Evaluation of the Energy Policy for Lebanon

Raymond Ghajar [1], Hassan Hamdan [2]

[1] *Department of Electrical and Computer Engineering, Lebanese American University*
PO Box 36, Byblos, Lebanon
rghajar@lau.edu.lb

[2] *Ministry of Energy and Water*
Rue Du Fleuve, Beirut, Lebanon
hassan.a.hamdan@gmail.com

Abstract—**The Lebanese Electric Power System (LEPS) suffers from technical and financial deficiencies that required the development of a policy paper to rescue it from its drastic situation to a new sustainable, reliable, and efficient delivery of electricity. An energy policy that includes ten strategic initiatives and 42 action steps that are integrated and correlated to cover the sector's infrastructure, supply/demand, and the legal aspects was proposed and approved by the Government of Lebanon. This paper describes the current technical and financial situation of the LEPS and the need for an energy policy. The stochastic Load Modification Technique (LMT) is then used to assess the impact of implementing the projects proposed in the energy policy on energy production, overall cost, technical and commercial losses, reliability and customer service. The proposed technique is used to establish a technical and financial baseline of the LEPS against which the full implementation of the energy policy is compared and the resulting tariff is calculated.**

I. Introduction

A. Current Situation and the Need for an Energy Policy

The Lebanese electricity sector is at the heart of a deep crisis. The sector is unable to supply the reliable electricity needed by homes, offices and industry. Tariffs do not cover operating costs; and plants are in poor and deteriorating condition. Electricity is generated from some relatively modern plants using gas-oil at a very high cost; and from old plants that use Heavy Fuel Oil (HFO) with high specific fuel consumption and low efficiency (i.e., high cost). The figure below shows the geographic distribution of thermal power plants over the Lebanese territories.

Fig. 1. Geographic distribution of thermal power plants in Lebanon

There are high levels of technical and non-technical losses, so the cost of delivered electricity is further increased. Conservative estimates of the cost to the Lebanese economy in 2009 from deficiencies in power supply range from $1 to $1.5 billion [3].

Power outages are a daily occurrence in Lebanon, and in some regions of the country; electricity is only supplied for a few hours a day during the summer peak period. This has led consumers and industry to a massive investment in backup arrangements. Indeed, this form of energy security is estimated to cost the population at least an additional 35% in spending on electricity per month. The interruption in supply by the national electric utility, Électricité Du Liban (EdL), is furthermore estimated to cost industry close to US$400 million in lost revenues. This additional spending and revenue loss has an obvious negative impact on these consumer categories, but also makes implementation of other macro-critical, non-electricity sector reforms, difficult; as consumers have difficulty absorbing increased overall spending (e.g., tax increases) [3].

Even worse, the poor service provided by EdL is costing the Government massive amounts in the form of generalized subsidies. Some subsidization of the sector may be warranted if at least the service was reliable and there was an underlying sound strategy justifying the subsidies (e.g., targeted assistance to the poor). In Lebanon today, however, the subsidies are required to cover insufficient revenues due to a tariff set far below cost recovery, and low billings and collections. In addition, the continued use of gas-oil (diesel) in two major power plants designed to use natural gas (despite the abundance of natural gas in the region), high O&M cost of all power plants due to insufficient regular maintenance and spare parts, as well as high technical and non-technical losses, result in very high production costs [3].

The sector is becoming a massive drain on government finances, crowding out expenditures to other sectors such as education, infrastructure, social protection, and health, and putting macroeconomic stability at risk. Without rapid action the condition of the sector can only deteriorate, possibly to the point of catastrophic failure in the near future.

B. The Main Components of the Energy Policy

It is clear from the description of the current situation that Lebanon faces serious challenges in assuring an affordable, reliable, secure and environmentally acceptable supply of

978-1-61284-286-8/11/$26.00 ©2011 IEEE

energy for its people and its economy. The country has few natural mineral resources; a dilapidated infrastructure; insolvent supply companies; highly unreliable supplies of electricity at high cost; very large unaccounted losses; inefficient final use and no consensus on the way ahead. Regional integration is not well developed. The country benefits from a long coastline relative to its size and population giving it access to international commodity markets, an industrious and educated population and some useful potential renewable resources [3].

