Challenges for CO2 mitigation in the Lebanese electric power sector

Dagher, Leila and ruble, isabella

2009

Challenges for CO_2 mitigation in the Lebanese electric power sector

Leila Dagher*, Isabella Ruble,

American University of Beirut /Department of Economics

P.O.Box 11-0236

Riad El-Solh / Beirut 1107 2020

Lebanon

* Corresponding author. Tel:+9613308891, Fax:+9611744461, Email:ld08@aub.edu.lb

Abstract

Similarly to other developing countries the electricity sector in Lebanon is monopolized by a vertically-integrated public utility, Electricite Du Liban (EDL). EDL's supply is characterized by frequent and lengthy power cuts that have given rise to an alternative, informal, and unregulated backup sector, which serves to satisfy electricity demand during the extended blackout periods. This paper examines the evolvement of the backup sector and its related CO_2 emissions via the use of scenario analysis. The economic and energy policy implications of each scenario are discussed and a number of policy options are presented to ensure that the growth in CO_2 emissions is contained. Results clearly indicate that the backup sector plays a critical role in the success of any greenhouse gas mitigation commitment undertaken by Lebanon. A clear strategy on dealing with this sector needs to be devised simultaneously if not prior to any climate change policy at the national level.

Keywords: Mitigation and scenario analysis; Climate policy; Electricity generation

1. Introduction

Lebanon is a small (10,452 km^2) Mediterranean country that enjoys mild winters and hot summers. It is considered to be a developing middle income country with a population of 4.2 million and a per capita GDP estimated at 10,742 (US$ at PPP) for 2008 (EIU, 2009). In 2005 Lebanon was the 83rd biggest emitter of CO_2 with a total of 17.5 million tons and was ranked 67th in per capita emissions which amounted to 4.4 tCO_2 (WRI, 2009). However, in comparison to other developing countries Lebanon's CO_2 per-capita emissions are on the higher end. For example, China the world's second largest polluter as of 2005 emits 4.3 tCO_2 per capita and India which ranks 6th worldwide has per-capita emissions of 1.1 tCO_2. Currently, the overall share of world CO_2 emissions coming from developing countries is around 50%. While per-capita emissions in developing countries are still much lower than in developed countries they are growing at a much faster rate due to the higher growth in energy demand.

Lebanon ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 and the Convention was entered into force in 1995. Lebanon's first national communication on climate change to the UNFCCC was submitted in 1999, and the second communication is expected to be submitted in 2009. Lebanon also ratified the Kyoto Protocol in 2006 and the Protocol was entered into force in 2007. Under the Kyoto Protocol developing countries such as Lebanon did not take on any binding commitments to reduce greenhouse gas emissions. But, for any international initiative to be effective, developing countries will have to actively participate in the mitigation efforts at some point. This could happen as soon as at the Conference of the Parties in Copenhagen in December 2009. On a regional level, Lebanon is a participant in the Euro-Mediterranean Energy Partnership that has adopted three energy policy objectives; security of supply, competitiveness of the energy industry, and environmental protection (Kagiannas et al., 2003). The third objective mainly focuses on promoting renewable energy and energy efficiency in the member countries.

Lebanon's participation in international environmental agreements can be viewed as an explicit declaration of its willingness to actively engage in greenhouse gas mitigation policies. In practice, there are two government-led programs aimed at reducing GHG emissions. One is the 'Lebanon cross-sectoral energy efficiency and removal of barriers to ESCO operation' that targets GHG emission reduction resulting from inefficient end-use energy consumption in all sectors of the economy (UN, 2002). The other is 'The climate change project' designed to address GHG issues in Lebanon (UN, 2002). The former effort is implemented by the Ministry of Energy and Water and the latter is implemented by the Ministry of Environment.

Similarly to many other countries, a big portion of CO_2 emissions in Lebanon stem from electricity generation. The Lebanese electricity sector is however, uniquely characterized by the existence of a large number of off-grid distributed generators that unofficially operate in parallel to the public utility. This situation makes regulating or monitoring the independent operators practically impossible and hence will seriously hamper any effort to commit to greenhouse gas mitigation. In this paper, we show that if we continue with business-as usual an investment of $6.47 billion is needed in the electric power sector. Furthermore, by the year 2016 the majority of CO_2 emissions will come from the backup sector. Alternatively, a solution to this problem, as we present in the following sections, would be for the public utility to expand its capacity to satisfy the growth in electricity demand through the use of renewable energy systems. This option requires an investment of $3.20 billion, less than half of what will be needed under business-as-usual circumstances.

In section 2, we present an overview of the Lebanese electricity sector while highlighting its particularities. Section 3 details the two alternative scenarios and the method used to obtain forecasts of electricity demand up to 2025. Then, in section 4 we present and discuss our results for the both scenarios. Finally, section 5 concludes with a number of policy implications.

