive upfront costs for more efficient devices and conservations are offset by savings in fuel expenditures.

Compared to the Reference scenario, the EE Promotion scenario includes new building standards and requirements to improve the efficiency of boilers, as well as an assumption that policies and programs will promote an increased penetration of energy efficient appliances (such as compact fluorescent lamp (CFLs), refrigerators, air conditioners). Under the EE scenario it is assumed that new buildings in residential and commercial sectors will be built under the standards adopted in 2009.[7] Buildings built before 2005 in the residential sector should be rehabilitated by 2030, including 40% of rural houses, 50% of urban houses, and 75% of multi-apartment buildings. It is also assumed that 80% of buildings in

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

[7] State Building Codes of Ukraine, http://dbn.at.ua.

commercial and public sectors can be rehabilitated by 2030. Renovation of old buildings covers all types of insulation technologies, including replacing windows. Data on the number of buildings (in square meters) that have to be rehabilitated, costs, and potential of energy savings were taken from the State target Economic Program on Energy Efficiency for 2010-2015 (adopted by the Resolution of the Cabinet of Ministers of Ukraine on March 1, 2010 #243).

New standards for boilers will lead to their modernization and upgrade so that overall average efficiency will increase from 66-70% to 85-90%. In particular, the average efficiency of gas boilers will increase annually by 1%. Under the EE scenario there is also the possibility to upgrade or install new boilers in commercial, public, and residential sectors. Another important measure of energy efficiency in Ukraine is to reduce electricity and heat transportation losses by 20% and 25% respectively. In the Reference scenario, the share of new technologies in industry may not be allowed to exceed 25%. In addition, higher discount rates for more advanced appliances were introduced to reflect the market barriers and costs of policies to overcome them. Under the EE scenario both of these impediments are relaxed.

Two scenarios are discussed below – an EE Promotion scenario where the above-mentioned additional energy efficiency options are made available to the model, and a second one where the NEEAP consumption reduction target is imposed. The first case illustrates the "economically efficient" potential of promoting efficiency, where the overall energy system cost sees over 16.4€ billion in savings with an associated reduction of about 4% in consumption. However, that is not sufficient to achieve the 9% NEEAP target and thus more ambitious policies and measures need to be pursued that slightly raise overall system costs by some 0.7€ billion. However, it does result in other important benefits for Ukraine, as discussed below.

Table 5 shows the key results as change between the EE Target and Reference scenarios. The slightly higher overall cost of the energy system is due to the increased expenditure (0.1% cumulatively) for better performing demand devices that, despite policies and programs, still command a premium over conventional devices, although this is lower than would otherwise be the case in the absence of such actions. In addition, since many electric devices are more efficient than their counterparts (e.g., heat pumps) there is a slight increase in electricity consumption of 1.3% in 2030 compared with the Reference scenario. Important benefits arise from the policy as well, with imports, primary energy supply, and final energy consumption dropping by 10.4%, 5.5%, and 7.2% respectively, resulting in fuel expenditure going down by 12.4%, which amounts to a saving of nearly 84€ billion, mainly in foreign exchange payments. Such savings enhance economic competitiveness and energy security.

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

Indicator	Units	Reference	Energy Efficiency		Energy Efficiency Target	
Total Discounted Energy System Cost	2005M€	953,639	-16,412	-1.7%	734	0.1%
Primary Energy Supply	Ktoe	3,903,618	-163,096	-4.2%	-215,617	-5.5%
Imports	Ktoe	1,612,863	-146,209	-9.1%	-168,484	-10.4%
Fuel Expenditure	2005M€	671,660	-64,052	-9.5%	-83,513	-12.4%
Power Plant New Capacity	MW	24,496	-12,800	-52.3%	-5,292	-21.6%
Power Plant Investment Cost	2005M€	29,178	-14,540	-49.8%	-9,617	-33.0%

Indicator	Units	Reference	Energy Efficiency		Energy Efficiency Target	
Demand Technology Investments	2005M€	669,099	10,189	1.5%	31,024	4.6%
Final Energy Consumption	Ktoe	2,495,374	-82,545	-3.3%	-180,521	-7.2%
CO2 Emissions	Kt	8,646,225	-419,251	-4.8%	-684,073	-7.9%

The contribution of different sectors to the targets is shown in Figures 7 and 8, indicating that energy saving potential is economy-wide, and that all sectors provide a significant contribution. Under the energy efficiency target scenario, the residential sector provides the largest savings (43% of total savings), followed by industry (29%), primarily due to the modernization of the metallurgy production, and the commercial sector (25%). In terms of fuels, the largest near-term reductions come from natural gas (residential and industry), coal (industry and commercial sector), and heat (residential and commercial sector).

Figure 7. Final Energy Reduction by Sector under Energy Efficiency Target

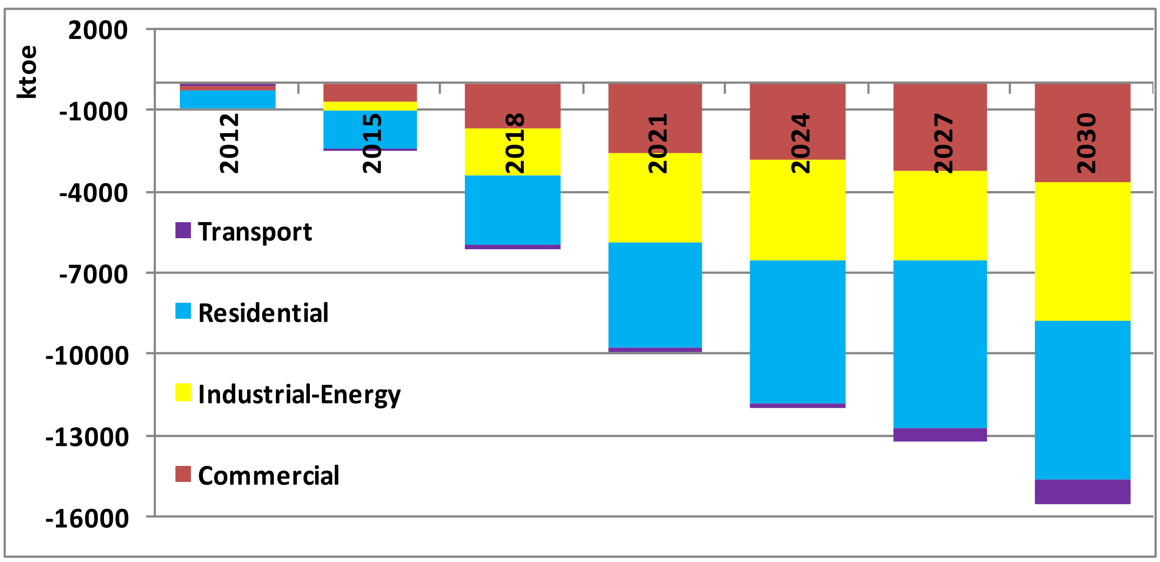
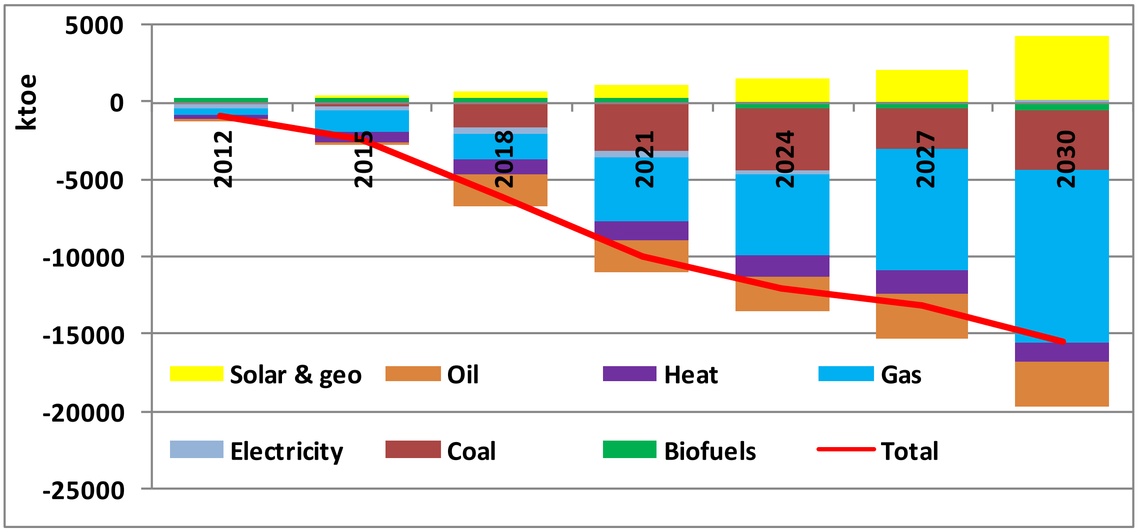
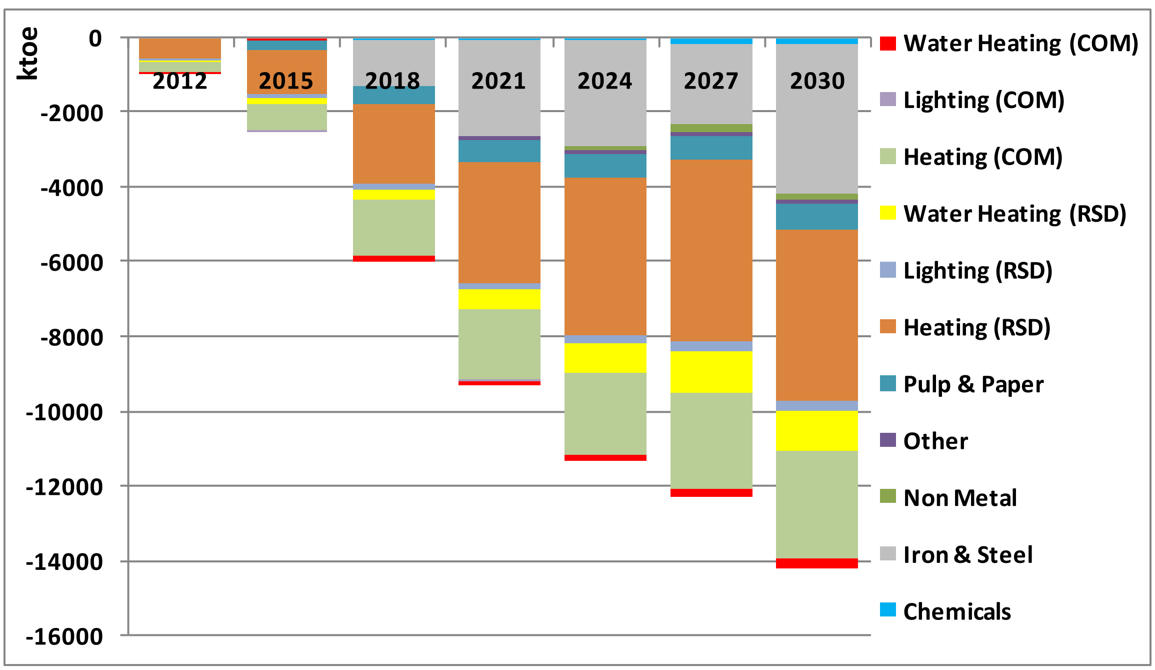


Figure 8. Final Energy Reduction by Fuel under Energy Efficiency Target



A more detailed overview of savings by energy service demands is shown in Figure 9 (the figure shows only those demands where energy saving exceeds 1%). The most cost-effective reductions occur in space and water heating, owing to increased insulation and use of heat pumps, more effective coal and gas boilers (efficiency over 85%), and the use of more efficient appliances (e.g., CFLs, refrigerators). This leads to a fairly strong reduction in gas and district heat consumption while solar and electricity consumption levels increase.