The Ministry of Energy and Water (MoEW) developed an energy policy that constitutes a global framework for the electric energy sector in Lebanon, and includes ten strategic initiatives that are integrated and correlated to cover the sector's infrastructure, supply/demand, and the legal aspects. The initiatives are developed into identified plans of action with required budget, financing schemes, and timeframe. The main policy objective is to rescue the power sector from the current drastic situation to a new sustainable, reliable, and efficient delivery of electricity. A transitional rescue period of 3 - 4 years is required to achieve the main goals of this policy.

The proposed energy policy remedies most of the problems of the electric energy sector starting by the addition of generating capacity to cover the existing gap, demand forecast and required reserve together with the necessary infrastructure to transmit and distribute the generated energy to consumers throughout the Lebanese service territory in a secure and economical manner. The transmission and distribution infrastructures will be upgraded to cope with the capacity additions and to improve the operability of the system, thus decreasing the technical losses. The policy calls for the establishment of a smart grid using meters with remote disconnects from control centers that will be operated with specialized service providers for the transitional period to modulate consumption and reduce non-technical losses.

On the supply side, the capacity addition shall include conventional energy sources that are the most economical with the least environmental impact mainly the natural gas; and renewable energies such as wind, solar, waste to energy, etc. The infrastructure requirements for the natural gas (LNG terminal, pipeline along the coast, etc.) are included in the policy. On the demand side, the policy aims to develop several demand side management and energy efficiency initiatives (e.g., CFL, SWH, etc.) to curb the load growth and improve the load factor which translates into guaranteed savings for the economy. To help increase the penetration of energy efficient devices, the policy calls for the adoption of standards and labels to promote them. Furthermore, a restructuring of the tariff, leading to a gradual balance in the fiscal budget of EdL, is necessary to both generate needed revenues on the treasury side and to unload the financial burden on the economy and the consumer side by eliminating the need for private generators and providing reliable service.

The multitude of the projects included in this policy will require a proper legal framework for a transition phase until a permanent and stable situation for the sector is established. Similarly, the necessary financial, administrative and human resources will be given to EdL to manage the transition phase until the corporatization of EdL is accomplished. All this will be done in collaboration and partnership with the private sector and the donor community to benefit from their vast experiences and resources.

The policy will result in a solid power sector with more than 4000 MW generation capacity in 2014 and 5000 MW after 2015, reliable transmission and distribution networks, and efficient delivery of electricity to cope with the overall socio-economic development of Lebanon. The policy targets a gradual implementation of the initiatives in the short and medium terms totaling \$4,870 million for 4000 MW (Government in Lebanon up to \$1,550 million, the private sector contribution of \$2,320 million, and the international donor community up to \$1,000 million), and an additional amount of \$1,650 million in the long term. The full implementation of all the strategic initiatives in the policy will reduce the total losses from \$4.4 billion in 2010 to around zero in 2014 where 24/24 hours of service is provided, and the possibility of profit making as of 2015; while it will reach \$9.5 billion in 2015 if no action is taken.

The policy was prepared by MoEW in collaboration of all concerned parties, whether internal or external, constitutional and political and it was approved by the Council Of Ministers (CoM) on June 21, 2010.

This paper will evaluate the technical and financial impact of generation expansion on the reliability and adequacy of supply using the Load Modification Technique (LMT). The effects of other initiatives will be included in the evaluation in terms of their financial impact on the policy and the resulting breakeven tariff.

II. ESTABLISHING A BASELINE SCENARIO

Before assessing the merit of the energy policy on the power sector and comparing its benefits to the current situation of no-policy implementation, it is important to establish a baseline scenario using a reference period to validate the model. The baseline scenario uses actual data for 2009 and forecast data for the period 2010 – 2015. The generation and load models together with the evaluation model used to develop the baseline scenario are described in the following sub-sections.

A. Generation Model

Power generation in Lebanon is mainly based on thermal power plants operating on heavy fuel oil and diesel with one gas turbine operating on natural gas piped from Egypt. Hydro power accounts for a small portion of the total energy produced every year (less than 10%) because most rivers dry up in the summer. Lebanon also benefits from regional interconnections with Syria and Egypt but the energy wheeled is not available during the summer peak periods.