2. Overview of the Lebanese electric power sector

As is common in most developing countries, electricity generation, transmission, and distribution in Lebanon is monopolized by a vertically-integrated public utility, Electricite du Liban (EDL). However, unlike other similar developing countries Lebanon enjoys a high degree of electrification; almost all households are connected to the electricity network (The World Bank, 2009). During the Lebanese civil war (1975-1990), the electricity sector suffered from both infrastructure damage and mismanagement problems (Chedid et al., 2001a). Subsequently, the Council for Development and Reconstruction (CDR) launched the Power Sector Master Plan between 1992 and 2002 that involved the rehabilitation of the transmission and distribution networks, as well as the expansion of the generating capacity. Currently, EDL operates seven thermal power plants with a total installed capacity of 2038 MW, and six hydro power plants with a capacity of around 221 MW (ALMEE). There are also two privately-owned hydro power plants with a capacity of around 50 MW that sell their electricity production to EDL (ALMEE).

Despite the rehabilitation plan, EDL remains impaired by a lack of capacity, inadequately maintained facilities and networks, and poor management. Moreover, the electricity supply is the most unreliable one in the region and is characterized by frequent and lengthy power cuts (World Bank, 2008). These power cuts are mainly due to rationing because of the shortage in capacity, but are also sometimes the consequence of bad weather, maintenance activities, or other causes. Typically, rationing is uneven and inconsistent, and the consumer cannot get any advance information on the rationing schedule. In many cases consumers depend on their backup generators for as many as 13 hours a day, however the capital Beirut fares better than other cities with rationing limited to three hours a day (World Bank, 2009). Reducing the occurrence of power cuts would bring about great benefits since the outages lead to substantial economic losses that have been estimated by The World Bank (2008) at roughly USD 360 million per year based on estimates for the year 2004. The losses are most severe for textile and clothing firms and hotels which represent some of Lebanon's key industries.

Furthermore, the utility contributes to the large public debt in the country; its annual subsidies in 2006 were just under a billion USD, which corresponds to 4% of the GDP or more than 20% of government revenues (Ministry of Finance, 2007; The World Bank, 2007). The average electricity tariff in Lebanon in 2006 was in the order of 9.4 US cents/kWh (World Bank, 2008). EDL's tariffs are not sufficient to cover costs due to various inefficiencies such as the choice of fuels, technical and non-technical losses, billing and collection problems and the tariff structure (The World Bank, 2008). These tariffs are among the highest in the region if one includes oil-producing countries, but are average when compared only to the tariffs of countries in the region that are also dependent on fuel imports. Unfortunately, the quality of service received by the Lebanese consumer is much lower than the average (The World Bank, 2008).

As mentioned earlier, the rehabilitation plan was not as effective as anticipated. EDL has been increasingly unable to meet the growth in electricity demand that is crucial for the economic growth and advancement of Lebanon. This shortage of supply has led to the development and rapid expansion of an off-grid backup sector as an alternate supply that operates in a legal gray zone. Approximately 58% of the households are hooked up to a backup generator (World Bank, 2009). This figure is expected to be much higher in the commercial and industrial sectors. In 2006 total electricity consumption was 12,490 GWh of which EDL provided approximately 8,056 GWh (65%) whereas the backup sector satisfied the remaining 4,434 GWh (35%) (The World Bank, 2008). This percentage hardly differs from 1994 when according to Chedid et al. (2001a) EDL was able to satisfy 66% of electricity demand. It must be noted that during those years, EDL capacity was being expanded as a part of the rehabilitation plan, otherwise the backup sector would have captured an increasing portion of the demand as has been happening more recently.

Two groups of backup generation providers can be identified; the first group generates electricity for its own consumption in the industrial, commercial and residential sectors, while the second group consists of neighborhood generators that sell electricity when power cuts occur (Abi Said, 2005). Due to the current informal and unregulated state of the backup sector, private generator owners are not held liable for any losses or damage incurred by technical faults, and they do not pay taxes. Neighborhood generators usually offer service at a flat monthly fee that depends on the subscription capacity; for example, a typical household would pay at least $60 per month for 10 Amperes. The rates are inconsistent throughout the country and vary widely from a monthly minimum of $60 for 10 amperes to a maximum of $100. Although the fee per kWh cannot be accurately calculated because it would be a function of the total number of hours the alternative supply operates, in any case it is much higher than that charged by EDL.

The typical Lebanese household faces two electricity bills at the end of each month. On the one hand the household is charged for the power provided by EDL, and on the other hand, the household is also charged a flat fee of at least USD $60 (for 10 Amperes) to benefit from power generated by backup providers. Although EDL's tariff has not changed since 1996, which implies a decline in the fee when inflation is taken into consideration (The World Bank, 2009), the Lebanese consumer ends up paying a very high price for electricity because he has to pay both the EDL bill as well as the standby generator's fee. The World Bank's social impact analysis survey (2008) reveals that expenditures on private generation are almost double those on public electricity. This could mean that the Lebanese are the highest paying electricity consumers in the region.