Figure 9. Final Energy Reduction by Energy Service Type under Energy Efficiency Target



In industry, the most significant effect observed is the technological transformations in metallurgy, which consume up to half of all energy and fuel in the sector. The share of cast iron production is expected to grow due to the use of more efficient pulverized fuel, which significantly reduces the use of natural gas and coke. The upgrade of the next stages of metallurgical production, with the abandonment of the Martin method of steel production by 2020, will have a tangible effect. Significant potential for energy savings in industry is present in other areas, such as in chemicals, non-metallic production, pulp and paper production, and other industries, whose combined share in the saving amounts to about 8.4%.

To introduce the new technologies in all the final consumption sectors, the investments needed exceed the baseline level of Table 6. However, these costs are substantially offset by the reduced expenditure of fuel which reaches about 84€ billion. In addition, this 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 arising from pursuing energy efficiency goals, including CO_2 reductions (7.9% reductions) and energy security through reduced imports (10.4% reduction).

E. ASSESSMENT OF A RENEWABLE ENERGY STRATEGY FOR UKRAINE

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 GHG emissions and make it less dependent on imported energy. In addition, this will help develop the renewables 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,[8] 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.[9] A 2020 renewables target of 12% of Gross Final Energy Consumption (GFEC) for Ukraine has been proposed by the ECS and was used in the analysis presented here.

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

- Cumulative energy system costs over the entire planning horizon are 3.3% higher. While this is a relatively modest increase, it is important to highlight that the additional power sector investments required to be made mainly by 2020 increase by 44%, or 12.8€ billion. The cumulative renewables capacity addition by 2020 is approximately 6,101 MW.

- Energy security is enhanced with a 5.1% cumulative decrease in the imports, while demand for final energy increases only by 0.6% as a result of increased use of solar energy for heating and water heating in residential and commercial sectors and increase of biofuels use in the transport sector. The total conventional final energy consumption (excluding solar energy and biofuels) under the RE-scenario decreases 4.6% or 34,190 ktoe.

- This policy contributes towards moving to a lower emissions pathway, with cumulative CO_2 reduction reaching 6.5% (between 2010-2030).

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	2005€ M	953,639	31,271	3.3%
Primary Energy Supply	Ktoe	3,903,618	-55,490	-1.4%
Imports	Ktoe	1,612,863	-81,723	-5.1%
Fuel Expenditure	2005€ M	671,660	-33,212	-4.9%
Power Plant New Capacity	MW	24,496	8,566	35.0%
Power Plant Investment Cost	2005€ M	29,178	15,949	54.7%

8 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.

9 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.

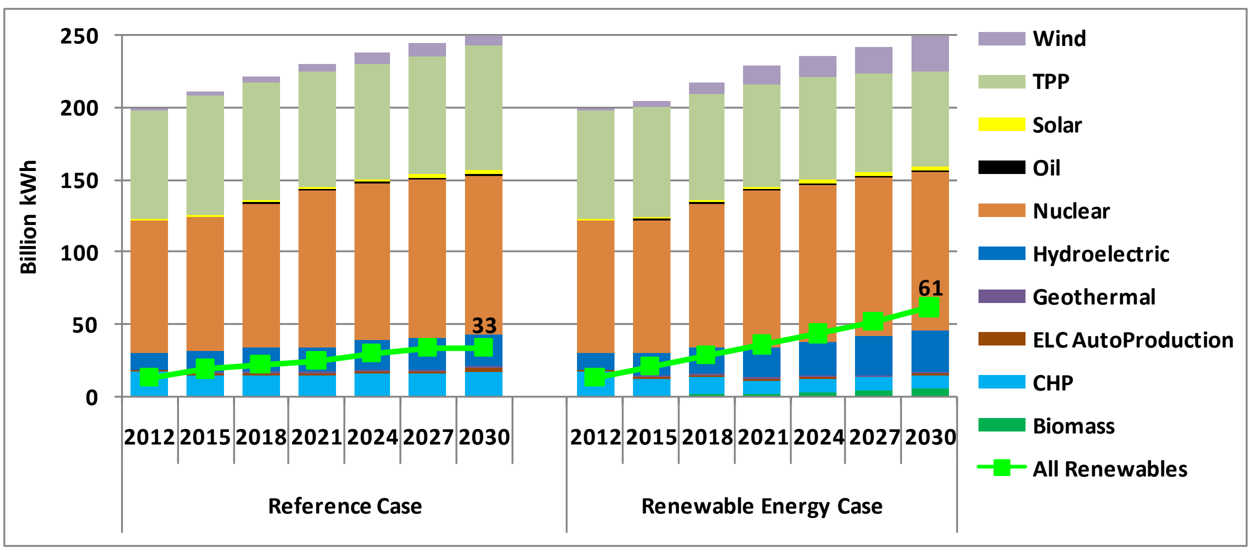
Indicator	Units	Reference	RE Target Change	
Demand Technology Investments	2005€ M	669,099	38,310	5.7%
Final Energy Consumption	Ktoe	2,495,374	14,034	0.6%
CO2 Emissions	Kt	8,646,225	-563,831	-6.5%

The Reference scenario shows an increase in new wind and solar power generation capacity of about 9,724 MW out of the total for new capacity additions of 24,496 MW. Such a significant renewable energy capacities increment is provided due to a feed-in tariff.

Under the RE Target scenario, cumulative additions of renewables capacity (between 2012 and 2030) total 13,115 MW, eliminating the need for 4,549 MW of new fossil fuel built under the Reference scenario and resulting in net new capacity additions of 8,566 MW compared with the Reference scenario. The new renewables capacity is composed of 69% wind, 19% hydro, 11% biomass, and 1% from geothermal. This suggests that meeting the target and critically sustaining it beyond 2030 will require strong policies to stimulate investment and attract high levels of capital in the end-use and power generation sectors. The additional capital required under the RE Target scenario in the end-use sectors and the power generation sector is estimated at 38.3€ billion and 15.9€ billion respectively.

Thus, renewable electricity generation is playing a crucial part in meeting future demand (see Figure 10) without an established renewable energy target. However, to further enhance energy security and address climate change, pursuing an even more aggressive renewables strategy has merit, though at a cost.

Figure 10. Generation Structure under the Reference and RE Target Scenario

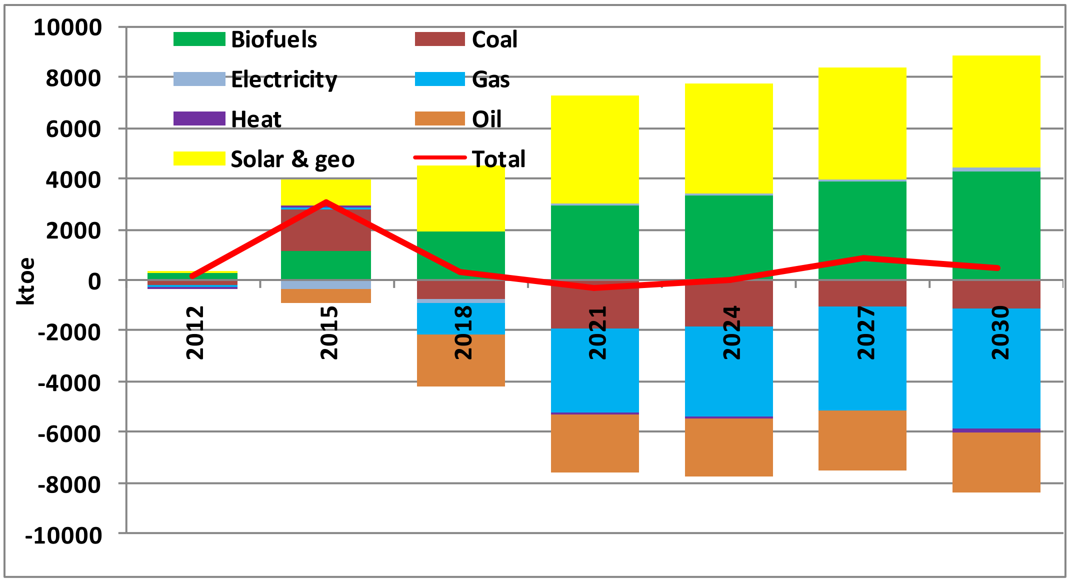


After 2020, when the target has to be met, there would be need for additional renewable capacity until 2030. Compared to the Reference scenario, the need for renewable capacities would be more than 7 GW.

The renewable capacity development under the RE Target scenario has little effect on gas-fired power plants (-579MW), as the gas plants are needed for peaking and to balance the generation mix. Coal thermal power plants (TPP) capacity decreases by 3,909 MW. While the composition of generation capacity under the RE Target scenario is different from the Reference scenario, there is similar total electricity production and slightly higher electricity prices.

To achieve the 12% Renewables in GFEC, increasing levels of biofuels, solar, and geothermal energy is consumed in the demand sectors, replacing fossil fuels (Figure 11).

Figure 11. Total Final Energy Consumption under RE Target (Compared to the Reference Scenario)



Once achieved, the reduction in the consumption of gas, oil products, and coal runs about 8,178 ktoe per year. Although under the RE Target scenario the cumulative Final Energy Consumption (FEC) grows by 0.6% or 14,034 ktoe, since less fossil fuels are consumed payments for fuel fall 4.9% or 33,212€ million, much of which is for imported natural gas.

There is increased use of biofuels in the Residential sector for cooking, water, and space heating by rural population, and in industry and agriculture for electricity and heat self-production. In addition, consumption of biofuels in the transport sector runs 10% in 2020 and 15% in 2030, resulting in a cumulative savings of about 35,298 ktoe of oil products.

Direct use of solar and geothermal energy for heating and hot water replaces an average of 4,560 ktoe of fossil fuels per year in the Residential and 1,786 ktoe in Commercial sectors. This requires additional investments in the Residential sector of 18.0€ billion, amounting to more than 17.7% in 2020 and 20.2% in 2030 of those demands being met by renewable energy (Figure 12). In the Commercial sector additional investment of 19.8€ billion is required, where 25.2% and 25.5% of total sector demand is met by the renewable energy sources (Figure 13).