The total installed capacity of hydro plants is 270 MW but scarcity of water resources during the summer peak period limits the annual energy production to 1000 GWh only. Hydro plants are therefore modeled as a single multi-state unit with energy limitations.

The installed capacity of thermal power plants is 2038 MW but the actual capacity is less than 1700 MW. Lebanon has six thermal units operating on HFO and diesel. Zouk and Jieh are the oldest HFO-fired steam turbine plants with very low efficiencies and availabilities. These plants must be decommissioned within the next 5 years and replaced with new baseload plants or rehabilitated to extend their lives for ~10 years until new power plants are commissioned. Zahrani and Deir Ammar are two new CCGT power plants operating on diesel which is very expensive because natural gas is not available in sufficient quantities (one of the turbines at Deir Ammar operates on natural gas). The efficiency and availability of the CCGT plants are within industry standards. Sour and Baalbeck are OCGT power plants also operating on diesel at a very high cost and therefore they are only used during the peak period. The energy produced from thermal plants constitutes ~88% of the total energy production at a fuel cost varying from 10 USC/kWh to 24 USC/kWh.

Lebanon imports power from Syria and Egypt throughout regional Interconnection. The purchases from Syria and Egypt constituted ~7.5% of the total energy production in 2009. The purchases from Syria were 589 GWh at an average price of 13 USC/kWh; whereas those from Egypt were 527 GWh at an average price of 11 USC/kWh.

B. Load Model

Obtaining a precise load model for the LEPS is a difficult task due to widespread rotating outages throughout the system. For the purposes of the studies reported in this paper, a peak load of 2450 MW, a demanded energy of 15 TWh, and a load factor of 0.6989 were used for 2009. The peak load was assumed to grow at 7% per year for a study period of 5 years. The shape of the Load Duration Curve (LDC) was approximated using 20 points, as shown in Figure 2.

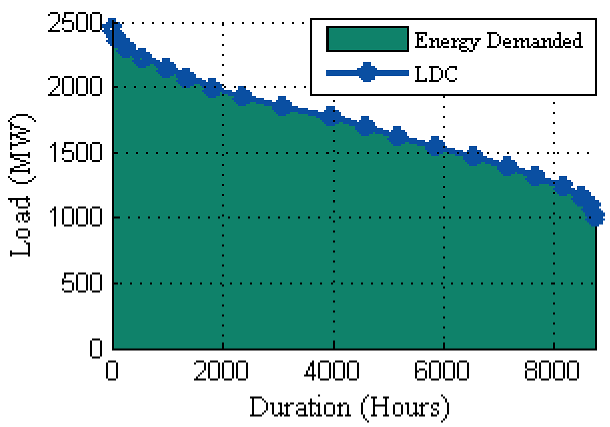

Fig. 2. Load duration curve for the LEPS

C. Load Modification Technique Method

The Load Modification Technique (LMT) is well known for its ability to calculate reliability indices such as the Loss of Load Probability (LOLP) and the Expected Energy Not Supplied (EENS) as well as the Expected Energy Supplied (EES) by individual generating units which is used to calculate the cost of production [1], [2], [6]. This technique can be applied to baseload generating units with no energy limitations and for peak-shaving units having some energy limitations such as the hydro plants in the LEPS.

The traditional LMT method was modified further in this research work to model off-peak scheduling for energy sources such as the imports from Syria and Egypt. The proposed method performs capacity and energy modification from the middle of the LDC curve and away from the peak until all the available energy is accounted for.

The generation and load models were convoluted using the load modification technique described above to obtain the energy produced by each generating unit and the expected energy not supplied by the system. To begin, the units were ordered in a priority list according to their average production costs from lowest to highest and they were dispatched one after the other. The results of the simulation for 2009 are summarized in the LDC curves shown in Fig. 3.