In Lebanon electricity is generated almost exclusively by burning either fuel oil or diesel oil. There are a few hydro power plants, but their share was less than 7.5% of the total generated GWh in 2006 (ALMEE). The latest two combined-cycle power plants in Ghazzieh (Zahrani) and Deir Ammar (Beddawi) were designed to operate on natural gas. But, unfortunately they have been using diesel oil since they became operational in 1996. As of yet, natural gas has not been used for power generation although a natural gas pipeline linking the Banias plant in Syria to Deir Ammar was completed back in 2005 and still remains inoperative due to political reasons.

2.1 Electric power sector emissions

The electricity generation's share of CO_2 emissions was approximately 30% in 2000 and increased to around 48% in 2006 (SNC, 2009). This percentage includes only EDL emissions that amount to 6.39 $MtCO_2$. It should be noted here that according to the IPCC Guidelines the national inventories of GHG define the power sector as being strictly limited to main activity producers, i.e. EDL, and thus under the sectoral approach the emissions from backup generators are included in the national inventory but are distributed between different sectors, namely the residential, commercial, and manufacturing depending on where the fuel is consumed. There are no reliable figures to help separate the quantities consumed in these sectors for electricity generation from the quantities consumed for other uses such as heating. Similarly, under the reference approach, emissions from the backup generators are included in the gas/diesel oil and fuel oil emissions, however these fuels are also used for heating, transportation, and other industrial activities and it is not clear what percentage of the total is used strictly for electricity generation purposes.

A modest literature body addresses Lebanon's electricity sector and its resulting CO_2 emissions. This includes Chedid et al. (2001a), Karaki et al. (2002), and UNDP (2003). In general, these studies tend to overlook the backup sector's emissions and its growing importance. Another two World Bank studies (The World Bank, 2009; The World Bank, 2008) draw attention to the informal backup sector, but do not examine it in much detail.

The electric power sector emissions were estimated using the default emissions factors (77.37 tons of CO_2 per TJ of fuel oil and 74.07 tons of CO_2 per TJ of diesel oil) recommended by the Intergovernmental Panel on Climate Change (IPCC) because national emission factors had not been calculated at the time the national greenhouse gas inventories were developed (FNC,1999; SNC draft, 2009). Recently, country-specific emission factors were developed by the Lebanese Center for Energy Conservation Project (LCECP) for the grid as a whole but not for each specific fuel (LCECP, 2008).

In general, CO_2 emission factors from fuel combustion are not expected to vary widely as they depend on the carbon content of the fuel in question, which is usually known with some precision. Moreover, the uncertainty related to fuel oil and gas/diesel oil emission factors is relatively lower than for other fuels and processes. In order to capture the uncertainty in emission factors, we use alternative country-specific emission factors developed by Annex I countries and recalculate the Lebanese electric power sector emissions for 2006. The alternative emission factors were taken from each country's Common Reporting Format document submitted to the UNFCCC. Table 1 presents the various country-specific emission factors, the Lebanese electric power sector CO_2 emissions recalculated using these factors, as well as the percentage deviation from the current total emissions that have used the default emission factors. For example, if we use Australia's emission factors instead of the default ones, our emissions from the electric power sector will be 5.26% lower than the current emissions. The computed deviations in Table 1 show a relatively narrow range of -7.36% to +2.30% which translates in terms of emissions to a range of 5.92 $MtCO_2$ to 6.53 $MtCO_2$ for the year 2006. One other study, El-Fadel et al. (2001) addresses the issue of uncertainty in emission factors in the reference approach using the Environmental Protection Agency's AP-42 as alternative emission factor values. They find deviations from the default values of 4.21% and 8.29% for gas/diesel oil and fuel oil respectively.