Figure 12. Final Energy Consumption in Residential Sector for Space and Water Heating under RE Target Scenario

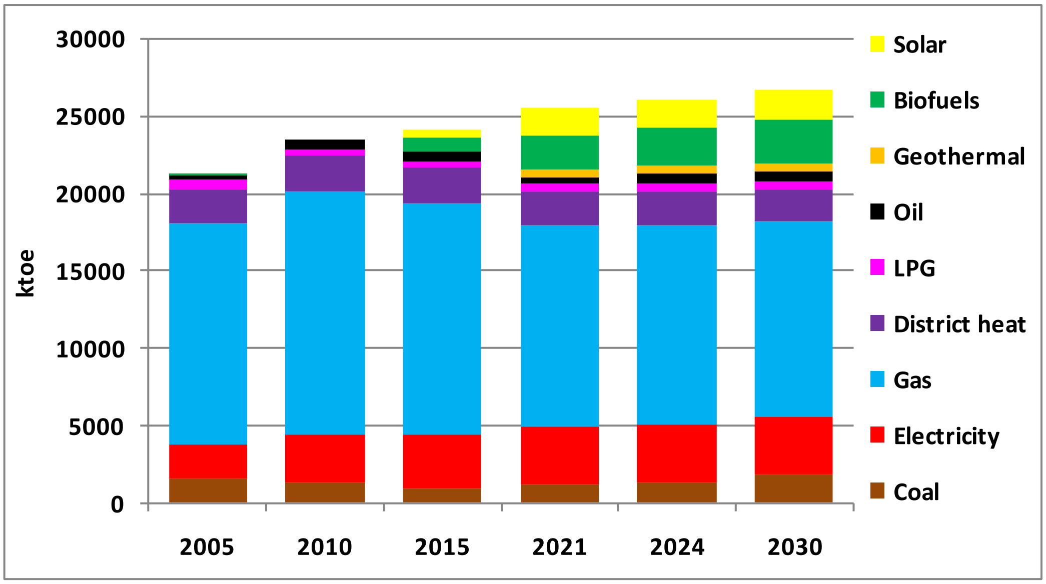
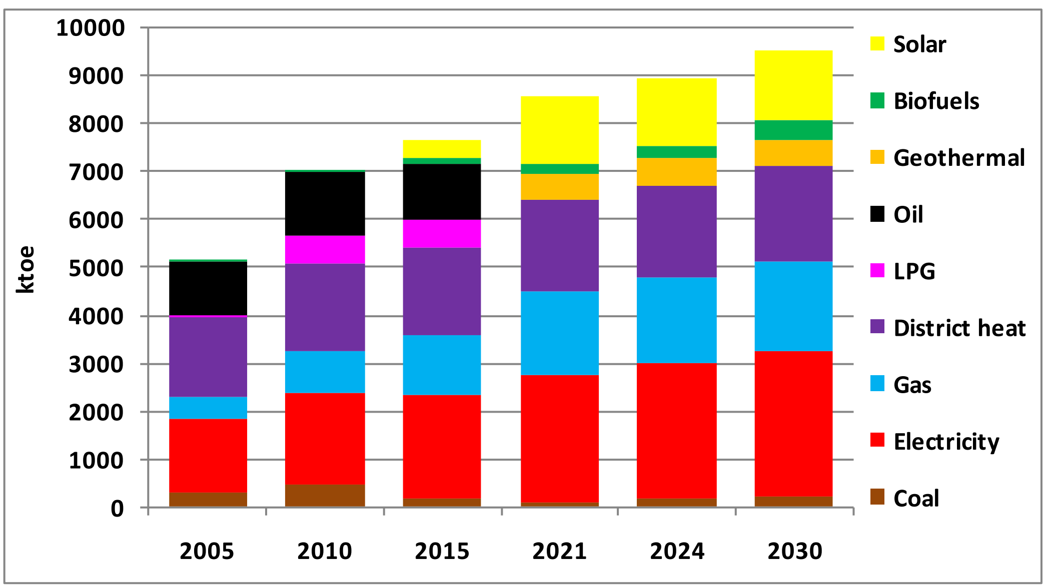
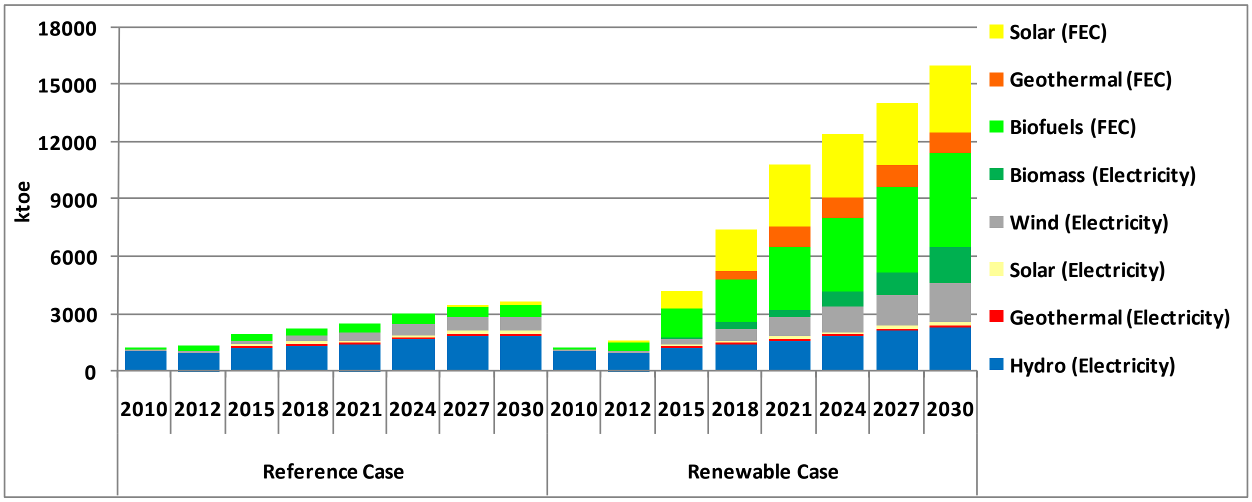


Figure 13. Final Energy Consumption in Commercial Sector for Space and Water heating under RE Target Scenario



Total renewable energy under the Reference and RE target cases are compared below, in Figure 14.

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



Retaining 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 substantial increased uptake of solar, geothermal, and biofuels in the final periods. 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. In order to achieve the renewables target of 12% in GFEC by 2020 the share of renewables in the residential sector final consumption needs to rise to about 18%, and 20% in 2030. Such fuel switching will be possible only if the cost efficiency of renewable technologies will be accompanied by the development of corresponding infrastructure (availability of resources) and supported by the relevant public policy.

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 (cumulatively) by over 5.1% and CO_2 emissions are reduced (cumulatively) by almost 6.5% relative to the Reference scenario. Moreover, compared to the Reference scenario in the RE Target scenario, in 2020 and 2030 overall energy imports are 11.8% and 17.4% lower respectively per year, and CO_2 emissions fall by 10.2% and 14.4% annually.

F. COORDINATED RENEWABLES AND ENERGY EFFICIENCY POLICIES FOR UKRAINE

Promoting both energy efficiency and renewable energy policy in parallel has strong synergies. Ukraine is currently seeking to simultaneously pursue an energy saving policy and support the producers of electricity from renewable sources, by means of feed-in tariffs[10] as well as the State Target Economic Program on Energy Efficiency and the Development of Energy Production from Renewable Energy Sources and Alternative Fuels for 2010-2015.[11] These programs are developed and implemented at the district and municipal levels.

Key insights are summarized below and elaborated upon in the rest of the section.

- Energy system costs increase by 18,093€ million or 1.9%, thus lowering the cost of achieving the RE target from 3.3%.
- The efforts to reduce final energy through energy efficiency (reduction of 6.5% or 161Mtoe) means a lower level of renewable energy is required, contributing to lowering the overall cost.
- Imports drop 14.8%, which, combined with less direct consumption of fossil fuels, saves over 108€ billion.
- CO_2 emissions are reduced by 13.5%, illustrating important synergies and co-benefits.

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

Table 7. Cumulative Impacts of Combined RE/EE Targets on the Energy System (Change from Reference Scenario)

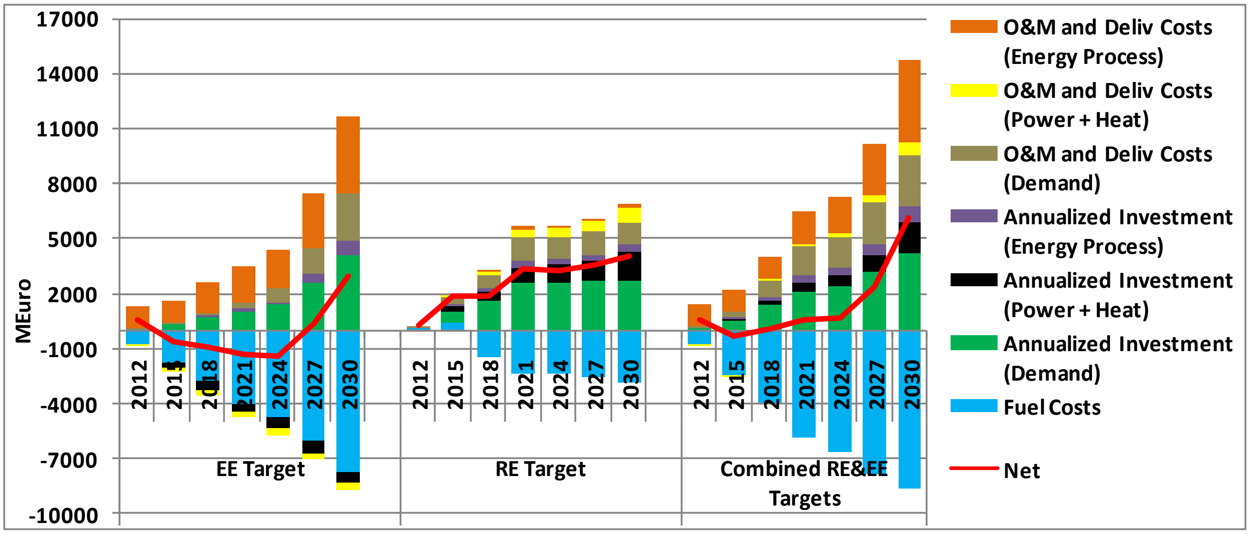
Indicator	Units	Reference	EE + RE Targets Change	
Total Discounted Energy System Cost	2005M€	953,639	18,093	1.9%
Primary Energy Supply	Ktoe	3,903,618	-275,315	-7.1%
Imports	Ktoe	1,612,863	-239,419	-14.8%
Fuel Expenditure	2005M€	671,660	-108,278	-16.1%
Power Plant New Capacity	MW	24,496	5,206	21.3%
Power Plant Investment Cost	2005M€	29,178	11,728	40.2%
Demand Technology Investments	2005M€	669,099	42,097	6.3%
Final Energy Consumption	Ktoe	2,495,374	-161,475	-6.5%
CO2 Emissions	Kt	8,646,225	-1,162,962	-13.5%

[10] The Law of Ukraine “On Electricity”

[11] The Law of Ukraine “On Electricity”