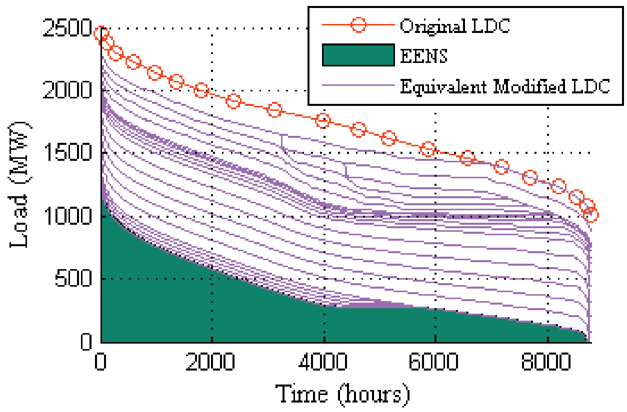

Fig. 3. Original and modified LDC curves representing the addition of all the generating units in the LEPS for 2009

The curves in Figure 3 summarize the behavior of the entire generation model including energy limited units and off-peak dispatching. The EENS, which is the shaded area under the lowest LDC curve, equals 3495 MWh which is 25% of the energy demanded of 15 TWh and the LOLP is 0.9947 which is approximately 1.0. This means that the available generating capacity is only capable of meeting the system load for few hours a year. These reliability indices suggest that the LEPS is nearing a catastrophic failure in 2009 unless the supply of electrical energy is improved. The situation gets much worse for the remainder of the study period as will be shown later in this paper.

D. Financial Burden of the LEPS

The financial situation of the LEPS in 2009 was very critical because the system is prone to high levels of technical (15%, $165 million) and non-technical (17%, $187 million) losses in addition to uncollected bills totaling $37.7 million (3%) of the metered energy. This translates in having only 55% of the energy produced available for sale and collection ($712 million) [3].

The average tariff is set at 9.58 USC/kWh which is well below the cost of production and operation of the system

($1.53 billion). With over 88% of its production from thermal power plants and no indigenous resources, Lebanon imports all of its fuel and therefore is prone to fluctuations in prices on the world market. This, together with the capital amortization of $381 million, increased the deficit in 2009 to $1.2 billion. The lack of elasticity of the tariff to oil prices makes the deficit a volatile parameter [3].

In addition to the direct losses stated above, the Lebanese economy is subjected to severe indirect losses emanating from the high level of unsupplied energy (EENS = 3,495 GWh). In the context of this research work, the EENS was divided into two components: 1) energy supplied by private generators (80% or 2,796 GWh); and 2) suppressed energy that cannot be supplied (20% or 699 GWh).

The high level of privately supplied energy (80%) is the result of many years of unreliable energy supply and rotating outages which forced most Lebanese to invest in private generators for their homes and businesses. These small generators are efficient high-speed diesel engines that begin operation as soon as the power is cut off from the main grid. Although these engines improve the overall reliability of electricity supply to customers, they have major detrimental effects on the environment due to their high levels of noise and air pollution. In addition, the average cost of privately-produced kilowatt-hour is much higher than the average tariff because the engines use diesel fuel which is very expensive. The cost of privately generated electricity in 2009 was calculated to be $1.305 billion using an average price of 46.43 USC/kWh [3].

Despite all individual and collective efforts to meet the energy demand at all times, a sizable portion of the demand (20%) is never met and causes indirect economic loss which is valued using the Value of Load Loss (VoLL). Estimating the VoLL for Lebanon is very difficult because it relates the economic activities in the country and their dependence on electricity. A modest value of 1,633 $/MWh [4] was used to estimate the indirect economic losses of $1.14 billion which is a huge burden on the national economy.

E. Results of the Baseline Scenario

A baseline scenario was established by simulating the existing system for the period 2010 – 2015 using 2009 as a reference without implementing any initiative from the energy policy. The purpose of this scenario is to determine the level of service and financial deterioration expected over the medium term and provide a basis for measuring the benefits resulting from the implementation of the energy policy. The baseline scenario was established using the following assumptions:

- Peak load increases by 7% per year
- Availability of existing units decreases by 2% per year
- Capacity of existing units decreases 2% per year
- Price of fuel increases by 3% per year.

The results of the baseline scenario are presented in TABLE I which shows all the relevant technical, reliability and financial parameters for each year in the study period. It can be clearly seen from this table that government subsidies remain relatively constant over the whole period because the total energy produced decreases slightly while the production cost increases by a small amount. The table also shows that the cost of self-generation increases rapidly as people tend to rely more on private generators to meet their energy demand. Similarly, the indirect economic costs increase rapidly with the EENS. The most alarming number in TABLE I is the "Total loss including subsidies" which increases from $3.65 billion in 2009 to $10.05 billion in 2015 with a cumulative total exceeding $45 billion.