Table 1. CO_2 emissions using different country-specific emission factors

Country*	Gas / Diesel Oil (tCO2/TJ)	Residual Fuel Oil (tCO2/TJ)	CO_2 emissions using other EF (tons)	Deviation from default (%)
Default (IPCC)	74.07	77.37	6,385,421	0.00%
Australia	69.90	73.60	6,049,326	-5.26%
Canada	69.15	73.61	6,015,700	-5.79%
Czech Republic	74.36	77.37	6,398,613	0.21%
Ireland	73.30	76.00	6,296,974	-1.39%
Italy	74.07	77.55	6,392,659	0.11%
Japan	68.68	71.59	5,915,152	-7.36%
Latvia	74.74	77.36	6,415,440	0.47%
Liechtenstein	73.59	77.37	6,364,102	-0.33%
Monaco	74.00	79.20	6,454,801	1.09%
Netherlands	74.30	77.40	6,397,231	0.18%
New Zealand	69.50	73.00	6,007,649	-5.92%
Norway	73.55	78.82	6,419,561	0.53%
Poland	74.07	78.10	6,414,372	0.45%
Portugal	72.97	75.90	6,278,047	-1.68%
Slovakia	74.36	80.76	6,532,528	2.30%
Slovenia	74.41	74.29	6,279,161	-1.66%
Spain	72.83	77.76	6,345,338	-0.63%
Sweden	74.40	76.19	6,353,880	-0.49%
Switzerland	73.67	77.00	6,353,017	-0.51%
Turkey	73.33	77.37	6,352,440	-0.52%
U.K.	74.47	78.53	6,449,603	1.01%
U.S.A.	69.33	74.68	6,066,646	-4.99%

* Annex I countries that use default emission factors for both fuels were excluded.

According to LCEC (2008), private generators emit more CO_2 per kWh than EDL; 0.802 Kg CO_2/kWh and 0.830 Kg CO_2/kWh, for EDL without and with the backup generators respectively. But if we also take into consideration the technical losses due to the longer transmission distances for EDL, we can assume that the amount of CO_2 emitted per kWh consumed is similar whether its source is EDL power plants or the backup generators. Consequently, and based on this assumption, CO_2 emissions from the backup sector are calculated as 3.51 MtCO_2 (range: 3.26–3.59) and hence the total is 9.90 MtCO_2 (range: 9.17-10.13). Using these figures, the CO_2 emissions from all electricity generated roughly amounts to 73% of the total energy-related CO_2 emissions in Lebanon, as opposed to 48% when backup generators are excluded.

3. Methodology

In this paper we rely on scenario analysis to examine the different paths that the electricity supply expansion in Lebanon could take. In each scenario we predict the growth of both the primary (EDL) and secondary (backup generators) supply and the respective share of CO_2 emissions due to electricity generation.

In our baseline scenario we assume that EDL will not expand its capacity between now and 2025, a period of 15 years in which all the growth in demand will be satisfied by a combination of extended usage of existing backup capacity and an expansion of the backup sector capacity. Hence, during the whole period EDL will keep providing the 8,056 GWh that it provided in 2006. This assumption can be justified for several reasons. First, constructing a new power plant requires a considerable investment. The Lebanese civil war led to a substantial public debt that reached 163.5% of GDP in 2008 making Lebanon's debt to GDP ratio the third highest in the World (CIA World Factbook, 2009). Consequently, funding for any large-scale project, such as a power plant is more difficult to achieve and will need to be funded by foreign sources. However, the state-controlled monopoly, EDL, can be a major disincentive to foreign direct investment (Kagiannas et al., 2003) and in fact there has been a lot of pressure by international lenders to privatize the electricity sector. This is probably the main reason why EDL has not expanded its capacity since the mid 1990s, when the two combined-cycle plants were installed as part of the rehabilitation plan, despite the increase in demand that it was facing. Second, even when funding is secured it takes between four and ten years for a plant to start generating electricity (Berndt, 1991).

In our alternative scenario, the renewable energy (RE) scenario, we assume that EDL completely satisfies the growth in electricity demand up to 2025 through the use of renewable energy systems. A viable option could be to install several wind power plant farms. Such a project has been under serious consideration during the last couple of years and some preliminary steps have been taken such as the recent development of a wind atlas for Lebanon. By examining the wind atlas one can discern several areas along the mountain ranges that have average wind speeds higher than 5 m/s such as Akkar, Marjeyoun, and others. In general, these areas that have high sustained wind speeds have a very low population concentration and land is abundant at very cheap prices to buy or lease for such projects. In the case where EDL captures all the growth in electricity demand, the backup generation will keep providing the 4434 GWh that it provided in 2006.

Of course other greenhouse gas mitigation scenarios related to electric power generation could be contemplated. For example, the growth in demand could be satisfied by distributed grid-connected renewable systems. Fuel switching from fuel oil to natural gas is another option but this option remains irrealizable in Lebanon for political reasons. On the regional level, both Jordan and Syria are shifting towards a higher use of natural gas in their fuel mix, while Egypt has already converted all of its oil-fired plants to natural gas (Green Line, 2007). Several studies have estimated the savings resulting from operating the Beddawi power plant on natural gas instead of diesel oil and their results range from $66 million to $208 million depending on the price forecasts of diesel oil and natural gas (World Bank, 2004; El Khoury, 2006; World Bank, 2008). El-Fadel and Bou-Zeid (2001) find that converting 50% of the power plants—not only Beddawi—to combined-cycle technology by 2020 would yield savings of $295 million per year, equivalent to a negative mitigation cost (benefit) of $111/t$CO_2$. Further, converting 100% of the power plants to combined-cycle technology by 2040 would yield savings of $900 million per year, equivalent to a negative mitigation cost (benefit) of $72/t$CO_2$.