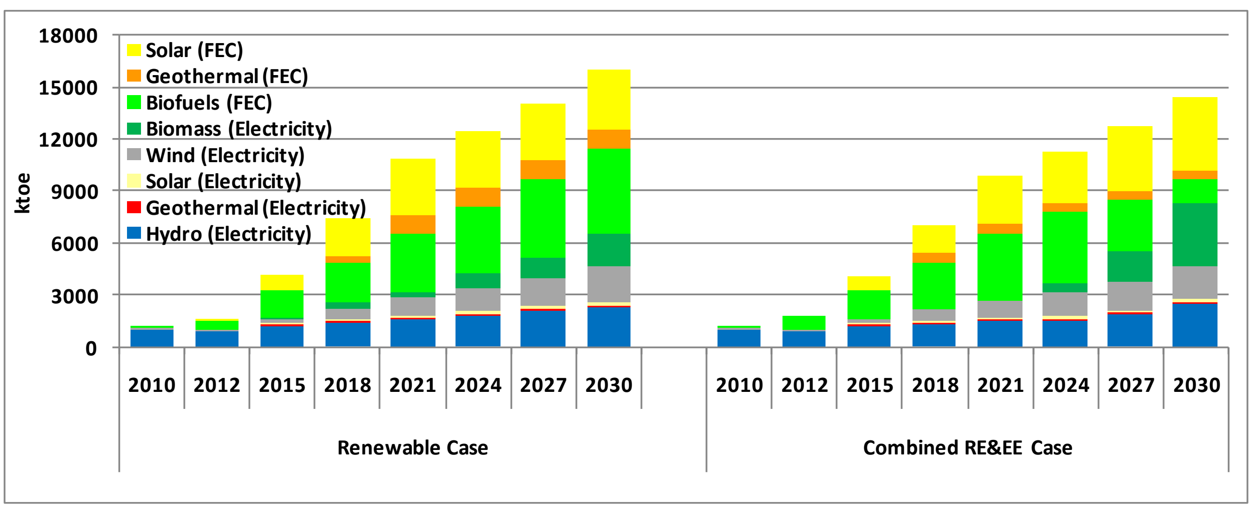
Figure 15 shows the change in annual energy system costs for the three policy scenarios relative to the Reference scenario. The bars show the increases (positive) and decreases (negative) in annual system cost components, and the change in net costs over time is shown as the red line. Overall, costs 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 6.1€ billion per year in the combined scenario by 2030.

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



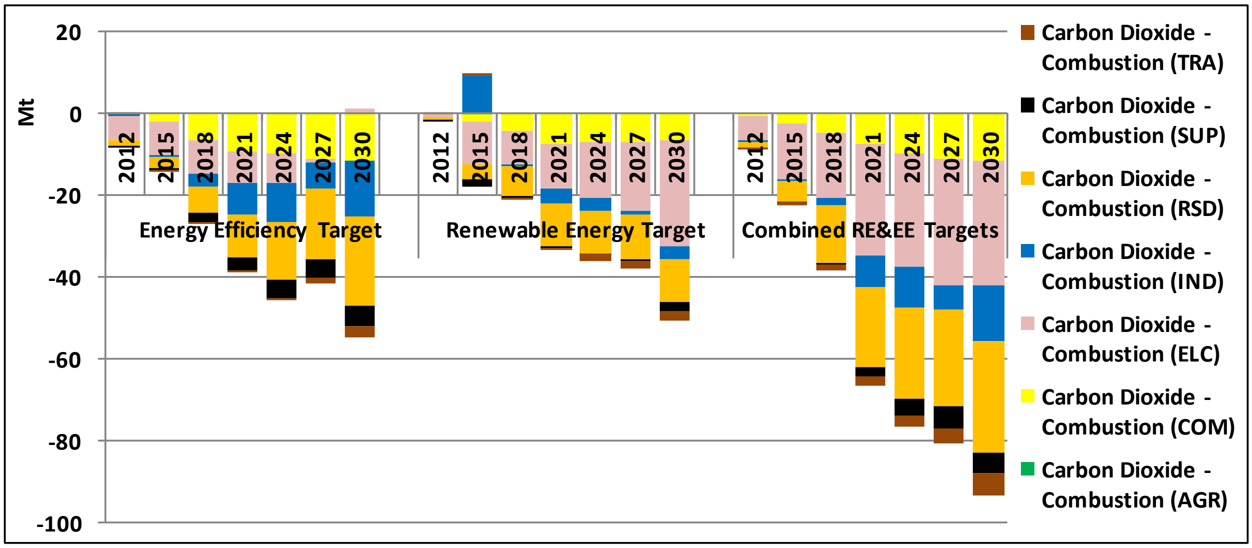
The synergies of meeting both targets at an overall lower cost are illustrated in Figure 16 below. Energy efficiency results in lower levels of renewable energy being required, as the renewable target is relative to GFEC. Under the combined scenario more solar for water and space heating are permitted under the RE Target scenario, pushing out biofuels for these demands.

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



CO_2 emission reductions are shown in Figure 17, illustrating the significant reductions realized with combined energy efficiency and renewable policy, with substantial reductions coming in from the efficiency measures in the residential, commercial, and industrial sectors discussed in Section D.

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



G. EXPLORING ADDITIONAL NATIONAL PRIORITIES – INCREASED PRODUCTION FROM DOMESTIC RESOURCES

A lot of heated discussions are underway in Ukraine with respect to plans to increase indigenous coal production, mainly for electricity and heat production and for blast-furnace processes, as well as natural gas from shale deposits. The coal scenario assumptions align with the "coal" scenario of the Energy Strategy of Ukraine until 2030, as summarized in Table 9.

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

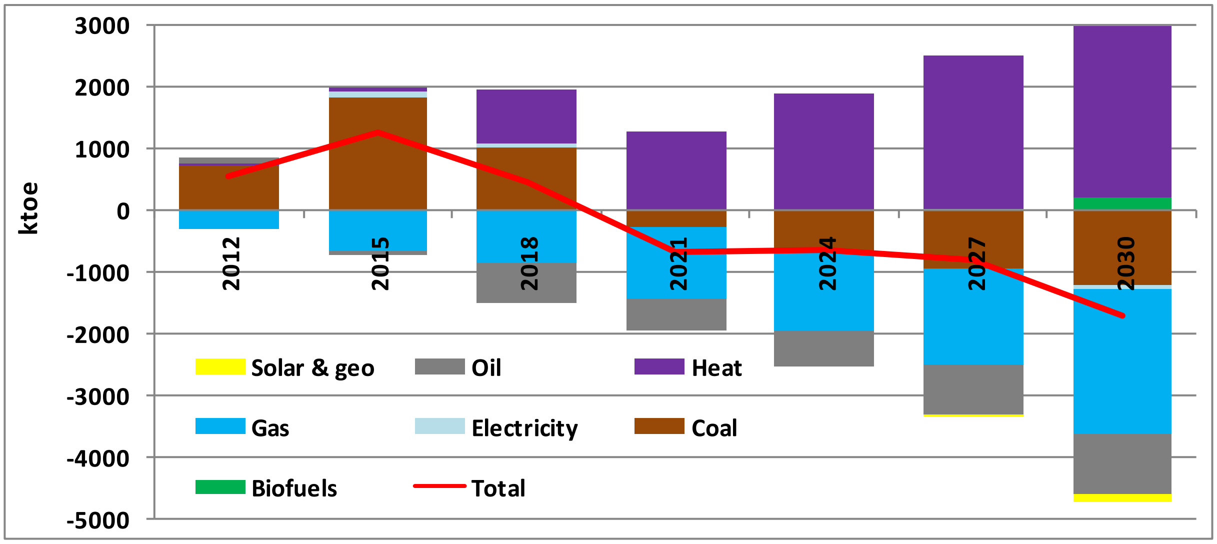
- The use of domestic coal instead of imported natural gas will lead to lower costs in a system that could cumulatively reach 12.0€ billion or 1.3%, while reducing fuel costs by 32.6€ billion or 4.9%.
- Total energy imports will decline by 57,829 ktoe, or 3.6%, which includes reduction of natural gas imports by 10.4% compared to the Reference scenario. In 2030 natural gas imports will be 33.1 billion m^3 – a drop of 45% compared to 2005 and 10% lower than 2010 levels.
- Conversion of gas combined heat and power units into water-coal plants with simultaneous technical improvements are much cheaper than construction of new coal or gas CHP or thermal power plants. This will increase electricity production from CHPs by 136% (or 16.4 billion kWh in 2020 and 23.7 billion kWh in 2030) compared with the Reference case, reducing the need to increase the electricity production at thermal, hydro, and wind power plants. Total electricity output will grow 1.9%, i.e. up to 256.9 billion kWh in 2030. However, the cost of construction for adding new and upgrading existing power plants runs 7.6€ billion less than that of the Reference scenario.
- Introduction of the use of pulverized coal instead of natural gas in the blast furnace production process reduces natural gas consumption by almost half, with a corresponding reduction of coke of 2.4% in 2030, while increasing cumulative consumption of coal products by metallurgy by 11,831 ktoe or 3.4 %.
- Due to the increased use of coal, substituting mainly for natural gas, CO_2 emissions increase by 156.8 Mt or 1.8% (cumulatively).

Table 8. Key Results: More Coal Difference from the Reference Scenario

Indicator	Units	Reference	More Coal	Change
Total Discounted Energy System Cost	2005M€	953,639	-12,036	-1.3%
Primary Energy Supply	Ktoe	3,903,618	8,551	-0.2%
Imports	Ktoe	1,612,863	-57,829	-3.6%
Fuel Expenditure	2005M€	671,660	-32,592	-4.9%
Power Plant New Capacity	MW	24,496	417	1.7%
Power Plant Investment Cost	2005M€	29,178	-7,583	-26.0%
Demand Technology Investments	2005M€	669,099	-1,122	-0.2%
Final Energy Consumption	Ktoe	2,495,374	-4,732	-0.2%
CO2 Emissions	Kt	8,646,225	156,782	1.8%