To illustrate the effect of no action on individual power plants, Figure 3 depicts the average production cost of individual power plants together with the existing tariff on a common scale. It can be seen from this figure that the production cost of all plants except hydro plants are higher than the tariff, hence the annual deficit.

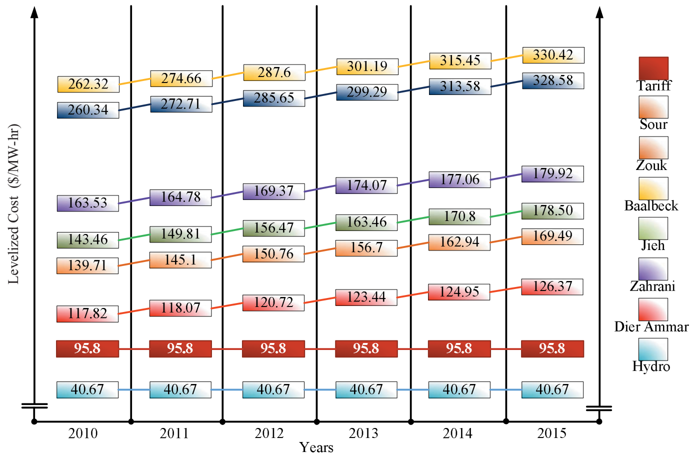

Fig. 4. Comparison of average production costs with existing tariff

III. Evaluation of the LEPS After Implementation of the Energy Policy

To evaluate the benefits of implementing the energy policy, an overall timeline was developed for all proposed projects. The timeline includes the following parameters for each project: start-date and end-date, technical requirements and constraints, financial cost/benefit. The simulation whose results are depicted in TABLE II was performed using the same assumptions used to develop the baseline scenario.

It can be clearly seen from TABLE II that there is a substantial improvement in the overall technical and financial performance of the system even with the existing tariff structure. This is mainly due to the utilization of Liquefied Natural Gas (LNG), improvement in the efficiency and availability of existing power plants after rehabilitation, reduction in technical and non-technical losses, implementation of energy efficiency and demand side management measures, and the addition of modern and efficient power plants to meet the expected load demand.

TABLE I
RESULTS OF THE BASELINE SCENARIO WITHOUT POLICY IMPLEMENTATION

Item	2009	2010	2011	2012	2013	2014	2015
Energy Demanded (GWh)	15,000	16,053	17,173	18,373	19,659	21,037	22,512
EES (GWh)	11,504	11,326	11,050	10,871	10,664	10,476	10,245
EENS (GWh)	3,495	4,726	6,122	7,501	8,994	10,560	12,266
Total Production Cost (MM$)	1,530	1,565	1,586	1,622	1,654	1,689	1,717
Total Gained Revenues (MM$)	711	700	683	672	660	648	634
Losses (MM$)	818	864	902	949	994	1,041	1,083
Deficit/Subsidies (MM$)	1,200	1,245	1,284	1,330	1,375	1,422	1,464
Cost of self-Generation (MM$)	1,304	1,764	2,285	2,800	3,357	3,942	4,579
Economic Cost VOLL (MM$)	1,141	1,543	1,999	2,449	2,937	3,449	4,006
Grand Total Losses (MM$)	**3,646**	**4,554**	**5,569**	**6,581**	**7,670**	**8,814**	**10,050**

TABLE II
RESULTS OF THE LEPS AFTER IMPLEMENTATION OF THE ENERGY POLICY

Item	2009	2010	2011	2012	2013	2014	2015
Energy Demanded (GWh)	15,000	16,053	17,173	18,189	19,267	20,828	22,285
EES (GWh)	11,504	14,404	13,820	16,361	18,279	20,422	22,253
EENS (GWh)	3,495	1,648	3,352	1,828	987	405	32
Total Production Cost (MM$)	1,530	2,013	1,964	2,326	1,656	1,696	1,634
Total Revenues (MM$)	711	896	876	1,088	1,309	1,568	1,799
Total Losses (MM$)	818	1,116	1,088	1,238	346	128	-164
Deficit/Subsidies (MM$)	1,200	1,499	1,515	1,786	1,020	970	826
Cost of self-Generation (MM$)	1,304	612	1,245	679	366	150	12
Economic Cost VOLL (MM$)	1,141	538	1,094	597	322	132	10
Grand Total Losses (MM$)	**3,646**	**2,650**	**3,855**	**3,062**	**1,710**	**1,253**	**848**