In order to forecast electricity demand between 2007 and 2025 for any scenario, we need a reliable estimate of the electricity demand growth during that period. Note that we chose to use 2006 as our base year because it is the most recent year for which a complete data set could be found.

The predominant rates of annual electricity demand growth in the literature vary between 2.5% and 8% (Chedid and Ghajar, 2004; Chedid et al., 2001a; Chedid et al., 2001b; Schutz, 1998; FNC, 1999) which is a considerably wide range. For our analysis we will use the growth rate of 2.5 % which falls at the lower end of the range, and can hence be designated as a conservative growth estimate. This rate of growth will be used in our scenario analysis to project future electricity demand values satisfied by both the primary and secondary generating sources. Naturally, if the required data were available one could use an econometric demand model for electricity and obtain more accurate future projections. Finally, the EDL historical time series itself does not give a good indication of the future change in demand. The average yearly growth for the period spanning 1991 to 2006 is a staggering12%, which was the result of a growing unsatisfied demand during the civil war and consequently led to a rapid expansion in capacity in the 1990s up until 2002. In contrast, the average yearly growth for the period spanning 2001 to 2006 is only 1.7%, a period during which growth in demand has been partly satisfied by an expansion of the backup sector.

4. Results

4.1 Baseline scenario

Figure 1 presents the forecast results for the reference scenario. Note that in this scenario we assume that the backup sector will satisfy all the additional demand that is not met by EDL, while EDL by not expanding its capacity will still supply the 8,056 GWh that it supplied in 2006. By the end of 2016 the backup sector would have already caught up with EDL, providing almost 50% of electricity consumed during that year and is hence responsible for almost 50% of CO_2 emissions. The World Bank (2008) estimates an even higher share (60%) of backup electricity provision for 2015, but they do not state the methodology and assumptions underlying this estimate.

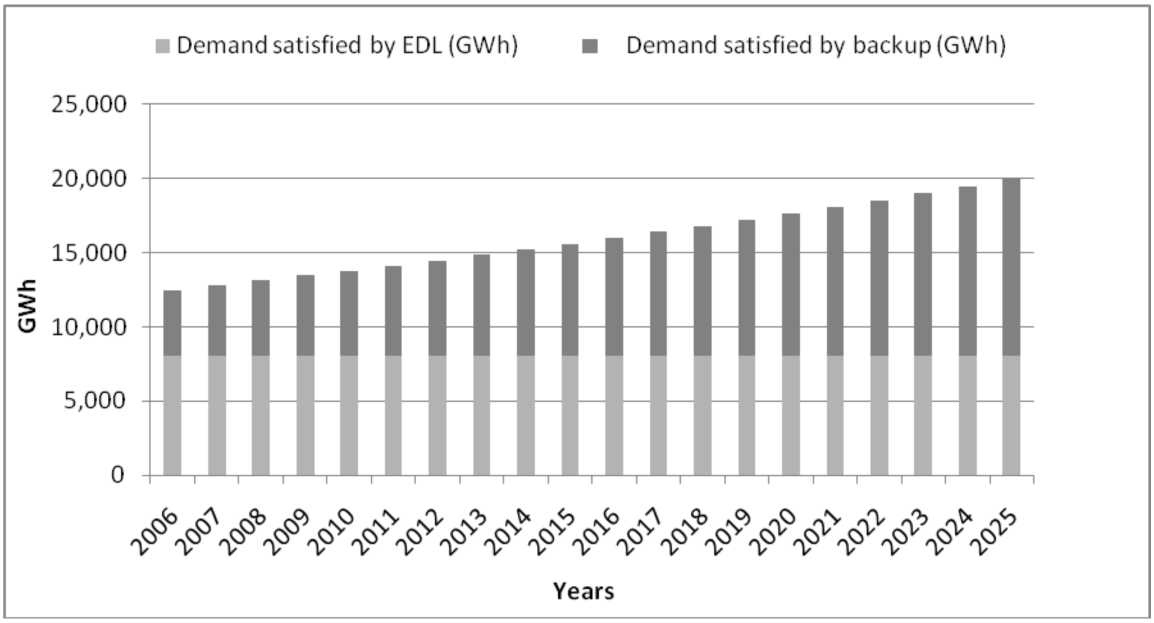

Figure 1. Baseline scenario forecasts of electricity demand

By the year 2025 the backup sector will provide almost 60% of the electricity consumed, while EDL provides the remaining 40%. This implies that approximately 60% of CO_2 emissions from electricity generation would come from thousands of privately-owned unregistered generating units spread all over the country. Under this scenario, the CO_2 emissions from the electricity sector will grow from 9.9 $MtCO_2$ (range: 9.17-10.13) in 2006 to 15.83 $MtCO_2$ (range: 14.66-16.19) in 2025.