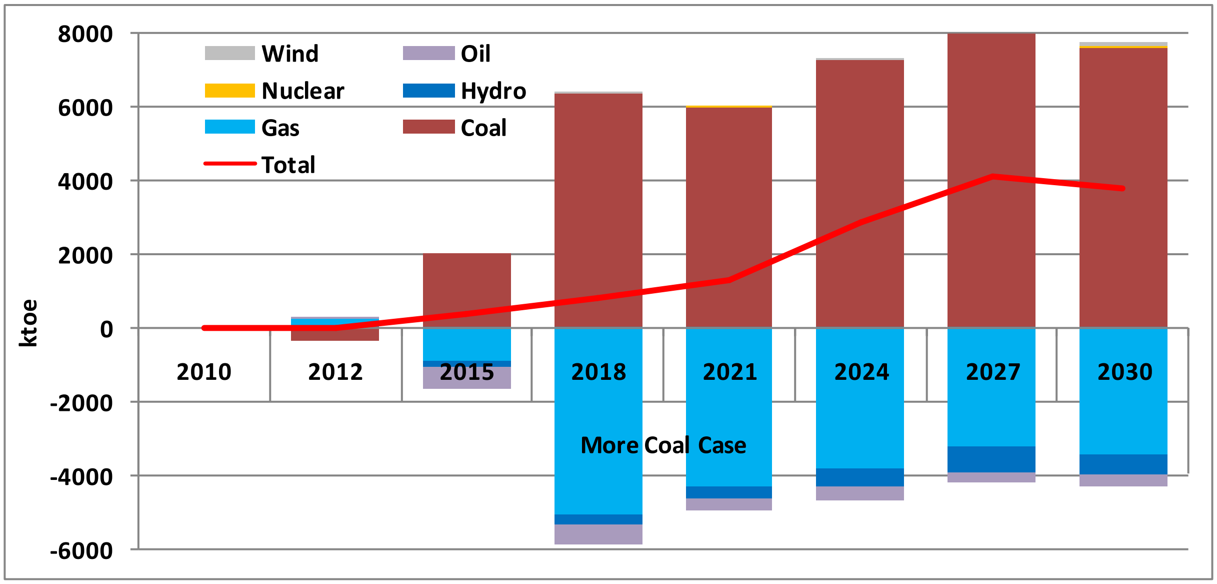
As shown in Table 8 and Figure 18, the level of end-use consumption under the More Coal scenario basically does not differ from that under the Reference Scenario – 4,732 ktoe (cumulatively). However, the total FEC mix differs such that under the More Coal Scenario the consumption of the natural gas decreases by 2,364 ktoe in 2030, while coal and district heat consumption grows. District heat consumption grows due to these plants switching from gas to coal. District heat to meet the households' commercial sectors grows approximately 30% and by 17% (cumulatively),which reduces the direct use of coal in these sectors for space and water heating by around 15%. Coal consumption does increase in the industry, primarily due to the introduction of pulverized coal injection blast furnaces for steel production.

Figure 18. Change in Final Energy under More Coal Scenario



There is a 1.9% increase in total electricity production in 2030 under the More Coal scenario or the 4.7 billion kWh compared to the Reference scenario, as well as switching over of CHP units from natural gas into coal. In particular, compared to the Reference scenario (Figure 19), the cumulative coal consumption to produce electricity and heat will increase by 22.7% (or 111,372 ktoe), whereas natural gas consumption decreases 18.1% (or 61,340 ktoe), consumption of oil products drop 36.4% (or 7,497 ktoe), and decrease electricity production from hydro and wind power plants by 27.3% (or -6,094 million kWh) and 15.2% (or -5,065 million kWh) respectively.

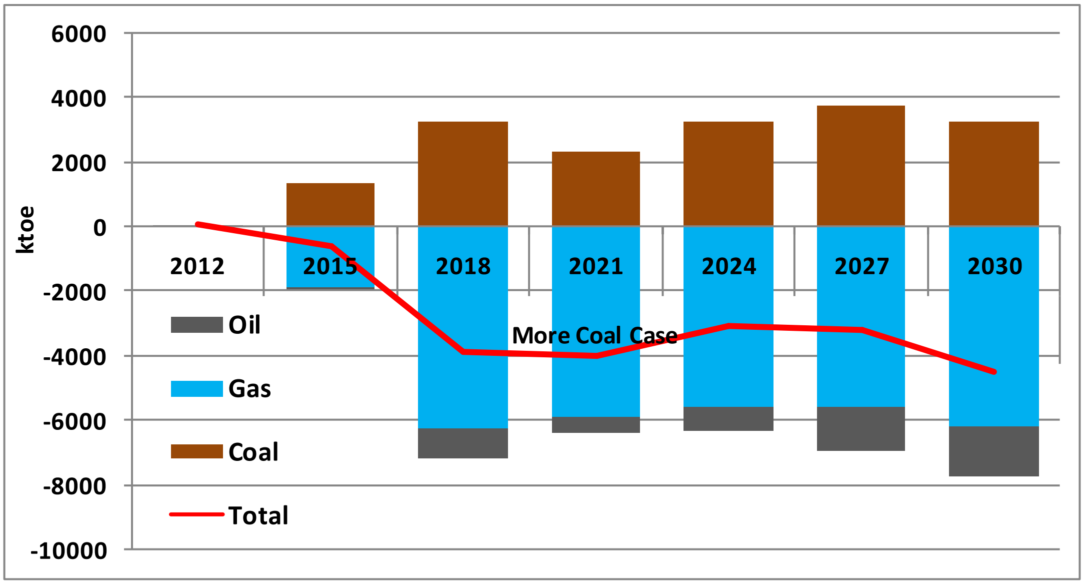
Figure 19. Change in Fuel Consumption for Electricity and Heat Production under More Coal Scenario



Coal extraction will increase up to 115.6, whereas under the Reference scenario it is forecasted at the 107.3 million tonnes level. The highest cumulative extraction increment during 2012-2030 is of the steam coal – 125 million tonnes and for anthracite – 33 million tonnes.

Potential of annual coal production is much larger than just discussed, but it is clear that coal from the state-owned mines of the second and third groups, as well as from new mines (considering an investment component in the cost of coal) would be uncompetitive with imported coal (mainly from Russia) that can be delivered using existing transportation facilities. Thus, economically viable growth of domestic coal extraction may not fully meet the growing stimulated demand for it. This primarily might be the case for the steam coal, whose import may grow till 8.2 million tonnes in 2030 (Figure 20). In the meantime, the export of coking coal may grow due to the implementation of pulverized coal injection in metallurgy, which technologically decreases the need in coke. However, the growth of cumulative import under the More Coal Scenario will be almost two times smaller than natural gas and oil imports decrease. Cumulative decrease of natural gas imports will be 118 billion m^3, which is the main contributor to reduced fuel expenditures that reach 32.6€ billion or 4.9%.

Figure 20. Change in Imports under More Coal Scenario



Ukraine also has a large potential reserve of shale gas. Initiation and intensification of shale gas production will almost completely displace the need for importing natural gas after 2020, which positively affects the energy security of Ukraine. The combination of More Coal and Shale Gas scenarios allows getting even greater energy independence.

The key findings for Shale Gas and Combined (More Coal + Shale Gas) scenarios are summarized below, and reflected in Table 9 and figures that follow.

- Energy system costs decrease by 8.0€ billion/19.0€ billion or -0.8/-2.0% respectively.
- Total energy imports (primarily of natural gas) will drop by 22-23% reducing foreign exchange payments by 167€ billion and 182€ billion accordingly.
- Due to the use of less expensive domestic resources, the overall fuel costs will be reduced by 3.3% (or 22.0€ billion) and 7.5% (or 48.8€ million) respectively.
- Under the Shale Gas scenario cumulative FEC will increase by 3,187 ktoe or 0.13% (gas consumption in 2030 will grow by 0.6%), while under Combined scenario cumulative FEC will decrease by 259 ktoe or by 0.01%.
- Increase of domestic production of shale gas and coal will affect the CO_2 emissions, which may grow by 1.9 and 3.5% compared to the Reference scenario following the decrease in the economic attractiveness of renewable resources for electricity/heat production and in TFC.

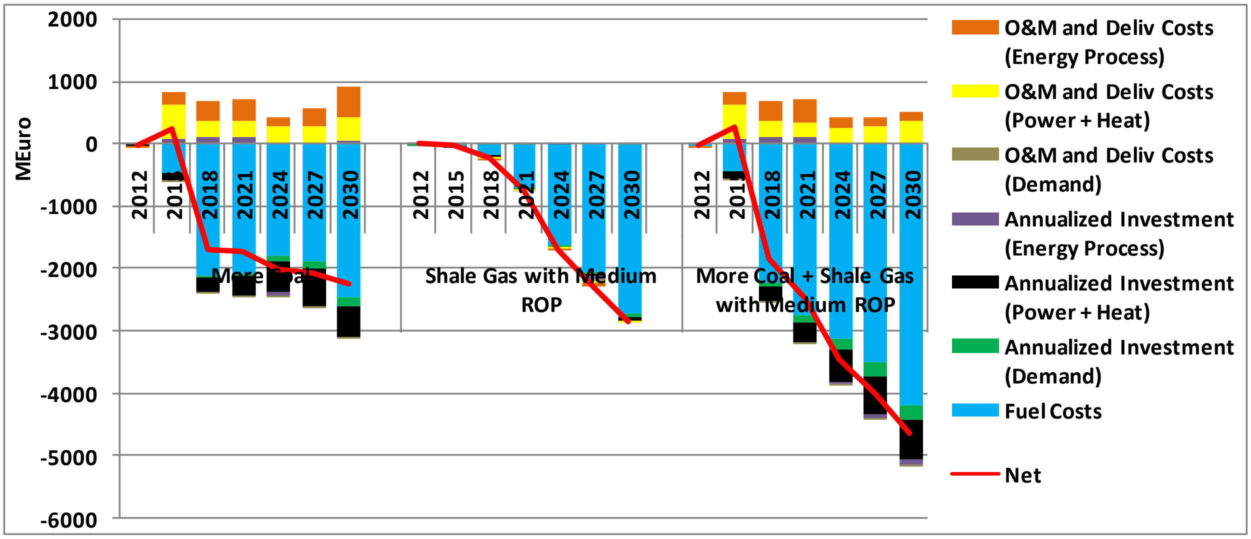
Table 9. Key Results: Shale Gas and More Coal + Shale Gas (Change from the Reference Scenario)

Indicator	Units	Reference	Shale Gas		More Coal + Shale Gas	
Total Discounted Energy System Cost	2005€ M	953,639	-8,043	-0.8%	-19,007	-2.0%
Primary Energy Supply	Ktoe	3,903,618	66,517	1.7%	68,926	1.8%
Imports	Ktoe	1,612,863	-360,255	-22.3%	-367,475	-22.8%
Fuel Expenditure	2005 €	671,660	-21,999	-3.3%	-48,816	-7.3%
Import Fuel Cost	2005€ M	24,496	-167,049	-25.0%	-181,521	-27.1%
Power Plant New Capacity	MW	29,178	246	1.0%	528	2.2%
Power Plant Investment Cost	2005€ M	669,099	-411	-1.4%	-7,871	-27.0%
Demand Technology Investments	2005€ M	2,495,374	-334	-0.05%	-2,391	-0.4%
Final Energy Consumption	Ktoe	8,646,225	3,187	0.13%	-259	-0.01%
CO2 Emissions	Kt	953,639	162,687	1.9%	305,787	3.5%

Intensification of coal and shale gas production can completely obviate the dependence of the imported gas. Under the Combined (More Coal + Shale Gas) scenario by 2030 total production of domestic conventional and shale gas will reach about 65 billion m^3, which would be sufficient to fully meet demand. Moreover, owing to the combination of scenarios the need for steam coal imports would decrease by 1.5% or 2.3 million tonnes (cumulatively) compared to the More Coal scenario, and no additional anthracite production would be required compared to the Reference scenario. As a result of this overall system cost is reduced by 19.0€ billion or by 2.0%, mainly by reducing imports (primarily natural gas) by 367mtoe, with annual fuel savings running 4.2€ billion per year from 2030 onward. At the same time there is very little change in total final energy consumption.

Electricity production under Shale Gas scenario will increase only by 0.4%. Cheaper gas prices and introduction of more efficient gas CHPs reduces the use of hydro and wind energy. A similar situation is observed in the Combined scenario.