TABLE III
TARIFF CORRECTION REQUIRED TO ELIMINATE SUBSIDIES

Item	2009	2010	2011	2012	2013	2014	2015
Yearly Tariff Increase (%)	0%	0%	0%	5%	8%	12%	15%
New Average Tariff (USC/kWh)	**9.58**	**9.58**	**9.58**	**10.06**	**10.86**	**12.17**	**14**
Total Production Cost (MM$)	$1,530	$2,013	$1,964	$2,326	$1,656	$1,696	$1,634
Total Revenues (MM$)	$ 711	$896	$876	$1,142	$1,1485	$1,992	$2,625
Total Losses (MM$)	$ 818	$1,116	$1,088	$1,183	$171	-$295	-$990
Deficit/Subsidies (MM$)	**$ 1,200**	**$1,499**	**$1,515**	**$1,7831**	**$844**	**$546**	**$0.00**

TABLE II also shows that the cost of private generation and the economic costs resulting from unsupplied energy decrease gradually from 2009 until 2015 where they become negligible. The government subsidies, however, fluctuate for the first three years and then begin a gradual decrease to $826 million in 2015. This value can be eliminated by increasing the tariff gradually over the simulation period as shown in TABLE III. It can be seen from this table that the average tariff was increased from its current value of 9.58 USC/kWh to 14 USC/kWh which represents a total increase of 46% over the 5-year simulation period. The cumulative increase in the average tariff is quite acceptable because the new tariff will still be much lower than the cost of private generation in 2015 (55.44 USC/kWh). Therefore, it can be concluded that the proposed energy policy has positive financial impacts on both consumers and the Government of Lebanon.

To illustrate the financial impact of policy implementation, the levelized production cost for each power plant was calculated with and without amortization of the capital expenditure. These cots are presented in Figure 5 which clearly shows the positive impact of LNG which is expected to arrive in 2013) on the production costs of most power plants. The figure also shows that plants with low duty cycles tend to have exorbitantly high levelized costs when CAPEX is included. This suggests that such expenditures are not justified and should be reconsidered based on progress in policy implementation.