The additional 7,477 GWh consumed in 2025 require an added capacity of 1067 MW of generators if we consider a load factor of 80%. Hence, the investment including both capital and fuel would be around $6.47 billion, which the electricity consumers in Lebanon will have to bear.

4.2 Renewable energy scenario

Figure 2 presents the forecast results for the alternative scenario, RE scenario. Note that in this scenario we assume that EDL expands its capacity in line with the growth in electricity demand via the introduction of wind power. Consequently, EDL captures the complete growth while the backup sector's production remains fixed at 4,434 GWh throughout the forecast period. By the end of 2021 the share of EDL would have grown to 75% and the backup sector's share would have diminished to 25% of the total electricity produced.

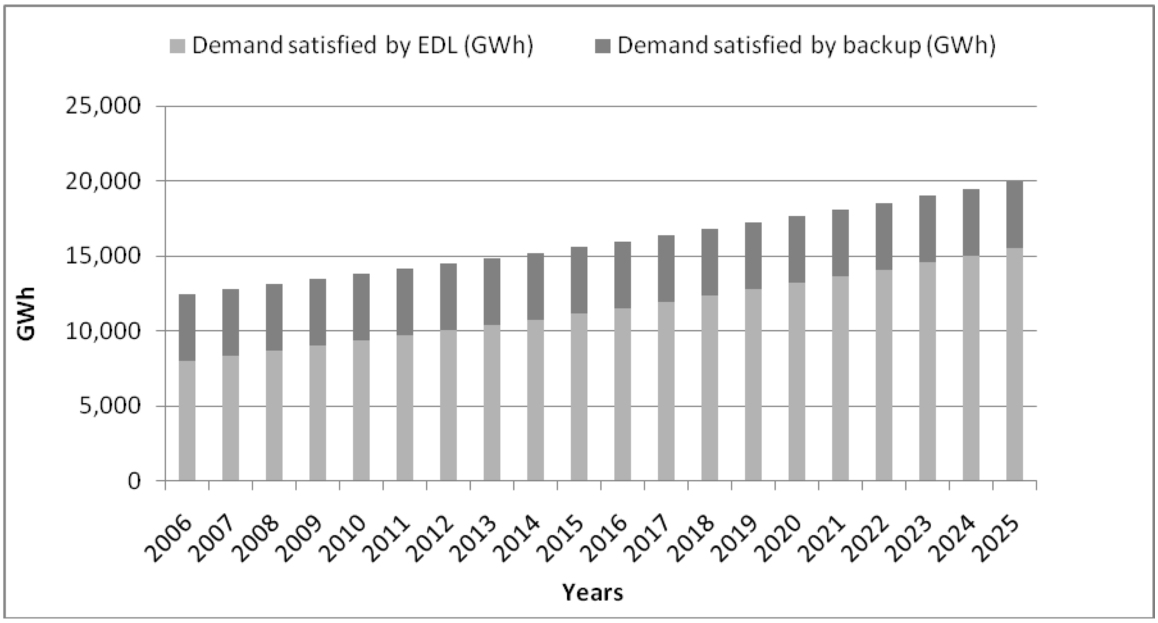

Figure 2. RE scenario forecasts of electricity demand

By the year 2025 the backup sector's share would be further reduced to a mere 22%, while EDL will provide a considerable 78% of the total. Under this scenario, the CO_2 emissions from the electricity sector will remain constant at 9.9 $MtCO_2$ (range: 9.17-10.13) until 2025.

For an additional 7,477 GWh by 2025, there is a need for 2133 MW of wind turbines if we consider a load factor of 40%. This amounts to an investment of around $3.20 billion at the current market price of $1.5 million/ MW of wind energy, nearly half the investment required under the baseline scenario.

5. Policy implications and concluding remarks

In the previous sections we highlighted the increasing importance of the backup sector in electricity provision and its related CO_2 emissions in Lebanon. We have considered two scenarios, the baseline scenario in which the public utility EDL does not expand while the backup sector continues to grow, and the RE scenario in which EDL expands its capacity to satisfy the growth in demand by introducing wind energy. We will now turn to the policy implications of these two scenarios.

5.1 Baseline scenario

In the business-as-usual scenario the backup generating sector which currently provides 35% of the electricity in the country is expected to increase its share to roughly 50% by 2016. This implies that around half the CO_2 emissions related to power generation will be due to thousands of private unregulated generators spread across the country. Indisputably, any national greenhouse gas mitigation plan cannot work if it does not involve this substantial portion of emissions from the power sector, which currently cannot be monitored because of the informal and unregulated status of the backup sector.