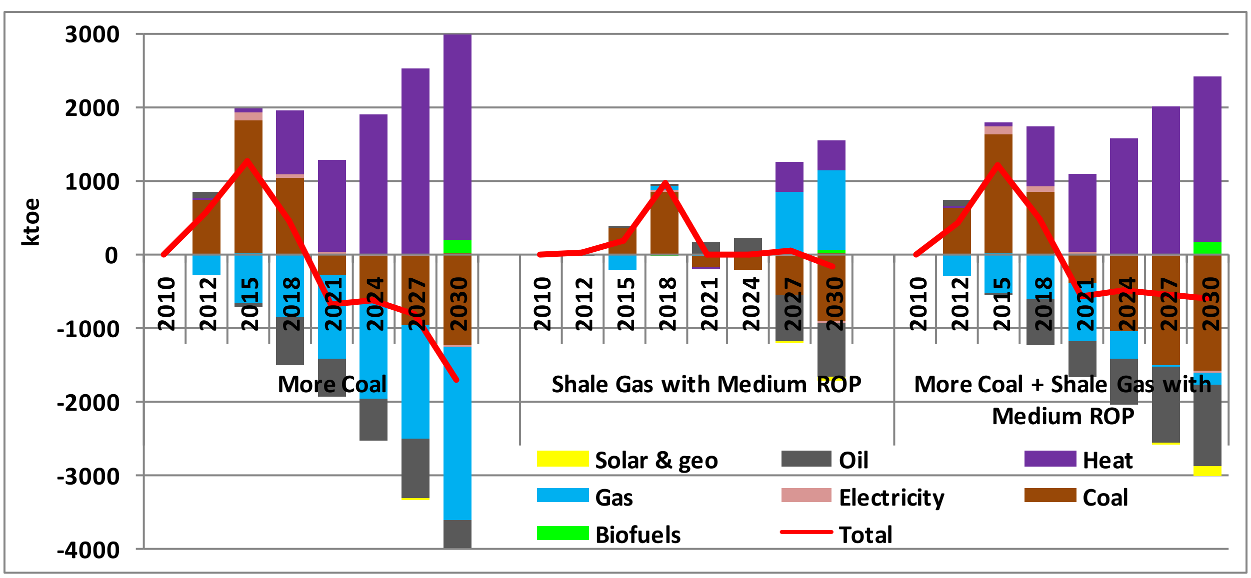
Figure 21. Costs and Savings from More Coal and Shale Gas Policies



Increased supply of domestic gas could lead to the slight decrease in gas prices on the internal market; however, only enough to encourage only a modest shift to gas by consumers. According to the Shale Gas scenario, the final consumption of gas in 2030 will grow only by 0.6% compared to the Reference scenario, and the cumulative FEC increases by 3,187 ktoe or by 0.13%; while under the Combined scenario the cumulative FEC decreases only by 259 ktoe or by 0.01%.

Switching a large number of boilers to coal and CHP to water-coal fuel will reduce the cost of central heat. This increases its share of total consumption, displacing gas, coal, and oil that were used for space and water heating in residential and commercial sectors in the Reference scenario. In the Shale Gas and Combined scenarios the increased availability of cheaper gas similarly results in more gas for direct use for these demands.

Figure 22. Change in Final Energy under More Coal and Shale Gas Scenarios



APPENDIX I: DATA SOURCES AND KEY ASSUMPTIONS

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

Table 10. Key Data Sources

Data Type	Data Source/Assumptions	Comments
Primary energy supply by fuel		
Domestic production	NSC Form 1П-НПП	By CPA 2002 nomenclature
Imports	NSC Foreign Trade Pattern	By nine-place nomenclature of *Harmonized commodity description and coding system. Third Edition (2002) World Customs Organization*
Exports and stock changes	NSC Foreign Trade Pattern, NSC Form 4-мтп	
Transformation: energy inputs and outputs		
Power plants by fuel and plant type	Ministry of Fuel and Energy of Ukraine (MoFE), NSC Forms: 1П-НПП, 4-мтп, 11-мтп, 6-тп, 6-тп (hydro), 6-ЕД, 23-Н, 24-energy	
Heat and coupled production plants by fuel and type	NSC Forms: 1П-НПП, 4-мтп, 11-мтп, 6-тп, 6-ЕД, 1-теп	
Refining and gas processing	NSC Forms: 1П-НПП, 4-мтп, 11-мтп, 1-газ	
Final energy consumption: by sector by fuel	NSC Forms: 4-мтп, 11-мтп	
Future import and production limits / Electricity T&D losses / Electricity, gas, and heat distribution grid / Data for New Power Plants	Energy Strategy of Ukraine till 2030	
Electricity import and export prices Domestic and imported fuel prices	State Statistics Committee	
Fuel consumption by subsector Share of consumption to each end-use Share of electricity consumption among the three modes of transport	NSC Forms: 4-мтп, 11-мтп	
Base-year value added for each	NSC Forms	

Data Type	Data Source/Assumptions	Comments
subsector		
Sector fuel prices Data Sources for Existing Power Plants	Ministry of Fuel and Energy of Ukraine	Information Analysis Energy Business Portal (http://e-b.com.ua)
Base-year number of households Number of persons per household by type	State Statistics Committee	http:// ukrstat.gov.ua/ control/ uk/ localfiles/ display/ operativ/ operativ2007/ zf/zf_u/ 2006_u.htm
Population:		
Base-year population;	NSC	
Projected population growth (%) to 2030 Projected annual change in household size (%) to 2030	Demographic projection for Ukraine to 2050	Edited by E. Libanova. Institute for demographic and social research. 2006
GDP:		
Base-year GDP in 2005EURM	NSC	
Projected GDP growth (%) to 2030	Projection of major macro-economic indicators of Ukraine to 2020	Institute of Economic and Forecasting, 2011 World Energy Outlook (WEO), International Monetary Fund, 2011
Industry:		
Base-year value added for each of the industry sectors (2005EURM)	State Statistics Committee	http:// ukrstat.gov.ua/ control/ uk/ localfiles/ display/ operativ/ operativ2005/ vvp/ vvp_kv/ vvp_kv_u/ kvart2005.htm
Projected annual growth for each of the industry sectors (%) to 2030	Projection indices of industrial production in Ukraine in 2015 for scenario options	Edited by M. Skrypnichenko. Institute of Economic Forecasting. 2008

Drawing on these data sources provisions for model development are therefore 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, such as surveys on energy consumption in residential and commercial sectors, self-sufficiency in residential sector, etc.

The Planning Team has ensured (to the extent possible) that current or planned policy is reflected in the Reference scenario (see Table 11). Sector experts have also been consulted to ensure that the Reference scenario is robust, and does not diverge significantly from other analyses of the energy system ("Energy Strategy of Ukraine until 2030") or analyses of the overall economy of the country ("State Program of Economic and Social Development of Ukraine for 2010").

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

Table 11. Key Assumptions in Reference Scenario

Category	Assumption[12]						
	2006	2009	2012	2015	2020	2025	2030
GDP growth rate	7.3	-13.9	3.9	4.6	4.7	4.6	4.3
Population	-0.7	-0.4	-0.3	-0.3	-0.3	-0.3	-0.4
Incomes of population	18.3	-9.2	6.4	6.0	5.8	5.5	5
Number of households	-0.4	-0.7	-0.4	-0.4	-0.5	-0.5	-0.5
Agriculture	9.5	-4.4	6.1	5.0	4.5	4.0	4.0
Sectoral growth rates[13]							
Industry:	4.8	-19.8	3.0	4.6	4.6	4.4	4.2
Steel production	4.8	-19.8	4.0	2.5	2.0	1.8	1.5
Production of industrial products of metallurgy	7.5	-24.3	5.0	4.5	2.5	2.0	1.6
Ammonia production	-1.7	-31.3	3.8	3.2	2.8	2.2	1.8
Production of industrial products of chemical industry	4.9	-26.0	3.5	3.2	3.0	2.7	2.5
Cement production	12.3	-36.2	4.2	4.0	3.4	3.0	2.7
Limestone production	2.0	-20.0	4.2	4.0	3.4	3.0	2.7
Paper production	0.8	-7.2	4.4	3.9	3.2	2.8	2.5
Production of nonferrous products	7.5	-24.3	8.9	6.3	5.8	5.2	4.8
Production of nonferrous mineral products	8.9	-39.2	5.2	4.0	3.8	3.4	3.0
Other industry	4.2	-25.0	7.0	4.6	4.7	4.8	5.0
Commercial sector	7.0	3.3	7.6	5.1	4.5	4.4	4.3
Transport	7.1	-17.1	5.4	4.4	4.1	4.0	3.8
Freight transportation	9.8	-22.5	5.4	4.4	4.2	3.9	3.5

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

Table 12. Existing Heat and Power Plants

Plant Type/Fuel	Capacity, (MW)	Average efficiency	Average Annual Availability
Coal-fired power plants	22,765	35%	34%
Gas-fired power plants	20,495	70%	21%
Nuclear power plants	13,835	33%	74%
Hydroelectric power plants	4,700		30%
Renewable and Other power plants	48	85-100%	30%
District heating plants (Coal)	50	66%	50%
District heating plants (Heavy Fuel Oil)	40	66%	50%

12 For 2006-2009 statistics from State Statistics Committee were used; for 2010 expert assumptions were made, using statistics for the first half of 2010.

13 Overall growth rate for useful energy based on projections for the different energy services in each sector.

Plant Type/Fuel	Capacity, (MW)	Average efficiency	Average Annual Availability
District heating plants (Natural gas)	12,547	66%	50%
District heating plants (Electricity)	255	66%	50%
CHP auto-production	3,936	25-45%	60%

Heat supply technologies by boiler houses are grouped by type of consumed fuel (coal, lignite, oil, natural gas, wood, electricity) and the installed capacity is according to the reports of State Statistics Committee (up to 3 MW, 3-26 MW, 26-116 MW, more than 116 MW). Auto-production of electricity and heat is possible by technologies in each sector, and separately for energy-intensive industries.

Electricity in the model is divided in three voltage levels: high (HV, 220-750 kV), medium (MV, 0.38-154 kV), and low (LV up to 380 V). High voltage electricity is generated by public power producers and auto-producers in industry and supply sector. A share of medium-voltage electricity is produced by auto-producers in commercial sector and agriculture.