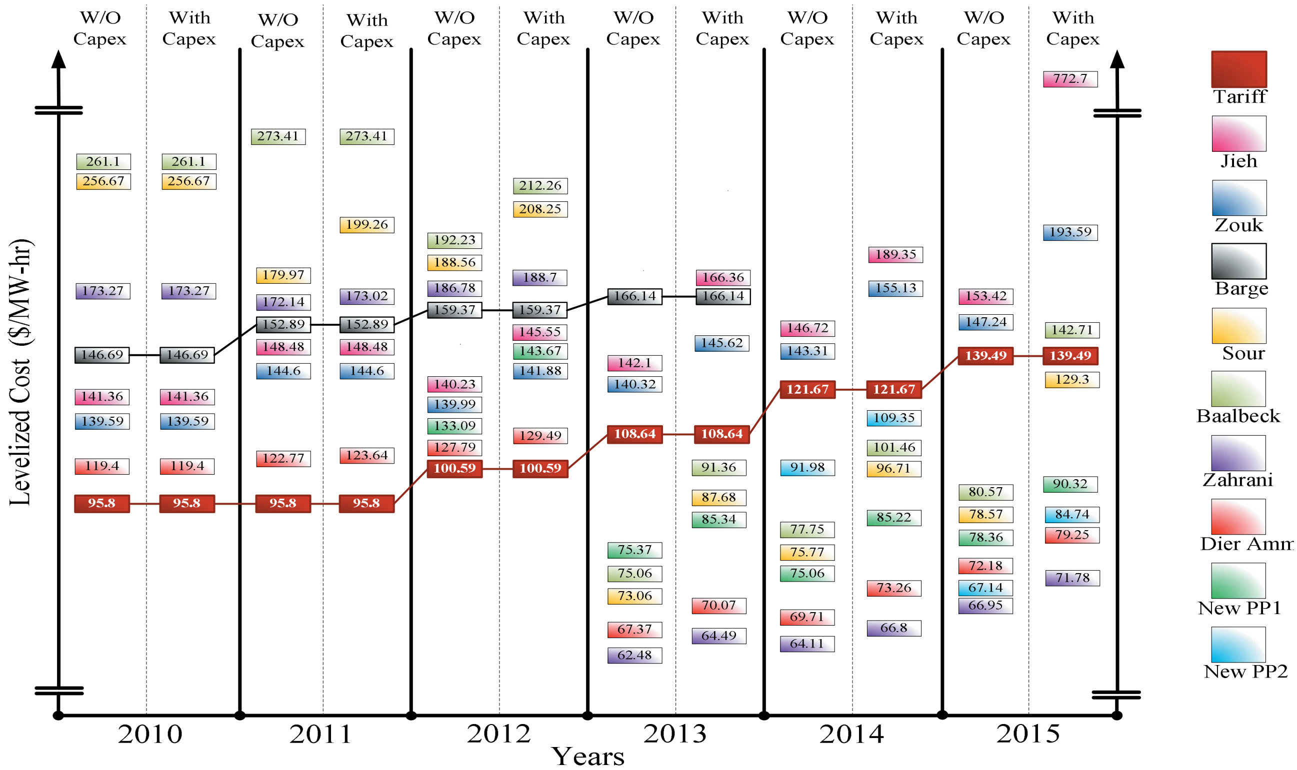

Fig. 5. Comparison of average production costs and new tariff after policy implementation

IV. Conclusion

This paper simulated the existing LEPS over a study period of 5 years and established a baseline against which the benefits of a newly proposed and government-approved energy policy were measured. The simulation clearly showed that implementation of the proposed policy is technical and financially beneficial to both government and consumers due to improvements in the overall quality of power supply and reduction of subsidies, economic costs and costs of private generation.

Acknowledgement

This work is supported in part by the Lebanese American University (LAU).

References

[1] R. Billinton, P.G. Harrington, "Reliability evaluation in energy limited generating capacity studies," *IEEE Transaction on Power System,* vol. PAS-97, No. 6, pp. 2076-2085, Nov. 1978.

[2] R. Billinton, R. N. Allan, *Reliability Evaluation of Power Systems,* New York: Plenum, 1984.

[3] H. A. Hamdan, "Stochastic-Based production costing model: Evaluation of the energy policy paper for the LEPS," M. Eng. thesis, Lebanese American University, Byblos, Lebanon, Oct. 2010.

[4] *Generation and transmission master plan for the electricity sector: generation master plan report*, Électricité Du France, Feb. 2008.

[5] *Republic of Lebanon electricity sector public expenditure review*, World Bank, 41421-LB, Washington, 2008.

[6] R. Allan, R. Billinton, "Power system reliability and its assessment: background and generating capacity" *Power Engineering Journal,* vol. 6, pp. 191-196, Aug. 2002.

Biographies

Raymond F. Ghajar is an Electrical engineer with 30 years of experience in the area of power systems. He spent the last 15 years at the Lebanese American University as a professor of electrical engineering and vice president for human resources and university services. He worked for several electric utilities and consulting firms in Canada, United States and Lebanon. Dr. Ghajar published extensively in internationally referred journals and conferences in the areas of power system reliability, planning, electricity metering, tariffs, operation and software development and he organized several local and international events. Since February 2008, Dr. Ghajar has been working as senior advisor to the Minister of Energy and Water in Lebanon. He helped develop the current energy policy and he supervises the implementation of a number of initiatives and projects.

Hassan A. Hamdan received his MSE degree in Computer & Communication Engineering in 2010 and a BE degree in Electrical Engineering in 2009 from the Lebanese American University. Currently he is a full time advisor to the Minister of Energy and Water and is working in the implementation of the Generation Expansion plan and the construction of a new tariff structure. His research interest includes energy policy planning and modelling, developing generation expansion and production costing models in addition to computer application to power systems.