Given the critical role that the backup sector plays in the success of any greenhouse gas mitigation commitment undertaken by Lebanon, a clear strategy on dealing with this sector needs to be devised simultaneously if not prior to any climate change policy at the national level. A natural approach is to officially recognize or legalize the backup sector. In that case, all privately-owned generators will have to be officially registered them with the designated regulatory agency and provide information as to the capacity, efficiency, and type of generator. While the registration and consequent regulation of backup generators has numerous advantages (see World Bank, 2009), this approach could be extremely challenging if not impossible to accomplish in view of the existing institutional barriers. Other less comprehensive options are available to policy-makers, but of course their success will depend on the proper implementation of the policies.

Marginal CO_2 abatement costs in this sector are expected to be relatively low because a large number of generators currently in use are old and no environmental or efficiency standards of any kind have been imposed so far. The government can impose a minimum set of efficiency standards on all imported generators, but this would only lead to substitution of foreign-made with local-made generators which are harder to control for appropriate standards. To facilitate the phasing out of old generators import tax breaks (for foreign models) or subsidies (for locally produced generators) could be introduced for environmentally-friendly models.

Climate change policies, which aim at reducing greenhouse gas emissions by reducing the demand for electricity, need to carefully take account of the backup sector. According to EDL its current tariff structure was last revised in 1996 and electricity prices are since then based on fuel prices of USD 25/barrel (The World Bank, 2008), and hence EDL does not recover the cost of each kWh sold. If the government were to consider an increase in electricity tariffs in order to reduce electricity consumption for example, that might simply lead to diverting demand to the backup sector and away from EDL, depending on the increase in tariffs. A coordinated general tariff structure or electricity price policy for both EDL and the backup sector is theoretically appealing but difficult to implement.

Alternatively, policies aimed at reducing energy consumption through energy-efficiency measures are more effective because they apply to both sectors simultaneously, and thus do not merely lead to diverting consumption from one sector to another. Chedid et al. (2001b) suggest such measures as import tax breaks, subsidies or financing for energy-efficient household appliances. Recently, there has been an effort to promote renewable energy and energy efficiency in the country. The LCECP has launched a national plan to replace 3 million incandescent lamps with compact fluorescent lights. The same agency is also working to set up a national fund for energy efficiency and renewable energy and another fund for residential solar water heaters. These efforts are but a small step in the right direction and evidently a more comprehensive effort should be made especially to promote the general public's awareness with respect to issues regarding efficiency in energy use and the benefits involved.

5.2 RE scenario

In the mitigation scenario in which EDL expands via the use of wind energy, CO_2 emissions from the power sector would remain constant at the current level. This constitutes a considerable reduction in CO_2 emissions of around 5.93 $MtCO_2$ (range: 5.49-6.06) for the year 2025compared to a business-as-usual case. The reduction of CO_2 emissions presented in the RE scenario could be further increased if at the same time as EDL satisfies the growth in electricity demand in its entirety, the backup sector is subjected to environmental regulation. If a first project of renewable energy is successfully implemented further projects could be introduced and the backup generators could gradually be driven out without any need for government interference.

Currently, electricity from renewable energy is limited to a couple of hydro power plants that generate less than 7.5% of the total generated GWh in 2006 (ALMEE). Wind and solar technology power projects are practically inexistent in Lebanon, although as mentioned above, a wind power plant has been under serious consideration in the last couple of years but no concrete steps have been taken as of yet.

In a country with a large public debt, such as Lebanon, it might be easier to finance several small or medium-sized renewable energy plants rather than one big plant. Theoretically, funding and implementation of renewable energy projects could be done under the Kyoto Protocol's clean development mechanism (CDM). The CDM allows a developed country to reduce emissions in a developing country and get credit for it. The developed country benefits because the marginal abatement cost is usually lower in the developing country, while the developing country benefits because it receives technology and it can sell the certified emission reduction (CER) credits and thereby receive funds. It is hence a win-win arrangement.

Although there is general consensus on the urgent need for reform, the long-standing political impasse has forestalled any credible reform initiatives and that has kept investors away (World Bank, 2009). Of course, if the electricity sector would be privatized, financing for such projects would be further facilitated and the shortage of supply could be overcome sooner. We have shown in the results section that the investment required in the RE scenario is less than half of that required in the baseline scenario. Consequently, there exists a strong incentive for consumers to support the alternative scenario if an appropriate mechanism can be applied.

Also, the introduction of financial incentives for homeowners to purchase renewable energy systems as well as a reasonable feed-in tariff would greatly facilitate the diffusion of renewable energy in the country. Chedid (2002) presents a detailed analysis of solar water heaters in Lebanon. He highlights the benefits, but stresses that these could only be attained via the design and implementation of adequate policies. As noted before, the LCECP has been working to set up a national fund for energy efficiency and renewable energy and another fund for residential solar water heaters that is supposed to aid the rapid penetration of solar water heaters.