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

Table 13. Key Constraints in the Reference Scenario

Supply & Power Sector	Assumptions Guiding the Reference Scenario
International energy prices	Correspond to average forecast of IEA over the modeling horizon
Coal ash content	At the level of 2010
Natural gas recovery	Moderate investments providing output of 23.5 billion m^3 in 2020 and 25.7 billion m^3 in 2030
Oil extraction	Moderate investments providing preservation of output 4-4.5 million t
Gas imports	Min limit of 3 billion m^3 with model choosing to import over 27 billion m^3
Production of electricity by NPP	From 2006-2030 not more than 48% of total electricity production may come from nuclear plants. Installed capacity of NPP can be increased by 2GW by 2030, existing NPP won't be closed
Share of coal in the fuel mix on coal TPP	Continuation of previous years trends (not less than 93-95%)
Hydro capacity potential	Max allowed total capacity of 13 GW in 2020 and 15.3 GW in 2030 (including 2.2 GW in 2020 and 8 GW in 2030 of new small hydro)
Wind capacity potential	Max allowed total new capacity 18 GW in 2020 and 24 GW in 2030
Solar capacity potential	Max allowed total new capacity 6 GW in 2020 and 8 GW in 2030
Electricity exports	Electricity exports kept constant (9300 GWh in 2030)
Heat production by municipal boiler houses	Not less than 40% in total heat production by 2013 and 32% by 2030
Heat production by municipal natural gas boiler houses	Not less than 95% from total heat production by boiler houses by 2015 and 80% by 2030
Steel Industry	• Moderate growth rates reaching full load of existing capacities after 2020 • Share of Martin process production in 2020 will decrease to 24% and will be closed till 2030, share of oxygen steelmaking will reach 80% till 2030
Technologies of cast iron	Share of new technologies, including pulverized coal injection, will not

Supply & Power Sector	Assumptions Guiding the Reference Scenario
production	exceed 5% by 2030
Coke production by metallurgical companies	Will remain stable at the level of 15%
New technologies in non-ferrous metallurgy, cement production, paper industry	Share of advanced technologies introduction by 2030 will not exceed 5%
New technologies in households, public and commercial sectors	Share of advanced technologies introduction for space, water heating and air-conditioning will not exceed 2% in 2020 and 5% in 2030
Rehabilitation of residential and commercial buildings and buildings	Share of buildings undergoing rehabilitation not to exceed 2% in 2020 and 5% in 2030
Subsidies	Elimination of cross-subsidies for different consumer types by 2020

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 World Energy Outlook (WEO) 2009 energy price projections for each fuel are adopted, as shown in the table below.

Table 14. Energy Price Trajectory Assumptions (2006Euro/unit)

Energy Form	Unit	2015	2018	2021	2024	2027	2030
Biomass		- - -	Individual	national	values	used.	- - -
Coal - Brown	Tonne	39.92	43.27	45.92	46.70	47.36	47.96
Coal - Hard	Tonne	60.54	65.63	69.65	70.83	71.83	72.74
Coal - Lignite	Tonne	25.13	27.24	28.91	29.40	29.82	30.20
Gas	MBtu	7.098	7.746	8.341	8.744	9.130	9.514
Nuclear	GJ	0.800	0.800	0.800	0.800	0.800	0.800
Oil - Crude	Barrel	64.664	70.454	75.687	79.044	82.388	85.790
Oil - Distillate	Litre	0.526	0.573	0.616	0.643	0.670	0.698
Oil - HFO	Litre	0.359	0.392	0.421	0.439	0.458	0.477
Oil - Kerosene	Litre	0.554	0.603	0.648	0.677	0.706	0.735
Oil - LPG	Litre	0.317	0.346	0.371	0.388	0.404	0.421

The average price (across all timeslices) of imported electricity is shown for each country in the table below.

Table 15. Assumed Import Electricity Prices Trajectory (2006Euro/kwh)

Country	2009	2012	2015	2018	2021	2024	2027	2030
Albania	0.0384	0.0396	0.0408	0.0420	0.0432	0.0444	0.0456	0.0468
BiH	0.0478	0.0478	0.0478	0.0478	0.0478	0.0478	0.0478	0.0478
Bulgaria	0.0384	0.0396	0.0408	0.0420	0.0432	0.0444	0.0456	0.0468
Croatia	0.0384	0.0396	0.0408	0.0420	0.0432	0.0444	0.0456	0.0468
Georgia	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400	0.0400
Macedonia*	0.0593	0.0712	0.0747	0.0783	0.0819	0.0854	0.0890	0.0925
Moldova	0.0365	0.0380	0.0394	0.0409	0.0424	0.0439	0.0453	0.0468
Romania	0.0384	0.0396	0.0408	0.0420	0.0432	0.0444	0.0456	0.0468
Serbia	0.0384	0.0396	0.0408	0.0420	0.0432	0.0444	0.0456	0.0468
Ukraine	0.0384	0.0396	0.0408	0.0420	0.0432	0.0444	0.0456	0.0468

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 datasets that start from a common point for all the national models are repositories for the characterization of future power plants and demand devices. Table 16 through 18 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, as well as 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 16. Future Electric Power Plant Characterization*

Power Plant Type	Start Date	Life-time	Efficiency* **	Availabil-ity 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	1,000 – 1,250	25.00 - 35.00	4.32
Coal Integrated Gasification Combined Cycle (IGCC)	2010	35	0.51	0.85	1,200	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	1,550	38.55	3.53

[14] The complete set of power plant characterizations as used in each national model is managed in an Excel template, and is available for review and consideration from the national Planning Teams.

Power Plant Type	Start Date	Life-time	Efficiency* **	Availabil-ity Factor	Investment Cost (M€/GW)**	Fixed O&M (M€/GW)	Variable O&M (€/MWh)
Hydro	2009	60 - 80	1.00	0.27 - 0.60	3,000 – 3,500	45.00 - 59.00	0.72 - 1.44
Wind	2009 - 2012	20 - 30	1.00	0.06 - 0.22	1,000 – 1,070	40.00 -43.00	0.00
PV	2009 - 2012	30	1.00	0.10	2,000 – 2,950	29.40	0.00
Geothermal (dry steam)	2009	30	1.00	0.85	5,000	275.00	4.32
Biomass	2009	30	0.37	0.80	1,800 – 1,820	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 17. 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	1,600 – 1,873	71.75 - 77.0	6.48
Hard coal	2009	35	1.43	0.35	0.85	1,200	54.50	9.20
Lignite	2009	30	1.25	0.29	0.80	1,400	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 18. 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 Ukraine, the characteristics of the key new power plants that are chosen by the model are shown in Table 19. The characteristics of the existing power plants are shown in Table 12.

Table 19. Characterization of Key Power Plants

Description	Start Date	Life-time	Fixed O&M (EUR/kW)	Var. O&M (EUR/GJ)	Investment Cost Euro/kW	Effic-iency	Avail-ability factor
Comb Cyc.GAS L. New	2015	35	19.00	0.43	440	0.58	0.85
Turb Peak.GAS	2015	30	11.50	0.57	250	0.38	0.55
Turb Peak.OIL	2015	35	18.00	0.57	250	0.36	0.55
Steam.Turb.Coal	2015	35	50.00	0.71	1,060	0.42	0.85
SC.Steam.Turb.Coal	2015	35	34.00	0.71	820	0.42	0.85
IGCC.Coal	2015	35	52.50	0.85	1,200	0.44	0.85
Wind Onshore	2012	20	75.00	0.00	1,250	1.00	0.20
Geothermal Power	2012	25	143.50	0.00	4,000	1.00	0.80
PV Plant Size	2012	25	65.00	0.00	3,180	1.00	0.10
Hydro.Run of River	2012	70	55.00	0.00	5,500	1.00	0.60
Hydro.Lake	2012	80	45.00	0.00	3,500	1.00	0.60
Nuclear Power plants	2012	60	42.10	0.83	2,400	0.33	0.89

In terms of demand devices, the approach taken involves drawing on the technology characterizations that were employed in the EU New Energy Externalities Developments for Sustainability 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/).

Base device characterizations are used to 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 base devices and then up to three levels of improved devices available to the analyst to include in their model. The cost and performance characteristics for a subset of the base devices are shown in Table 14 and Table 21.

Table 20. Example Characterization of some Demand Devices in the Commercial Sector

Energy Service Demand	Demand Device	Efficiency	Investment Costs (1000 €/Unit)
Commercial Space Heating			
	Comm. Space Heat.Large.OIL.01.Furnace	0.75	0.227
	Comm. Space Heat.Large.OIL.01.Furnace	0.89	0.273
	Comm. Space Heat.Large.GAS.01.Furnace	0.95	0.131
	Comm. Space Heat.Large.LPG.01.Furnace	0.89	0.365
	Comm. Space Heat.Large.ELC.01.Resistance	1.00	0.700
	Comm. Space Heat.Large.HTH.01.Heat exchanger	1.00	0.700
	Comm. Space Heat.Small.COA.01.Furnace	0.80	0.083

Energy Service Demand	Demand Device	Efficiency	Investment Costs (1000 €/Unit)
	Comm. Space Heat.Small.COA.01.Furnace	0.89	0.100
Commercial Water Heating			
	Comm. Water Heat.Small.LPG.01.Furnace	0.60	0.018
	Comm. Water Heat.Small.LPG.01.Furnace	0.65	0.022
	Comm. Water Heat.Small.OIL.01.Furnace	0.65	0.018
	Comm. Water Heat.Small.OIL.01.Furnace	0.70	0.022
	Comm. Water Heat.Small.GAS.01.Furnace	0.80	0.031
	Comm. Water Heat.Small.GAS.01.Furnace	0.85	0.037
	Comm. Water Heat.Small.GAS.01.Furnace	0.88	0.024
	Comm. Water Heat.Small.ELC.01.Water heater	1.00	0.041
	Comm. Water Heat.Small.HTH.01.Heat exchanger	0.96	0.223
Commercial Space Cooling			
	Comm. Space Cool.Small.ELC.01.Central	3.30	0.242
	Comm. Space Cool.Small.ELC.01.Windows	2.03	0.050
	Comm. Space Cool.Small.ELC.00.Heat pump. New	2.00	0.060
	Comm. Space Cool.Large.ELC.01.Central	3.30	0.242
	Comm. Space Cool. Large. ELC.01. Windows	3.00	0.050
Commercial Lighting			
	Comm. Lighting.ELC.01.Incandescent.STD	1.00	0.010
	Comm. Lighting.ELC.01.Incandescent.IMP	2.20	0.060
	Comm. Lighting.ELC.01.Halogen	2.20	0.020
	Comm. Lighting.ELC.01.Fluorescent	3.50	0.025

Table 21. Example Characterization of some Demand Devices in the Industrial Sector

H. Technology Description	I. Energy type	J. Availability factor	K. Fuel input per unit output	L. Investment Cost M. (1000 €/Unit)
N. IAL.Hall Heroult. Point Feeders. 01				
	LFO	0.95	0.5	4,700
	N.Gas		1.5	
	Electricity		37.6	
IAL.Hall Heroult. Regular. 011				
	LFO	0.95	0.5	4,500
	N.Gas		1.5	
	Electricity		39.0	
IAL.Hall Heroult. OPTIMAL ELECTROLYSIS. 05				
	LFO	0.95	0.5	4,650
	N.Gas		1.5	
	Electricity		38.0	
IAL.Hall Heroult. reduced electrolyte temperature. 10				
	LFO	0.95	0.5	4,575
	N.Gas		1.5	
	Electricity		36.5	
IAL.Inert Anodes. 01				
	N.Gas	0.95	1.5	4,100
	Electricity		44.0	
IAL.Recycled Production. 01				
	N.Gas	0.9	4.0	950
	Electricity		1.4	
IAL.Recycled Production scrap pre-heat. 05.				
	N.Gas	0.9	3.6	23.75
	Electricity		1.4	
IAL.Recycled Production enhanced furnaces. 10.				
	N.Gas	0.9	2.0	970
	Electricity		1.4	