Expanding the supply of electricity by introducing renewable energy has several more advantages in comparison to an expansion with conventional power plants. First, whether one big wind power plant is constructed or several smaller-sized renewable energy plants are implemented, renewable energy will in either situation reduce Lebanon's dependency on fuel imports and thereby contribute to the diversification of our energy mix. Second, if the introduction of renewable energy takes the form of numerous distributed providers this would enhance the security of supply in times of conflict which are all too common in this region, especially that electric power facilities have been directly targeted in the last two decades. Combined with easier financing this will also facilitate driving out the current backup generation providers.

Finally, the introduction of RE will not only allow for a reduction of CO_2 emissions but also for a reduction in electricity bills by not having to pay the backup generator fee. This potential is of major importance since the Lebanese electricity customer currently pays one of the highest electricity bills in the region. While a detailed tariff analysis in the different scenarios is beyond the scope of this paper and will be covered in a forthcoming paper we nevertheless raise this point as it is important when considering the introduction of renewable energy and its effects on electricity tariffs.

References

Abi Said, C., 2005. Electric energy and energy policy in Lebanon. Report.

Berndt, E. R. (1991). The Practice of Econometrics: Classic and Contemporary. Reading, MA: Addison-Wesley.

Chedid, R., 2002. Policy development for solar water heaters: the case of Lebanon. International Journal of Energy Conversion and Management,

Chedid, R., Chaaban, F., Salameh, S., 2001a. Policy analysis of greenhouse gas emissions: the case of the Lebanese electricity sector. Energy Conversion and Management, 42 (3), 373-392.

Chedid, R., Ghaddar, N., Chaaban, F., Chehab, S., Mattar, T., 2001b. Assessment of energy efficiency measures: the case of the Lebanese energy sector. International Journal of Energy Research, 25 (4), 355-374.

Chedid, R., Ghajar, R., 2004. Assessment of energy efficiency options in the building sector of Lebanon. Energy Policy, 32, 647-655.

CIA, The World Factbook, 2009. Accessed at https://www.cia.gov/library/publications/the-world-factbook/geos/LE.html .

Economist Intelligence Unit (EIU), Country Report Lebanon, February 2009.

El-Fadel, M., Bou-Zeid, E., 2001. Economic valuation of greenhouse gas emissions reduction. International Journal of Environmental Studies, 58, 459-486.

El-Fadel, M., Massoud, M., Semerjian, L., 2001. Energy related GHG emissions: assessment of emission factor uncertainty. World Resource Review, 13, 61-73.

El Khoury, P. (2006). The use of natural gas for power generation in Lebanon.

Green Line Association, 2007. Status and potential of renewable energy technologies in Lebanon and the region.

Intergovernmental Panel on Climate Change (IPCC), 2006. 2006 IPCC guidelines for national greenhouse gas inventories.

Kagiannas, A., Askounis, D., Anagnostopoulos, K., Psarras, J., 2003. Energy policy assessment of the Euro-Mediterranean cooperation. Energy Conversion and Management, 44, 2665-2686.

Karaki, S., Chaaban, F., Al-Nakhl, N., Tarhini, K., 2002. Power generation expansion planning with environmental consideration for Lebanon. International Journal of Electrical Power and Energy Systems, 24, 611-619.

Lebanese Center for Energy Conservation Project (LCECP), 2008. Approach to Greenhouse Gas emission reduction analysis.

Ministry of Finance, 2007. Public Finance Prospects 2007.

Republic of Lebanon's First National Communication to the UNFCCC (FNC), 1999.

Republic of Lebanon's Second National Communication to the UNFCCC (SNC draft), 2009.

Schutz, G., 1998. Restructuring of the Lebanese electric power sector. Final Report.

The Lebanese Association for Energy Saving and for the Environment (ALMEE), 2006. Energy Balances in Lebanon.

The World Bank, 2004. Republic of Lebanon hydrocarbon strategy study.

The World Bank, 2007. Lebanon - Energy sector DPL.

The World Bank, 2008. Electricity Sector Public Expenditure Review. Sustainable Development Department, Middle East and North Africa Region, Report No. 41421-LB.

The World Bank, 2009. Lebanon social impact analysis – electricity and water sectors.

United Nations, 2002. Johannesburg Summit 2002, Lebanon Country Profile.

United Nations Development Program (UNDP), 2003. Republic of Lebanon climate change top-up enabling activity.

World Resource Institute (WRI), 2009. Climate Analysis Indicators Tool, available at http://cait.wri.org/cait.php?page=yearly&mode=view&sort=cou-asc&pHints=shut&url=form&year=2005&sector=natl&co2=1&update=Update

Captions

Table 1. CO_2 emissions using different country-specific emission factors

Figure 1. Baseline scenario forecasts of electricity demand

Figure 2. RE scenario forecasts of electricity demand