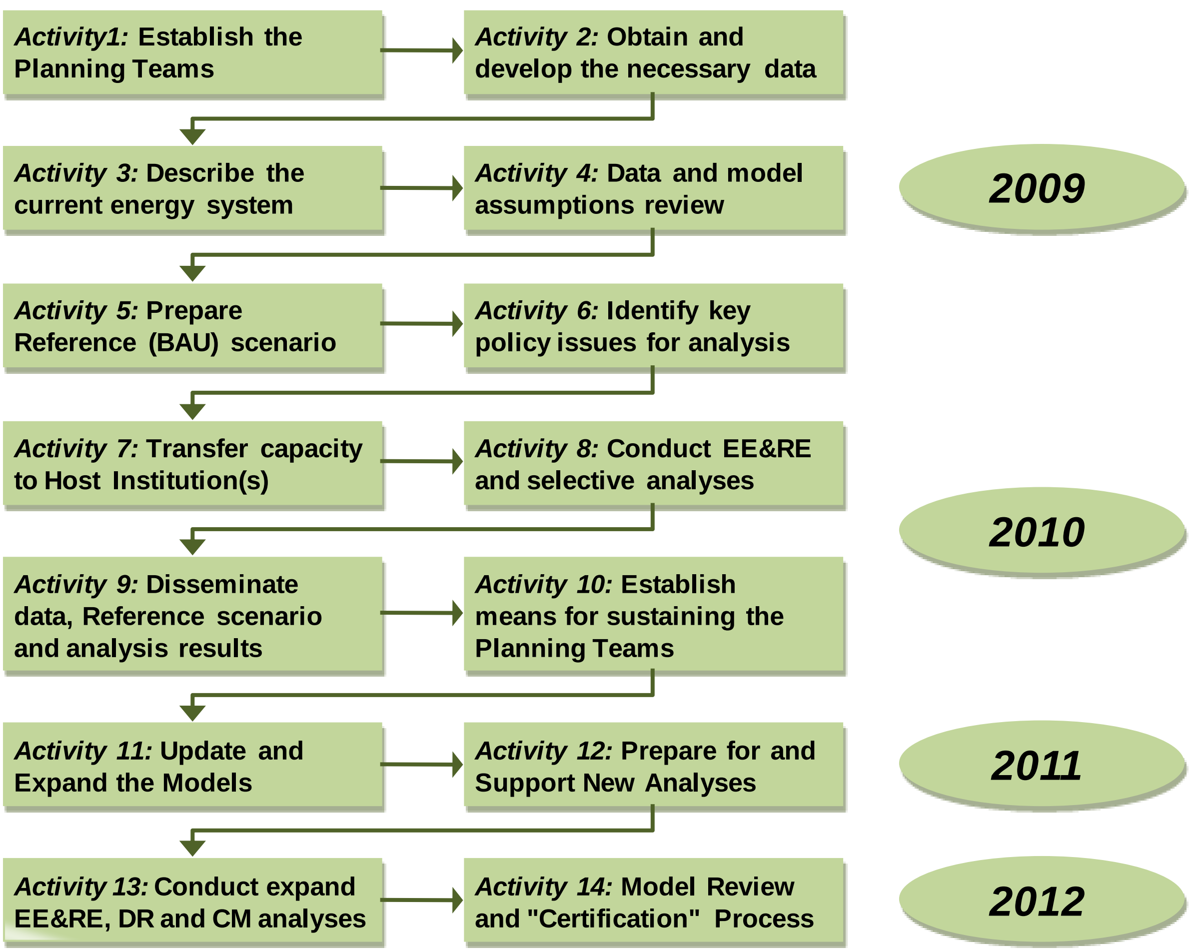
APPENDIX II: PROJECT ACTIVITIES AND METHODOLOGY EMPLOYED

MAJOR PROJECT ACTIVITIES

The consultant teams for International Resource Group (IRG) and the CRES worked with key personnel from the Ukrainian Ministry of Energy and Coal Industry (MECI) and the Ukrainian Ministry of Regional Development, Construction, and Communal Living (MRDCCL) to establish a credible TIMES-Ukraine 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 23).

Figure 23. Sequence of Project Activities



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.

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, and provide the foundation for useful policy analysis and assessment.

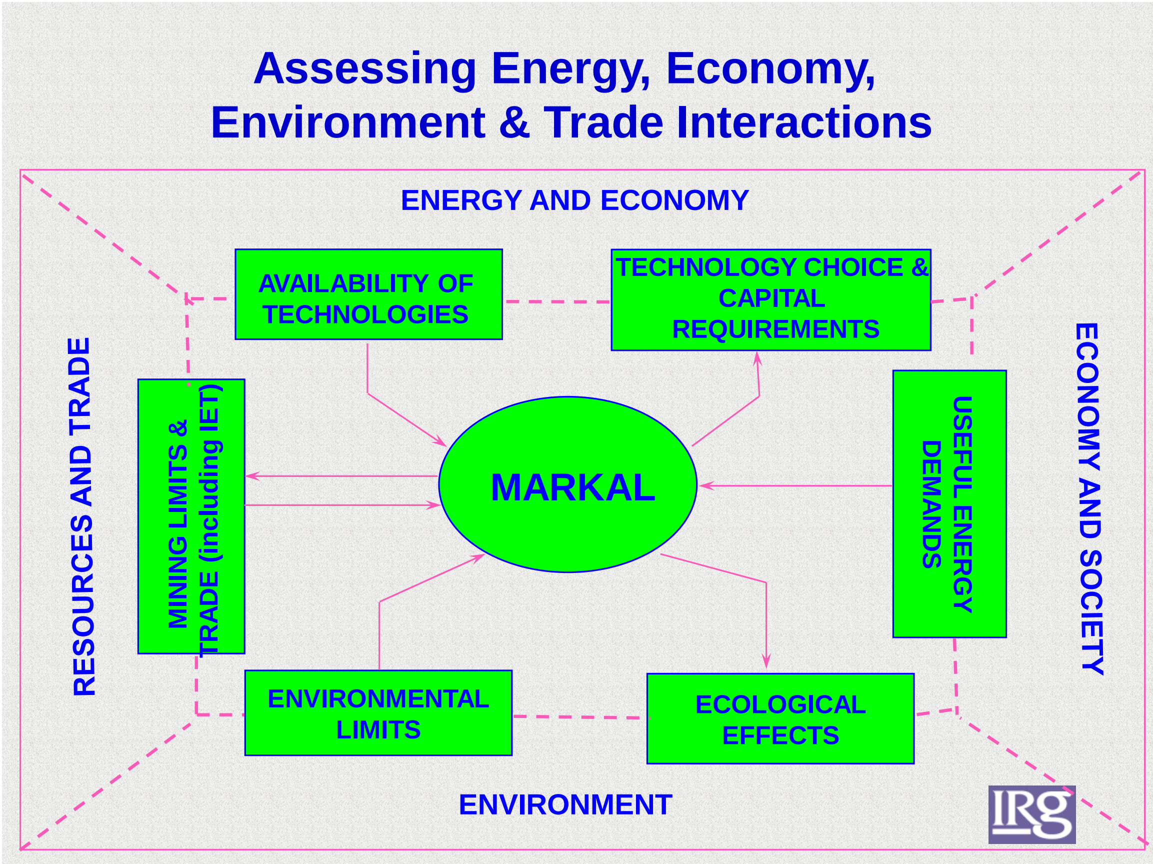
At least as important as the energy balances themselves, and the accompanying information systems, is the process of building a team of professionals in each country who can work with the data, maintain the information systems, and support higher level analytical approaches. This team-building should 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 24).

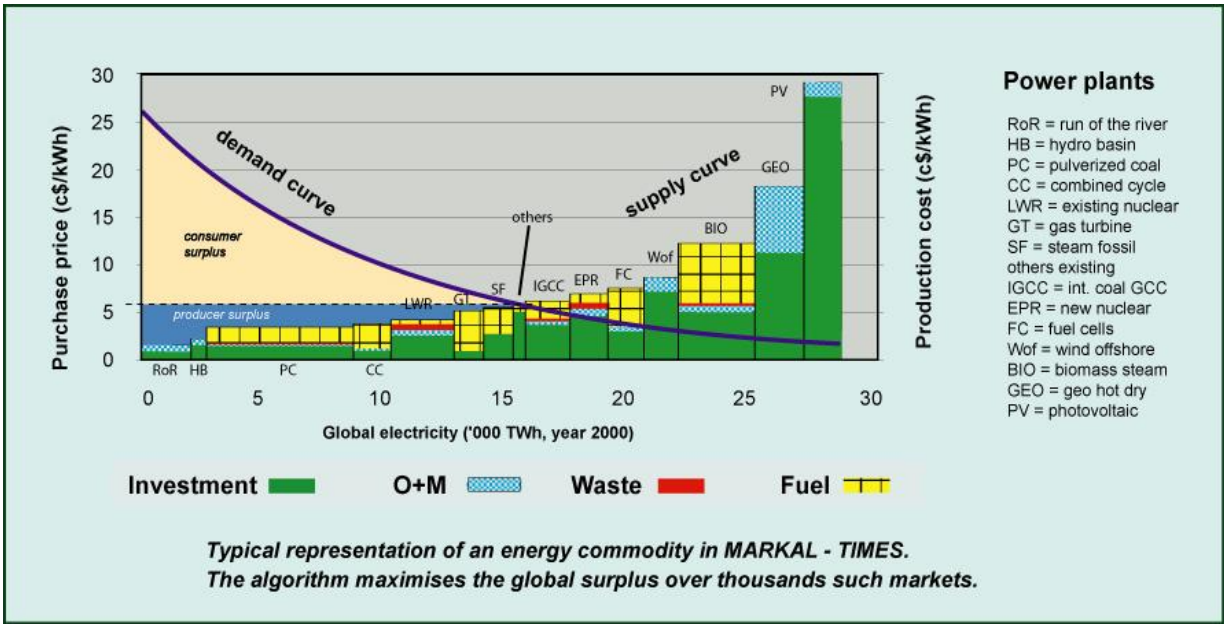
Figure 24. Interactions in the MARKAL/TIMES Model



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



One of the most relevant suite of studies conducted recently using is that sponsored by the European Union that employs MARKAL/TIMES to represent the pan-European energy picture as a closely tied integration of the national energy systems. The initial incarnation of this was realized as part of the New Energy Externalities Developments for Sustainability (NEEDS)[15] undertaking. The Pan-European TIMES model (PET)[16] evolved from the original NEEDS model and has been employed for series of high profile EU projects, including RES2020[17] examining the EU renewables directive,[18] REALISEGRID[19] 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).[20] Another pair of high-profile uses of MARKAL/TIMES is the IEA Energy Technology Perspectives[21] and United Kingdom (UK) Climate Change Policy "White Paper."[22]

---

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

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

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

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

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

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

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

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

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov