The Power Sector

4.1. Sector Overview

4.1.1 Current Situation

The Lebanese electric power sector is run by the Electricité du Liban (EDL), an autonomous state-owned power utility, whose mission is to generate, transmit, and distribute electricity to all Lebanese territories (EDL, 2012). The power utility is a public establishment with an industrial and commercial vocation, and is operating under the Administrative Tutelage of the MoEW, which is responsible for policy formulation of the water, power, and fuel sectors.

EDL, founded by Decree No. 16878 dated July 10, 1964, controls over 90% of the Lebanese electricity sector (EDL, 2012). Other participants in the sector include hydroelectric power plants owned by the Litani River Authority, concessions for hydroelectric power plants such as Nahr Ibrahim and Al Bared, and distribution concessions in Zahle, Jbeil, Aley, and Bhamdoun. Hydro power plants have a total installed capacity of 274MW, but due to their old age and the drop in water resources, the nominal generation capacity is around 190MW, constituting around 10% of the total generation capacity of the country.

In 2009, EDL produced more than 15,000 GWh through 7 major thermal power plants owned directly or indirectly by the Establishment and located in different areas of Lebanon and it purchased a limited quantity of electric energy from the concessions (MoEW, 2010). The thermal generation units are operating using heavy fuel oil-fired steam turbines at Zouk, Jieh and Hreysheh; diesel-fired combined cycle gas turbine (CCGT) commissioned in 1994 at Beddawi and Zahrani; and diesel-fired open cycle gas turbines (OCGT) at Tyre and Baalbeck. In addition to the thermal units, the sector includes hydroelectric power plants with a total installed capacity of 274MW, but due to their old age and the drop in water resources, the nominal generation capacity is around 190MW, constituting around 11% of the total generation capacity of the country.

Until 2010, additional power has been purchased from Egypt (527 GWh) and Syria (589 GWh) depending on the availability of surplus (WB, 2009). Moreover, Lebanon imports liquefied natural gas (LNG), which is much more dense than natural gas (1/614 of the volume) or even compressed natural gas (CNG), and the project to connect Baniyas in Syria with Beddawi power plant using a 42-km pipeline has been completed in 2005 (EDL, 2008). In 2009, the Beddawi power plant was operated partially on Egyptian natural gas, but the supply of the gas has been discontinued and the 2 combined-cycle plants are currently run on diesel oil.

EDL suffers from substantial technical and non-technical losses in the transmission and distribution networks. Technical losses are in the order of 15%, compared to a world average of 8%, and non-technical losses, which essentially comprise non-billed consumption of electricity through illegal connections on the distribution network, are reported to vary between regions from 9.6% up to 58%, depending on the region, with an average of around 18%. Moreover, bills collection rates vary from 62% to 97%. As a result, and considering the substantial increase in fuel prices in the world and local markets, see Table 4, and the high technical as well as non-technical losses, the power utility has been running in the last decade with annual deficit mounting to around USD 1-1.5 billion. EDL relies considerably on government transfers aimed mainly at covering the deficit rather than investing in further development activities.

Table 4 - Variation of fuel prices over the past decade

Fuel Type	Year						
	2000	2002	2004	2006	2008	2010	2011
Fuel oil [USD/barrel]	26.8	33	43	61	46	91	105
Natural gas [USD/million Btu]	9.78	5.34	6.84	6.3	5.97	4.41	3.6

Source: (US-EIA, 2012)

With the huge increases in international oil prices in recent years reaching current levels of around USD 110/barrel, the lack of tariff adjustment since 1996 when it was set for oil price of USD 21/barrel has become a clear and present cause of the fiscal drain of the sector (WB, 2009). Lebanon's electricity tariff level is too low to cover the production costs. The contribution of the fuel bill to the total cost was around USD 1,450 Million (75%) and USD 1,165 Million (62%) in 2008 and 2009, respectively. The deficit is further inflated by the high operation and maintenance cost of all power plants, and lack of spare parts.

GHG emissions from the power sector constituted 49% in 1994 and up to 54% of total emissions in 2004, and the sector came second behind the waste sector in having the biggest increase in GHG emissions, see Table 5. This is due to the significant growth in demand for electricity, due in part to the changing socio-economic conditions and to the expansion of the national grid. According to the SNC (MoE/UNDP/GEF, 2011) , the sharp increase between the 1994 and 2000 emissions is due to the increase in gas/diesel oil consumption that resulted the installation and operation of the Baalbeck, Tyre, Beddawi and Zahrani diesel power plants during this period.

Table 5 - GHG emissions from Lebanon

	1994	2000	2004
Total emissions [Gg]	15,901	18,507	20,299
Energy Sector emissions [Gg]	7,743	9,892	10,979
Energy as % of total	48.69	53.45	54.09

Source: (MoE/UNDP/GEF, 2011).

Due to these circumstances, power supply is intermittent in Lebanon, and major power shortages of up to 20 hrs/day interrupt the supply. Therefore, self-generation is playing an increasing role in electricity supply and demand, especially for the industrial and residential sectors. It constituted up to around 500MW, 34% of total consumed power in 2009 (WB, 2011). Standby private generators have ratings up to few hundred KW, and are distributed randomly throughout the country, mainly in residential and commercial sectors, where electricity is distributed to citizens in return of a fee that ranges between USD 100-120 per 5A. Their uncontrolled operations add to the problem of local air quality degradation and noise pollution, in addition to emitting excessive GHG emissions due to the lack of proper and periodic maintenance. The operation cost of private generation is adding substantially the electricity bill that has to be paid by the Lebanese citizens.

To encourage the participation of the private sector in the economy, the Government of Lebanon with support from the World Bank initiated the Power Sector Restructuring and Transmission Expansion Project which calls for a sector- wide structuring and reform aimed to introduce competition and private sector participation in utility operations. The legal framework for privatization, liberalization and unbundling of the sector, as stated in law 462, exists but is not applied yet. Law 462 states that private electricity producers are only allowed to produce electricity for their own private use and cannot distribute electricity to others. Changes have been suggested to ensure the proper and legal implementation of renewable energy technologies and cogeneration. However, the Ministry of Energy and Water is still in the process of modifying these aspects of the 462 law.

4.1.2 Existing Policies and Measures

Since the turn of this century, a number of policies and regulatory decisions in relation to the power sector have been adopted. Table 6 presents a summary of the main laws and policies.

Table 6 - Existing policies and measures

Rules/Policies/Regulations	Description
Oil and Gas Law, approved by GoL in January 2012.	The law is developed to administer the country's oil and natural gas exploration, and to allow for the drilling process to start in undisputed off shore territories.
Policy Paper, prepared by the MoEW in June 2010, and adopted by GoL in 2011.	The Policy Paper constitutes a global framework for the power sector in Lebanon, and constitutes 10 strategic initiatives. According to the Policy, the power sector will have more than 4,000 MW generation capacity in 2014 and 5,000 MW after 2015, in addition to a reliable transmission and distribution networks. The Policy calls for resources diversification such that natural gas will constitute 2/3 of the fuel mix with multiple sources of supply; more than 12% of energy used for power generation will be renewable energies by 2020.
Distribution Service Provider project, as suggested in the Policy Paper, initiated by EDL in 2011.	The Distribution Service Provider project has been developed to consolidate a number of currently outsourced EDL tasks in a new contractual framework that ensures proper investment planning, effective execution of network extension, network operation and maintenance, metering and billing activities. The Lebanese power network has been divided into 3 regional distribution service areas based on the energy supplied in the network and energy consumed, billed and collected.
Institutionalization of the LCEC as the National Energy Agency for Lebanon, January 2011.	The Lebanese Centre for Energy Conservation (LCEC), initially funded by the UNDP, is a national governmental organization affiliated to the MoEW. LCEC addresses end-use energy conservation and renewable energy at the national level. It supports the Government in developing and implementing national strategies that promote the development of efficient and rational uses of energy and the use of renewable energy at the consumer level.
The National Energy Efficiency Action Plan 2011-2015, prepared by the LCEC, adopted by the MoEW in July 2010, and approved by the Council of Ministers in November 2011 (Decision No.26).	The National Energy Efficiency Action Plan for years 2011-2015, called upon in the 6th strategic initiative of the Policy Paper, is the first comprehensive strategy in energy efficiency and renewable energy to be ever adopted by a Lebanese Government. The NEEAP includes 14 initiatives including energy efficiency and renewable energy. It takes into consideration the Government's declaration on energy issues, and the strategic target of having a 12% of power generated in 2020 from renewable resources, and to achieve 5% consumption reduction through energy efficiency measures on the demand side.
Energy Law, approved by the Parliament in August 2010.	The Energy law paves the way for off shore fuel and natural gas exploration in the Lebanese territories of the Mediterranean.
Memorandum of Understanding between Central Bank and UNDP. Circular 236, 2010.	Establishment of the National Energy Efficiency and Renewable Energy Account (NEEREA), as a funding mechanism for organizations and private sector to develop EE and RE projects.
Energy Supply Strategy, Council of Ministers, adopted via Decision 13/2004.	The objective is to set an energy strategy based on fuel diversification, and on harnessing renewable resources at national level.

Rules/Policies/Regulations	Description
Law of Electricity Sector Organization, Law 462, adopted by GoL in September 5, 2002.	Electricity Law 462 calls for the unbundling of Lebanon's power sector and the creation of regulatory authority for the sector. This law sets up the rules and principles governing the power sector, including the role of the GoL, and the basis of transferring the sector or its management, totally or partially to the private sector. Several amendments to the law 462 are being currently discussed by the Government and the Parliament to make the law more applicable to present Lebanese conditions, to allow for future plan expansions, and for the penetration of renewable energy technologies. The amended law is expected to make provisions for the feed- in tariff for co-generation, and should call for the introduction of a transition period during which the corporatization of EDL will take place. It shall also call for the gradual introduction of the private sector into EDL through service providers law and new independent power producer (IPP) to build and operate new CCGT units.

In reaction to the current alarming situation of the power sector, the Government of Lebanon has set a number of priorities for the development of the energy sector in general, and for the modernization and expansion of the power sector in particular. The government committed itself in Copenhagen in 2009 to a voluntary target of reaching 12% renewable energy in the current energy mix and presented this commitment in a Policy Paper in 2010.

The MoEW Policy Paper

The policy paper (MoEW, 2010) prepared in June 2010, and approved by the GOL in 2011 constitutes a global framework for the electric power 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 new policy includes plans to remedy most of the existing generation problems and highlights the necessary infrastructure needed for a secure and economical transmission and distribution networks. According to the Policy, the power sector will have more than 4,000 MW generation capacity in 2014 and 5,000 MW after 2015, in addition to a reliable transmission and distribution networks, and efficient delivery of electricity to cope with the overall socio-economic development of Lebanon. GOL has approved the policy and the implementation process has begun, though with one year delay. The Policy provided the following plans for both the supply, as well as the demand sides.

On the supply side, the additional capacity shall include conventional energy sources, with energy-efficient technologies, that are the most economical with the least environmental impact mainly the natural gas; and renewable energies such as wind, solar, and waste to energy. The infrastructure requirements for the natural gas are also included in the policy. The generation expansion will constitute the following phases:

- Renting 250- MW barges as a standby for units to be rehabilitated.
- Building new 600-700 MW generation units, to be operated using CCGT and/or reciprocating engines.
- Securing additional 245 MW through rehabilitation and upgrading of existing plants.
- Building additional 1,500 MW generation units by 2015.
- Increasing the share of hydro power by 40 MW.
- Introducing, in collaboration with the private sector, around 60-100 MW wind power.
- Encouraging the private sector to invest in waste- to- energy units (15-25 MW).

The transmission expansion plan includes:

- Completing the 220- kV transmission line.
- Completing the 400- kV substation infrastructure for the Arab interconnection.
- Establishing the Lebanese Electricity National Control Center.
- Reinforcing existing substations.

The distribution plans include:

- Improving in participation of the private sector, the distribution services.
- Contracting private service providers for distribution.
- Establishing centers for automatic meter reading.
- Introducing new tariff structures and upgraded services for customers.

The Policy calls for fuels and sources diversification such that natural gas will constitute two third of the fuel mix with multiple sources of supply; more than 12% of energy used for power generation will be renewable energies by 2020; and the remaining from other sources of fuel while selecting technologies that work on both natural gas and fuel oil. Initiatives for enhanced energy supply include:

- Developing a plan for an infrastructure to supply and distribute natural gas based on the existing land pipeline in Beddawi and LNG marine station and to interconnect them with the power plants.
- Gradual shift to natural gas as the main fuel for most power plants. Gas could be imported from Turkey, Syria, Egypt, Qatar, Algeria, former Soviet republics, Russia and others.
- Taking all regulatory measures for finding and extracting natural gas from the territorial waters of Lebanon.
- Completing a prefeasibility study and construct a liquefied natural gas (LNG) marine terminal in Salaata or Zahrani.
- Building a coastal gas pipeline to feed all power plants to reduce their operating costs.

On the demand side, the policy calls for several demand side management and energy efficiency initiatives to curb the load growth and improve the load factor. This will lead to guaranteed savings for the economy. These initiatives include compact fluorescent lamps and solar water heater distribution. The new policy also calls for the adoption of standards and labels to promote cleaner technologies. A restructuring of the tariff, leading to a gradual balance in the fiscal budget of EDL, will also be implemented to generate revenues and to unload the financial burden on the economy and the consumer side by eliminating the need for private generators and providing reliable service without interruptions. EDL will be provided with the necessary financial, administrative and human resources to manage the transition phase until the corporatization is materialized. Collaboration and partnership with the private sector and the donor community to benefit from their vast experiences and resources is also sought.

The MoEW policy paper was followed by the preparation of the National Energy Efficiency Action Plan (NEEAP) aiming at preparing a road map for the development of the energy efficiency and renewable energy sectors and to reach the 12% target of renewable energy by 2020.

4.1.3 Baseline technologies and scenario

Demand for electric power has grown in Lebanon from 7,839 GWh in 2000 to 10,191 GWh in 2004, and to 15,000 GWh in 2009, while the peak electric load in Lebanon increased from 1,666 MW in 2000 to 1,936 MW in 2004, and to 2,100 MW in 2009, with instantaneous peak load in summer reaching 2450 MW (MoEW, 2010, MoE/UNDP/GEF, 2011). Due to the old age of most generation units, the available thermal power capacity is currently around 70 - 80% of the installed capacity. In 2009, the installed capacity was around 2,038MW and available capacity reached 1,685 MW.

Thermal units constitute heavy fuel oil-fired steam turbines at Zouk, Jiyeh and Hreysheh; diesel-fired combined cycle gas turbine (CCGT) commissioned in 1994 at Beddawi, in the north, and Zahrani, in the south; and diesel-fired open cycle gas turbines (OCGT) at Tyre and Baalbeck. In 2009, the Beddawi power plant was operated partially on Egyptian natural gas, but the supply of the gas has been discontinued and the 2 combined- cycle plants are currently run on diesel oil.

The baseline technologies, based on 2010 data, are listed in Table 7 and include the installed capacity of existing thermal power plants, fuel type, annual energy output, fuel consumption rate, emission rates, fuel purchase prices, and annual GHG emissions. Lifecycle emission factors for selected fossil fuels as well as for different types of renewable resources are listed in Table 8. The adjusted emission factor for the power grid is 0.75 tonnes CO_2/MWh.

Table 7 - Baseline data for the existing thermal power plants

Power Plant	Installed Capacity [MW]	Fuel Used	Annual Energy Output [MWh/yr]	Fuel Consumption [gr/kWh]	Fuel Price [USD/ tonnes]	CO_2 Emissions [tonnes/ year]
Zahrani	339	Diesel oil	2,553,888	200	1,100	1,986,925
Beddawi	339	Diesel oil	2,553,888	200	1,100	1,986,925
Zouk	395	Fuel oil	1,981,122	290	700	1,541,313
Jieh	199	Fuel oil	1,098,239	320	700	854,430
Tyre	66	Diesel oil	284,996	330	1,100	221,727
Baalbeck	99	Diesel oil	285,051	330	1,100	221,770
Private generators	500	Diesel	3,478,000			2,705,884
Total	1,937		12,235,184			9,518,974

Source: (MoEW, 2010)

Table 8 - Lifecycle emission factors in the power sector

Technology	Emission Factor [tonnes of CO_2/MWh]
Heavy fuel (HFO)	0.778
Diesel oil (DO)	0.778
Natural gas	0.443
Wind, onshore	0.01
Hydro	0.01
Solar PV cells	0.032
Biomass	0.03

Source: (Savacool, 2008)

Projections for the baseline scenario have been made until the 2020 year, based on the policy paper that states that generation will reach 4000MW by 2014, and 5000MW by 2020. In the absence of secure supply of natural gas, the baseline projection assumes total reliance on heavy fuel oil and diesel oil for the thermal plants. Also, the hydro power available capacity will remain unchanged. Table 9 presents the baseline scenario of power production and related emissions.

Table 9 - Baseline projection till 2020

Year	Thermal available capacity at EDL [MW]	Private power generation [MW]	Available capacity, including private generation [MW]	Annual thermal Energy Output [GWh/year]	Hydro energy production [GWh/year]	Total annual energy [GWh/year]	Annual emissions under BAU* [tonnes of CO_2/year]	Annual emissions with 12% reduction by 2020** [tonnes of CO_2/year]
1994	1,531	50	1,581	5,184	689	5,873	4,040,042	3,378,140
2000	1,366	300	1,666	10,926	635	11,561	8,506,895	7,216,289
2004	1,437	400	1,837	12,048	540	12,588	9,378,450	8,737,035
2010	1,437	500	1,937	12,703	468	13,171	9,887,967	8,701,411
2014	4,000	0	4,000	26,233	468	26,701	20,414,153	17,964,454
2020	5,000	0	5,000	32,792	468	33,260	25,516,521	22,454,538

* Based on the adjusted grid emission factor of 0.778 tonnes CO_2/MWh for thermal power and 0.01 for hydropower
** Assuming a 12% reduction in emissions by 2020, according to the Energy Policy Paper (MoEW, 2010)

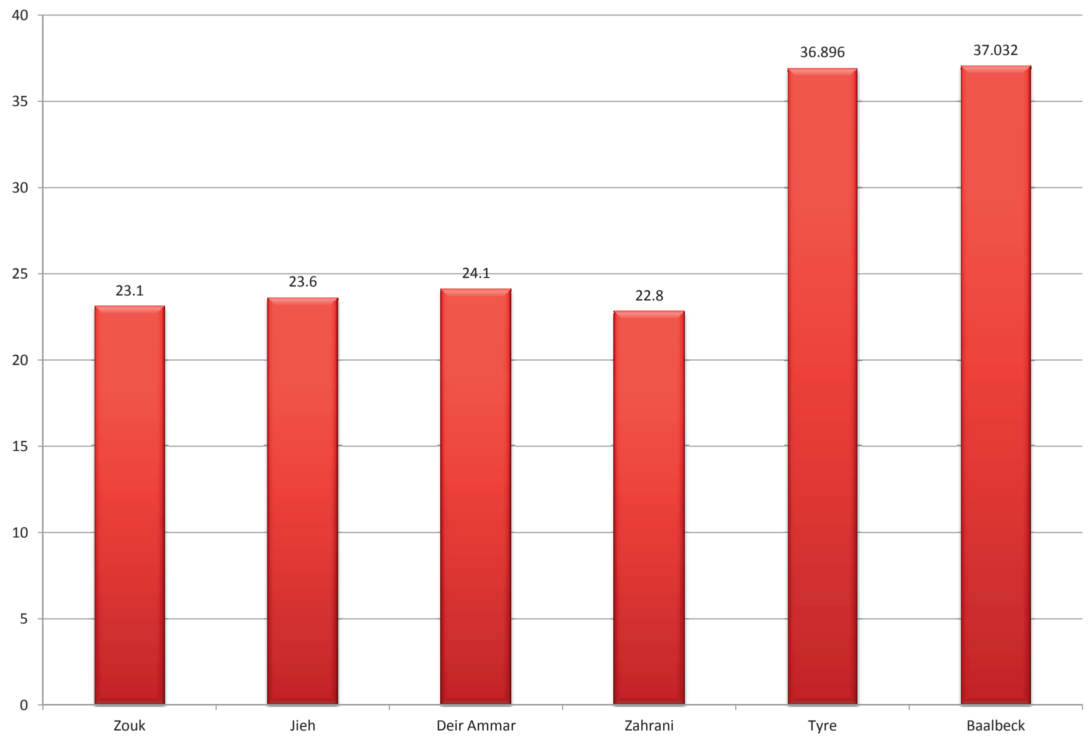

Fig. 3 - Levelized costs of existing power plants

Source: (MoEW, 2010)

The levelized costs of the existing power plants in the baseline are indicated in Fig. 3. The heavy fuel units of Tyre and Baalbeck have the highest cost of around 37cents/kWh, followed by the CCGT units of Beddawi and Zahrani when run on diesel oil, and then by the old units of Zouk and Jieh, run on fuel oil. Levelized costs are based on real figures of power production in Lebanon and take into account fuel prices, additional operation and maintenance costs, and transport costs only for Tyre and Baalbeck plants.

4.2 Possible mitigation technology options in the power sector and their mitigation benefits

4.2.1 Assessment Methodology

The mitigation technologies for the power sector were identified in consultation with experts in the field who contributed to the assessment and also provided local expertise and knowledge on what fit best to the Lebanese conditions. Accordingly, potential mitigation technologies for the power sector have been identified and categorized into small and large scale, and for short, medium, and long terms. Feasibility of these options has been examined through national reports, from the initial TNA report of 2002 (MoE/UNDP/GEF, 2002), and from similar studies conducted in other countries and reports published by international organizations. In addition, estimations based on expert judgment were used when needed data were unavailable.

Based on stakeholders requests and recommendations, the technology selection phase has been concentrated only on hard and soft technologies on the supply side and the analysis was preferred to be restricted to power generation. Concerns were raised on the risk of duplicating existing work, since options related to Demand Side Management (DSM) and energy efficiency have already been extensively explored under other projects and initiatives. Indeed, with the establishment of the Lebanese Center for Energy Conservation in 2002 by a financing by the GEF, the implementation of the Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon (CEDRO) project since 2007 and the latest National Energy Efficiency Action Plan released in 2011, the demand side management of the power sector is being adequately assessed and analyzed at the national level and appropriate measures have been already deployed on various levels to tackle this issue. The policy paper of the MoEW has indeed identified a number of objectives for the energy sector, however, it did not include the general basis for energy-policy making in terms of import dependence, domestic development potentials in the fields of renewable energies and the challenges the Lebanese society has to face in this context.

Therefore, the scope of the TNA project as set by the stakeholders, was agreed not to tackle energy efficiency and DSM in order to avoid duplication and take the opportunity of the TNA project to assess qualitatively and quantitatively new technologies on the supply side.

4.2.2 Combined Heat and Power

Combined heat and power systems (CHP) capture the excess heat, from power generation to be used, for domestic or industrial heating purposes. CHP is an efficient, clean, and reliable approach for generating power and thermal energy using one energy resource. Such systems involve providing hot water, with temperature in the range of 80-120°C, for district heating by installing new steam turbines from which a portion of the steam can be extracted after being fully expanded in the turbine. Steam can as well be extracted before being fully expanded and therefore by varying the amount of extracted steam it is possible to control the amount of electricity and heat generated. The overall efficiency is around 70%. This scheme, however, requires installing of hot water network that connects the plant to the residential or industrial areas. CHP is an established technology that can greatly increase the facility›s operational efficiency and decrease energy costs.

Baseline: In Lebanon, combined heat and power systems are non-existent. Heating services are not provided by the government, instead, heat is being provided on individual basis in the residential, commercial, industrial and service sectors mainly through the use of electricity, diesel oil, LPG and kerosene. However, in this report, it is assumed that the proposed CHP is only replacing the use of electricity for space heating and the use of LPG, diesel oil and kerosene is therefore ignored in this case. Accordingly and estimating that 10% of annual electricity supply is used for space and industrial heating (WB, 2009), the baseline annual emissions for heating purposes sum up to 988,796 tonnes of CO_2 (based on the adjusted grid emission factor of 0.75 tonnes CO_2/MWh) .

Reduction potential: CHP technologies, with 70% conversion efficiencies, are twice more efficient than existing thermal power plants, and therefore adopting this technology for all thermal power plants would reduce the amount of fuel needed to generate the power required for space heating by around 50%, and consequently would cut the annual CO_2 emissions by half, from 988,796 tonnes down to 494,398 tonnes. Emissions from other fuels such as kerosene, LPG and diesel oil are assumed to remain unchanged.

4.2.3 Combined- Cycle Gas Turbines

In a combined cycle power plant, or combined cycle gas turbine (CCGT) plant, a gas turbine generator generates electricity and the waste heat from the gas turbine is used to make steam to generate additional electricity via a steam turbine. This last step enhances the plant efficiency to levels around 45% to 55%. Deployment of the technology can be achieved either through new installation or by offsetting and modernizing the existing thermal units. This scheme involves installing, in addition to the existing gas turbine, a steam turbine to which steam extracted by the heat recovery unit is fed. The turbine is coupled to a separate electricity generator and therefore using this steam results in generating more electricity. The cost varies between USD 800 and USD 1,200/kW (MoEW, 2010) depending on the fuel type and mode of operation.

CCGT operation requires experienced and expert people from different engineering backgrounds such as Civil, Mechanical, Computer, Communication and Electrical. Lebanon today has two CCGT plants with installed capacity exceeding 400 MW each. Due to the lack of local expertise, EDL relies on specialized utilities and operation companies to manage the plants through operation and maintenance contracts. CCGT is considered in the MoEW Policy paper as an economically feasible option for generation expansion and GHG mitigation. Moreover, the availability of natural gas will also lead to its penetration into the industrial sector. Adopting this technology for the existing Beddawi and Zahrani plants, and at a later stage for the refurbished plants in Zouk and Jieh would reduce the levelized cost from around 23 USC/kWh down to around 9.3 USC/kWh.

Baseline: Currently no CCGT plant is operating on natural gas in Lebanon. In 2009, the Beddawi power plant was operated partially on Egyptian natural gas, but the supply of the gas has been discontinued. The 2 combined- cycle plants (Beddawi and Zahrani) are currently run on diesel oil. Baseline annual emissions from each of these plants are estimated at 1,986,925 tonnes of CO_2, summing up to 3,973,850 tonnes of CO_2.

Reduction potential: Switching from diesel oil to natural gas in the Beddawi and Zahrani power plants would inflict an average annual reduction of emissions from 3,973,850 tonnes of CO_2 to 2,262,744 tonnes of CO_2 or 57% emission reduction.

4.2.4 High Efficiency Diesel Generators

Reciprocating internal combustion engines or high efficiency diesel generators are a widespread and well-known high- efficiency technology generally available for power generation applications in sizes ranging from a few kilowatts to over 5 MW (MoEW, 2010). There are two types: spark ignition and compression ignition. Spark ignition (SI) engines for power generation use natural gas, other fuels such as gasoline and propane can be used as well. Compression ignition engines (diesel engines) that operate on diesel fuel or heavy oil, are the more widespread of the 2 types for both small and large power generation applications.

High Efficiency Diesel Generators offer attractive low first cost, fast start-up, proven reliability when properly maintained, excellent load-following characteristics, and significant heat recovery potential. The efficiencies of such engines range from 35-40%. The emissions rate of these engines has improved significantly in the last decade through better design and control of the combustion process and through the use of exhaust catalysts. High Efficiency Diesel Generators start quickly, follow load well, have good part load efficiencies, and generally have high reliabilities. They also have higher electrical efficiencies than gas turbines of comparable size, and thus lower fuel-related operating costs. The cost varies between USD 1,000 and USD 1,600 per each installed kW (MoEW, 2010) depending on the project mode of operation, speed type and the size of units.

Baseline: The difference between the peak demand of 15,000 GWh and EDL's energy supply of 11,522 GWh has been compensated through self-generation and electricity imports from Syria and Egypt during some years. Therefore, small and medium size diesel generators are widely spread in Lebanon in the form of standby generators used in industries, office buildings, services, and residential sectors, estimated at a total installed capacity of 500MW in 2010. Data on the performance characteristics of existing private standby generators are almost non-existing. It is certain, however, that due to improper maintenance and generators location, the general conversion efficiencies are in the range of 25-30% (EPA, 2008) and their annual emissions are estimated to 2,705,884 tonnes CO_2. Moreover, the random allocation of these units in residential areas is causing excessive local air and noise pollution.

Reduction potential: High efficiency diesel generators with generation capacities up to 50MW and with typical conversion efficiencies reaching 35-40% would be a feasible mitigation option to replace all standby generators and provide up to 500 MW to the grid (EPA, 2008). This would consequently reduce emissions by at least 10% that is by around 270,588 tonnes/year. Moreover, if properly allocated, reciprocating engines would solve problem of air quality degradation and noise pollution.

4.2.5 Wind Power

Windmills are installed to capture mechanical power from the wind to generate electricity on small and medium scale basis. Wind power drives the installed AC (or DC) generators to generate power, which is either stored into batteries, or consumed by the owner, or fed to the network. Small wind generators are used for applications such as battery charging, or auxiliary power for a house; whereas large grid-connected arrays of generators are becoming an increasingly large source of commercial electric power on global scale.

Offshore wind power can make use of higher wind speeds that are available offshore compared to on land. Small onshore wind facilities are used to provide electricity to remote locations. The strength of wind varies, and to assess the frequency of wind speeds at a particular location, a probability distribution function is often fit to the observed data. Different locations will have different wind speed distributions. A wind atlas for the Lebanese territories has been developed in 2010, and could be useful for feasibility analysis of wind power penetration as a clean and renewable resource. The capital cost is estimated around USD 1,900/kW (MoEW, 2010).

Main features of wind power include fuel diversification, producing no waste and no GHG emissions, power supply for remote areas, and establishment of new jobs.

According to the Global Wind Energy Council, there are now thousands of wind turbines operating, worldwide, with a total capacity of around 194 GW in 2010. It has been also reported that the World's wind generation capacity has more than quadrupled between 2000 and 2006, doubling about every three years. In Lebanon, the wind atlas estimated the potential installed onshore wind power capacity to 6.1 GW, adjusted through sensitivity analysis to 1.5 GW (CEDRO, 2011).

Baseline: Lebanon has witnessed a very limited spread of windmill generators used at micro scale levels, limited currently to the residential sector. The wind farm concept is yet to be deployed in the country. Currently, no wind mill farms are operational in Lebanon and electricity is only being provided through conventional thermal technologies and some limited hydropower. In 2012, a tender for the installation of 60 MW of wind energy was launched by MoEW.

Reduction potential: According to the MoEW Policy Paper, wind mills of around 60 to 100 MW are planned to be installed by 2013 in Lebanon via the involvement of the private sector. If achieved, the 100MW wind power would reduce GHG emissions from 144,540 tonnes CO_2/year from the grid to 1,928 tonnes/year, assuming a capacity factor of 0.22 for wind (MoEW, 2012) and a lifecycle emission factor of 0.01 tonnes/MWh (Savacool, 2008).

4.2.6 Photovoltaic Cells

Photovoltaic (PV) cells are technologies used for direct transfer of solar power to electricity. Photovoltaics were used almost exclusively in space for powering satellites› electrical systems since mid 20th century. It is a process of direct conversion of solar light into electricity at the atomic level. Semiconductor materials, such as silicon, used in PV cells exhibit a property known as the photoelectric effect that causes them to absorb photonnes of light and release electrons. Basically, when light strikes the cell, a certain portion of it is absorbed within the semiconductor material. This means that the energy of the absorbed light is transferred to the semiconductor. The energy knocks electrons loose, and electric current is generated. This power can be stored into batteries, or used after inversion into AC power.

Due to the growing global demand for clean and renewable energy sources, the manufacturing of solar cells and PV has advanced considerably in recent years. Solar PV cells have been growing rapidly to a total global capacity of 40 GW at the end of 2010, distributed in more than 100 countries. In Lebanon, the CEDRO project has started installing PV cells in around 25 public schools and community centers in different parts of the country.

Main features of PV cells include being renewable and combustion free, support fuel diversification strategy, and like other renewable, could lead to new jobs and expertise. The capital cost is around USD 4,000/kW (MoEW, 2010). The region is rich in solar radiation, and therefore with proper policies and incentives, could witness widespread outside major cities. Feasibility studies associated with the LCEC and NEEAP projects have also been conducted for the deployment of PV cells for street lighting.

Baseline: a limited number of PV standalone systems have been installed in Lebanon as part of private initiatives, or internationally funded projects (CEDRO). This technology is still in its early phases in Lebanon and the NEEAP has identified a number of pilot projects to initiate the deployment of PV systems.

Reduction potential: Penetration of PV cells in Lebanon is expected to be limited to up to 1MW, with a capacity factor of around 0.2 (MoEW, 2012). Considering that the lifecycle emission rate of PV cells is 0.032 (Savacool, 2008), while that of the grid is 0.75, then the 1 MW PV installed would lead to a reduction of to 1,258 tonnes/year or 95% reduction.

4.2.7 Hydropower

Hydropower is the oldest type of renewable energy used by mankind for centuries. Hydro electric power is generated through the use of the gravitational force of falling or flowing water to drive a turbine connected to an AC generator. The generated power is then connected via a transformer to the national grid. It is the most widely used form of renewable energy. It is a combustion- free energy resource which is well established on global scale, and in Lebanon. Worldwide, the installed capacity in 2010 was in the excess of 1,000 GW. Approximately 16% of the world›s electricity is renewable, with hydroelectricity account for 21% of renewable sources and 3.4% of total energy sources (REN21, 2011). The capital cost is around USD 5,800/kW, but the operational cost is much smaller than those of fuel- driven power plants. Like other renewable, reliance on power leads to fuel diversification and GHG reduction. Hydroelectric power plants have long economic lives, with some plants still in service after 50–100 years.

Baseline: In Lebanon, some smaller hydro units along Kadisha river date back to 1917 (Chaaban, 2003). Hydropower has been established in Lebanon for a long time, and therefore, unlike other renewable resources, local expertise is already available. The MoEW policy paper has set a target to generate additional 40MW from hydro resources at an estimated cost of USD 200 million (MoEW, 2010). Moreover, the rehabilitation of the existing hydro plant would provide an additional capacity of around 20 to 30MW.

Reduction potential: Providing additional 70MW of hydropower through new plants and through the rehabilitation of existing ones would reduce emissions by 181,507 tonnes of CO_2 per year assuming a capacity factor of 0.4 (MoEW, 2012) and a lifecycle emission factor of 0.01 tonnes CO_2/MWh for hydropower compared to 0.75 tonnes CO_2/MWh from the grid (Savacool, 2008).

4.2.8 Biomass, or Waste- to- Energy

Biomass utilization, specifically urban solid waste and farm waste, could offer an economically feasible option for GHG mitigation (MECTAT 2011, Senayake, 2009). It will also solve the prominent solid waste management issue of Lebanon. There are two proven technologies that give good results, i.e. in terms of waste management and generation of electricity.

Anaerobic digestion of organic waste, which produces biogas, mainly methane gas, is used for power generation. This is a proven technology and it is widely implemented in the EU. Cost of implementing the anaerobic technology is estimated by around USD 1,900/kW.

Dendro Liquid Energy (DLE) technology, a recently developed one, where mixed wastes, including plastics and large size wooden logs, are treated in a reactor to produce carbon monoxide and hydrogen gases, that are clean fuels for generating electric power. DLE, with 80% conversion efficiency, is four times more efficient in power generation, compared with anaerobic digestion. No emissions, no effluents and no nuisance problems take place at the plant sites. At the end of the process 4% inert residues (sand, gravel, etc.) remain that are used for land-filling. It is a close to “zero-waste” technology. This technology is a proven tool in EU that solves the waste management issue of cities and farms and at the same time contributes to the renewable energy basket of countries.

Baseline: No Biomass or waste to energy plant is implemented in Lebanon, although using waste for fuel replacement has been considered by a number of energy- intensive industries as a mean to reduce the fuel bill.

Reduction potential: According to the Policy paper and latest NEEAP, it is estimated that 15-25 MW can be produced every year from waste (MoEW, 2012), hence introducing 25 MW from waste to energy would lead to reducing CO_2 emissions by around 102,492 tonnes per year.

4.2.9 Technology prioritization

Selection Criteria

The assessment of various technologies for the power sector is based on their contribution to sustainable development of the country. The main objectives for technologies selection are maximizing the resilience of the sector to climate change impacts, minimize GHG emissions from the sector, maximize development priority benefits in terms of environmental, social, and economic, and to minimize any negative consequences of the technology (UNDP, 2010).

Accordingly, and after presenting and discussing the selection criteria with stakeholders during individual meetings as well as in the first expert consultation workshop, the defined criteria and the attributed weights have been identified as following:

1. GHG reduction potential. Being the main objective of the TNA and TAP project, this criterion has been given the highest weight of 30%. Proposed mitigation technologies would result in GHG reduction, though of different levels, as identified with each proposed technology.

2. Fuel cost. Since fuel cost constitutes a substantial part of the operational cost of the technologies, and due to the high fuel prices over the last decade at global scale, rising from $16/barrel up to current levels of over $110/barrel, a weight of 30% is also assigned for this criterion.

3. Capital cost. The cost of selected technologies should be affordable, capable of attracting investments, and to be in demand. Several options will require substantial investment for the purchase of equipment, establishment of infrastructure, and training. This criterion has been assigned a weighting of 15%.

4. Additional Operation and Maintenance costs. These periodic costs, over the technology lifetime, are associated with running and sustaining emission-reduction measures after initial implementation. They would cover periodic maintenance and repairs, spare parts, plants management fees and others. Fuel costs are not considered as part of this criterion. The weight allocated for this criterion has been set at 10%.

5. Option sustainability. Some options can be financially self-sustaining since the GHG emissions reduction can be associated with a drop in operational costs and more appropriate pricing of natural resources. Win-win opportunities are anticipated from some of the recommended abatement options. This criterion has been also assigned a 10% weight.

6. Societal and economic benefits. Several technologies would contribute to the country's environmental, social, and economic development by inducing growth in rural areas, creating new jobs, and strengthening citizens' participation. Since some of these benefits are partially accounted in the energy saving and options sustainability criteria, hence, a 5% weight has been assigned.

Prioritization Process

The technology prioritization process was elaborated following Multi-Criteria Analysis (MCA) approach. Technologies were identified and analyzed based on literature review, field experience and results of individual meetings conducted with different experts working in the field and knowledgeable of specific technologies. Accordingly, factsheets were elaborated and disseminated to a wider spectrum of researchers and technicians from national and international institutions for review and commenting. These factsheets contained detailed information on technology characteristics, institutional and organization requirements, adequacy of use, capital and operational cost, advantages as well as barriers and challenges.

An expert consultation meeting was held to present an overview of the proposed mitigation technologies for the energy sector, and to validate the proposed weights. The ranking was conducted individually and all scoring sheets were collected and an average scoring was deduced.

Results of the technology prioritization

Based on the above-defined criteria, the ranking results were obtained from running the Multi Criteria Analysis (MCA) using the DEFINITE package. During the exercise, the CHP technology was ruled out from the start by the stakeholders that judged it as unsuitable for the Lebanese conditions due to its high infrastructure requirements. Accordingly, the MCA exercise was used to score and rank the remaining technologies. Table 10 represents some figures and values related to the technologies that were used in the prioritization exercise. It should be noted that although societal benefits and option sustainability are generally inter-related when discussing advantages of renewable technologies, the emphasis here under societal benefits is on the environmental benefits and remote areas developments through tourism and job creation whereas option sustainability reflects mainly better prices stability and increased security. Table 11 presents the final average scores and ranking of the technologies. The results show clearly that the most feasible technology is CCGT followed by hydro, wind, and PV cells.

Table 10 - Values of selected criteria to technologies

Technologies	GHG reduction potential Tonnes CO_2	Fuel cost* USD/MWh	Capital cost 10^6/MW	Additional O&M costs USD/MW	Option sustainability** Average score	Societal and economic benefits** Average Score
CCGT	1,711,106	70	0.4	556,764	1.9	2.0
DG	270,588	209	1.05	358,328	2.0	1.8
Wind	142,612	0	1.9	19,000	2.9	2.1
PV	1,258	0	4	40,000	2.9	3.9
Hydropower	181,507	0	3.5	35,000	2.0	3.8
Biomass	102,492	50	5	284,700	3.2	3.4

*average cost of fuel feeding the grid
** as scored by stakeholders, 5 for being the best and 1 for being the worst

Table 11 - Weighed average scores and ranking of technologies

Selection criteria	Weight	CCGT	DG	Wind	PV	Hydro	Biomass
		Weighed relative score					
GHG reduction potential	0.30	0.300	0.047	0.002	0.000	0.032	0.018
Fuel cost	0.30	-0.010	-0.030	0.000	0.000	0.000	-0.007
Capital Cost	0.15	0.000	-0.021	-0.049	-0.117	-0.101	-0.150
Additional O&M cost	0.10	-0.100	-0.063	0.000	-0.004	-0.003	-0.049
Option sustainability	0.10	0.000	0.008	0.077	0.077	0.008	0.100
Societal and economic benefits	0.05	0.005	0.000	0.007	0.052	0.050	0.040
Total weighted ‹relative› score		0.195	-0.059	0.037	0.008	-0.015	-0.049
Rank		1st	6th	2nd	3rd	4th	5th

When using the Marginal Abatement Cost (MAC) (Fig. 4) to compare and evaluate the selected technologies, the ranking of the top 4 technologies slightly changes, prioritizing hydropower over PV technology. This can be explained by the fact that MAC takes only into account the greenhouse gas reduction potential with its respective costs, while the MCA includes another social and institutional dimension to the assessment, which favors in this case the PV technology over hydropower. Nevertheless, the two methodologies do converge to one ranking of the 4 priority technologies that are to be assessed in this project.

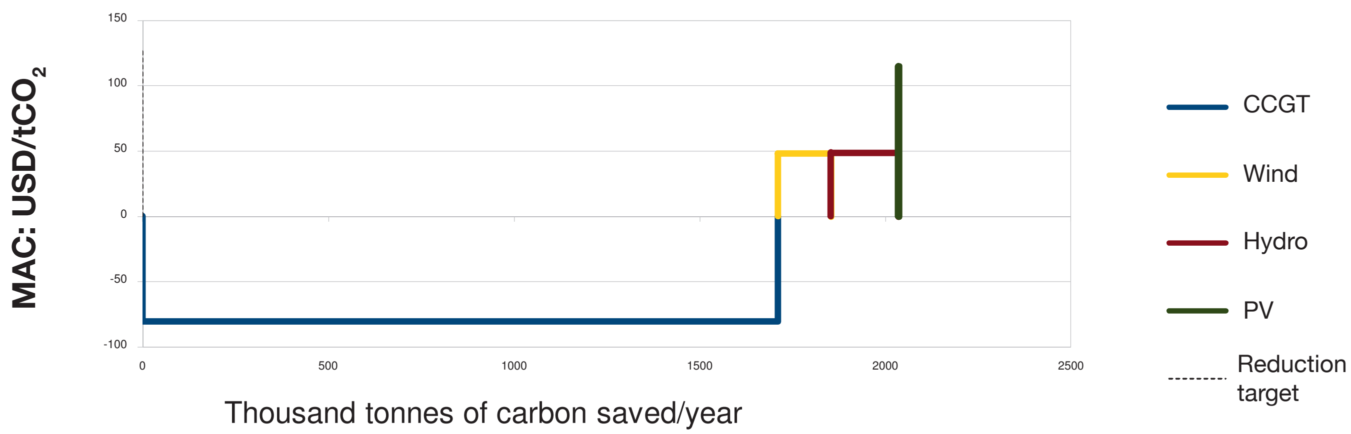

Fig. 4 - Marginal Abatement Cost of the 4 prioritized technologies

4.3 Barrier Analysis and Enabling Framework

After having identified and prioritized through country-driven participatory processes, the technologies that can contribute to mitigation goals of Lebanon, while meeting the national sustainable development goals and priorities, this section aims at identifying barriers hindering the acquisition, deployment, and diffusion of the prioritized technologies and specifying activities and enabling frameworks to facilitate the transfer, adoption, and diffusion of these selected technologies in Lebanon.

4.3.1 Preliminary targets for technology transfer and diffusion

The main target is to find the technologies that would reduce GHG emissions in addition to helping the country meet its commitment of 12% renewable energy mix by 2020.

The government policy commits to launching, supporting and reinforcing all public, private and individual initiatives to adopt the utilization of renewable energies to reach 12% of electric and thermal supply by 2020. To make this reality and encourage renewable resources, the MoEW is seeking a substantial amount of financing and benefit from CDM and other market mechanism with the collaboration of the Ministry of Environment and other carbon financing schemes for the implementation of renewable energy project.

4.3.2 Methodology

To identify barriers to the technology transfer in the power sector, a general classification has been established, based on a desk review of relevant research, similar projects and initiatives in developing countries and neighboring states in addition to a thorough analysis of successes and failures of previous national projects that tackled these specific technologies. Accordingly, a list of all types of market barriers, both technical and non-technical was drafted for stakeholders review and validation. This process resulted in the drawing of problem trees specific to each technology and consequently, the consent on a series of measures that would facilitate the transfer of the assessed technologies. Stakeholders included representatives from the MoEW, EDL, ESCOs, industries, academic institutions, and NGOs as well as international organization, a diversity that ensured a complete integrated approach on assessing the power sector problem in Lebanon.

4.3.3 Generic Barriers for the Power sector

Many of the barriers hindering the deployment of alternative and renewable technologies could be considered "market distortions" that unfairly discriminate against these technologies, while others have the effect of increasing their costs relative to the existing technologies (Beck and Martinot, 2004). As a result, renewable or alternative technologies are put at an economic, regulatory, or institutional disadvantage relative to conventional forms of energy used for power generation.

Barriers for the power sector in general in Lebanon include subsidies for conventional forms of energy, high initial capital costs coupled with lack of fuel-price risk assessment, imperfect capital markets, shortage of expertise or information, poor market acceptance, technology prejudice, financing risks and uncertainties, high transactions costs, and a variety of regulatory and institutional factors. Table 12 gives a summary of the main barriers, their key characteristics, and typical measures adopted in many countries to overcome these barriers.

Table 12 - General barriers and their alleviation measures

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Institutional	Outdated legal framework	• Regulation based on industry tradition laid down in standards and codes not in pace with developments. • EDL in control of electricity generation, transmission and distribution. • Insufficient legal framework in Law 462, that inhibits independent power producers to invest in power production and sell power to the utility or to third parties.	• Amend Law 462. • Induce regulatory reform. • Propose performance based regulation. • Establish of a Feed-in-Tariff scheme. • Set the platform for fruitful collaboration amongst governmental entities.	X	X	X	X
	Weak institutional structure	• Aging staff and administration at EDL. • Ban on employment at EDL. • Incompetent staff. • Financial deficit.	• Amended law 462 for the corporatization of EDL. • Gradual introduction of the private sector into EDL through service providers law and new independent power producer (IPP) Attract new expertise through a regular employment process. • Update existing governance and management bylaws. • Introduce institutional reforms to establish a clear energy strategy for the country, and for proper implementation of feasible and marketable alternatives.	X	X	X	X
	Liability insurance requirements	• Small IPP feeding into the utility grid under “net metering” provisions may face excessive requirements for liability insurance.	• Proper equipment standards can prevent islanding. • Prohibit utilities from requiring additional insurance beyond normal homeowner liability coverage.	`	X	X	X

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Institutional	Restriction on siting and construction	• Renewable energies may face building restrictions based upon height, noise, or safety. Competition for land use with agricultural, recreational, scenic, or development interests accompanied by substantial increases in property can also occur. • Urban planning departments or building inspectors not familiar with the technology and siting requirements.	• Familiarizing urban planning departments or building inspectors with renewable energy technologies. • Establishing procedures for dealing with siting and permitting. • Modern architecture to integrate renewable in the design.		X	X	X
	Transmission access for IPP	• Utilities may not allow favorable transmission access to renewable energy producers, or may charge high prices for transmission access. • New transmission access to remote renewable energy sites may be blocked by transmission-access rulings or right-of-way disputes. • Safety and power-quality risk from non-utility generation is a legitimate concern of utilities. In turn, the transaction costs of hiring legal and technical experts to understand and comply with interconnection requirements may be significant.	• Granting transmission access (FIT). • Sorting right-of-way disputes. • Policies for uniform interconnection standards. • Subsidies offered for private industries to create in a competitive market. The subsidy can be delivered either by offering higher prices than those available commercially or by creating a cost increment by issuing certificates confirming the origin and then obliging the power utility or service providers to buy at these tariffs.		X	X	X

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Institutional	Insufficient political awareness	• Large number of decision makers and local authorities are not aware that renewable and alternative technologies could play a supportive role in the social and economic development of the country. • Conflicting information on cost and efficiency make the private sector hesitant to participate in the sector operation.	• Promotion campaigns • Capacity building and training. • New development objectives. • Pilot projects implementation projects.	X	X	X	X
Financial	Fuel subsidies	• Costs associated with alternative technologies are at a disadvantage since fuel costs are generally subsidized and life-cycle costs are not adopted.	• Regulation to internalize 'externalities' or remove subsidies. • Special offsetting taxes or levies. • Removal of subsidies. • externalities Integration into fuel market cost.	X	X	X	X
	High capital cost	• Initial cost may be high threshold. • Imperfections in market access to funds.	• Third party financing options. • Private sector involvement. • Special funding. • Adjust financial structure.	X	X	X	X
	Buyer's risk	• Perception of risk may differ from actual risk (e.g. 'pay-back gap'). • Difficulty in forecasting over an appropriate time period due to rapid and unexpected changes in global fuel prices. • Investors may have knowledge gaps and high uncertainties is estimating the payback periods for their investments, especially in renewable technologies.	• Long term fuel import agreements with regional countries. • Routines to make life-cycle cost calculations easy.	X	X	X	X

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Financial	Difficult access to credit	• Consumers or project developers may lack access to credit to purchase or invest in renewable energy because of lack of collateral, poor creditworthiness, or distorted capital markets. • In rural areas, “microcredit” lending for household-scale renewable energy systems do not exist. According to some banks, available loan terms are mostly at retail level, and may be too short relative to the equipment or investment lifetime.	• Loan with sufficient terms to match the equipment or investment lifetime. • Honoring long-term power purchase agreements to buy the power.		X	X	X
Economic	Unfavorable power pricing rules	• Renewable energy sources feeding into an electric power grid at distribution level are underpriced, and regarded as an intermittent discontinuous source. • Two factors are considered: first, renewable energy generated on distribution networks closer to final consumers rather than at centralized generation facilities may not require transmission and distribution. Utilities, however, tend to pay rates that do not account for this feature. • Second, renewable power is often an intermittent discontinuous source whose output level depends on factors that cannot be controlled. Therefore utilities may tend to regard r power as a non- reliable resource and hence reduce their purchase prices.	• Pricing should account for transmission losses and maintenance costs. • Tariff restructuring including fossil fuel subsidies removal. Price reform will lead to more rational use of electricity. • Financial incentives should be provided to encourage investments in alternative and renewable energies. • Economic incentives can be used to encourage investment by reducing the investment cost directly. • Fiscal incentives to reduce the cost indirectly through an appropriate taxation system. Tax deductions are most attractive to those who pay most tax. • The state should normally obtain benefits from either set of incentives because the subsidies paid to EDL will be reduced with the drop in reliance on fossil fuels for power generation.		X	X	X

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Economic	Transactions costs	• Costs of administering a decision to finance, purchase and use renewable and alternative technologies due to performance uncertainties.	• Reliable independent information sources. • Convenient & transparent calculation methods for decision making.	X	X	X	X
	Environmental externalities	• Environmental impacts of fossil fuels result in real costs to society, in terms of human health. Dollar costs of environmental externalities are difficult to evaluate and depend on assumptions that can be subject to wide interpretation and discretion. Investors rarely include such environmental costs in the bottom line used to make decisions.	• Quantification of the social cost of carbon.	X	X	X	X
Technological	Commerciality and competitiveness of technologies	• This is Influenced by the monopoly powers that reduce incentives to innovate and erect barriers that may discourage investments. On the other hand, the immaturity of some technologies coupled by ignorance of stakeholders of its potential benefits may restrain the marketability of new technologies.	• Sector restructuring. • Incentives. • Testing facilities. • R&D. • Skilled labor for regular maintenance. • Availability of local supportive manufacturing facilities.	X	X	X	X

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Technological	Technological development	• Absence of technological infrastructure to support the expansion of the renewable energy market.	• Small industries should be established and supported to manufacture spare parts and components for renewable energies in order to compete with export. This measure would lead to substantial reduction in the operation and maintenance costs. It is also necessary to provide trainings to the labor forces mainly for O&M of the plants, establish testing facilities, and set codes for installation in addition to standardization and labeling.		X	X	X
	Shortage of Information and standardization	• Availability and nature of a product must be understood at the time of investment.	• Standardization. • Labeling. • Promotion campaigns. • Codes for installation.	X	X	X	X
	Shortage of relevant skilled labor force and expertise	• New technologies are still developing and there is a need to keep in pace with evolving systems and equipments. • They also may lack up-to- date information about the technology characteristics, economic and financial costs and benefits, wind and geographical resources, installation and operating experience, maintenance requirements, and sources of finance.	• Training for technical staff. • Special trouble-shooting training for operation and maintenance.	X	X	X	X

	Barrier	Key characteristics	Typical measures	Relevance			
				CCGT	Wind	PV	Hydro
Technological	Scarcity of cleaner energy resources	• Some alternative resources may not be easy to obtain such as natural gas for CCGT, or wind and hydro power.	• Long term agreements for NG import. • Infrastructure for storage and distribution. • Accurate data base on availability of renewable resources.	X	X	X	X
Political	Political Instability	• The implementation of mitigation plans are impacted by political alliances and frequent changes in government. Strategies and decisions to restructure the power sector are lost in the political turmoil and the ever changing governance and alliances of political parties.	• Long term strategy to be approved and implemented. • Strengthen institutional procedures.	X	X	X	X
	Corruption	• Almost 25% of the generated electricity is not paid for, which leads to irrational, and excessive electricity consumption. It also reduces the income of the power utility, making it more difficult to adopt and invest in new renewable and alternative technologies.	• Proper law enforcement. • Automation of the billing system. • Remote sensing-based billing. • Stopping political interference.	X	X	X	X

4.4 Analysis of prioritized technology: Combined- Cycle Gas Turbines

In a combined- cycle gas turbine (CCGT) plant, a gas turbine generator generates electricity and the waste heat from the gas turbine is used to make steam to generate additional electricity via a steam turbine which enhances the plant efficiency to levels around 45% to 55%. CCGT is considered in the MoEW Policy paper as an economically feasible option by using natural gas in the existing CCGT units in Beddawi and Zahrani, and for building new plants that can run on natural gas. The supply of natural gas from the regional countries, namely Syria and Egypt has been interrupted due to political events in these countries. Moreover, the import, storage and distribution of natural gas amongst the local market required an infrastructure with a very high capital cost.

4.4.1 Identification of barriers

Some of the generic barriers identified in Table 12 are more significant with regards to the deployment and diffusion of the CCGT technology, namely:

High capital cost: The initial capital cost needed for the infrastructure of a modern gas storage and distribution network is high and beyond the financial capability of the Government. Since 2 CCGT plants already exist in Lebanon, the initial capital cost is mainly related to the cost of the pipeline infrastructure, which is estimated at USD 1.5 million/km for the 180 km needed to be covered. The contribution of the private sector is highly anticipated in order to share the cost with the government and expedite the diffusion of this technology.

Insecure supply of natural gas: Lebanon relies totally on the import of different types of fuels including natural gas. Although the Government has made several agreements with regional countries such as Syria and Egypt, the supply has been discontinued for several reasons. Moreover, Lebanon is yet to be connected to the regional network for natural gas that is established to distribute gas amongst several regional countries. Gas and oil exploitation from the Mediterranean coastal territories is not expected to start in the near future. It would take another decade before exploitation can actually begin.

Lack of local expertise in CCGT technologies: Two existing CCGT power plants, Beddawi and Zahrani, are being contracted for foreign firms for the operation and management due to the lack of local expertise needed to operate CCGT units.

Absence of supporting infrastructure: CCGT is a new technology for Lebanon, and its deployment would require supporting infrastructure such as connecting network, testing laboratories, skilled labor for regular maintenance, and availability of local manufacturing facilities to support minor modifications and supply spare parts.

Unfavorable electricity tariff: The economic hardship over the past decades has forced a freeze on the electricity tariff in Lebanon. This low tariff has imposed on EDL, and on the Lebanese government, an annual deficit of around $1.5 billion. Moreover, this low tariff constitutes a major barrier facing the participation of the private sector in the operation and management of the power industry due to the extended payback periods.

The consequences of the barriers facing CCGT technology include:

- High generation cost due to the reliance on diesel oil as a generation fuel since Diesel Oil has an average cost of 0.23US¢/kWh while the shift to natural gas will drop the cost to 0.09US¢/kWh.
- The use of Diesel Oil in CCGT units leads to more rapid deterioration of the units. Diesel oil combustion required more frequent and more costly maintenance.
- Excessive GHG emissions associated with Diesel Oil combustion since the latter has a carbon dioxide emission rate of 778g/kWh compared to 443g/kWh for natural gas.

The root cause analysis is conducted using the problem tree method that determines the major barriers facing the deployment of CCGT as a GHG mitigation option. The highlighted points by no means present all the constraints, their causes, and impacts. The focus is on the main issues. Fig. 3 reflects the results of root cause analysis for the barriers facing the deployment of CCGT technology as a GHG mitigation option.

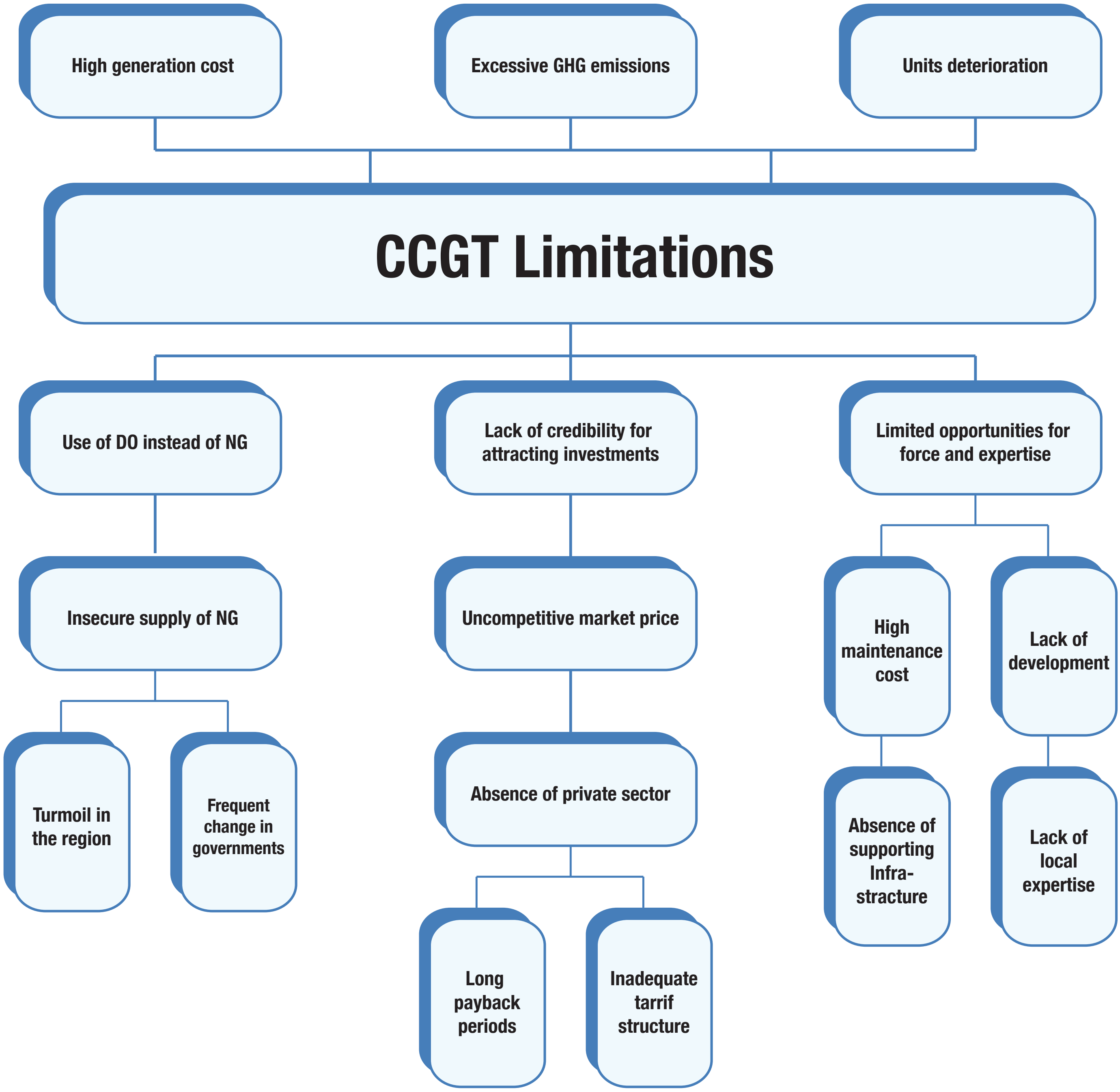

Fig. 5 Root cause analysis for CCGT.

4.4.2 Identification of measures

Among the generic measures proposed in Table 12, financial reforms are the most significant to overcome the barriers linked to the deployment of the CCGT technology. Pricing reform would produce much substantial motivation for the private sector and industrial end-users and household consumers to invest and to ensure the system operated as efficiently as possible. The sector must be rigid and financially viable to attract investors since private investment would not be attracted to a utility that has a yearly deficit of more than 1.5 billion USD.

Removal of Subsidies on Fuel: The current subsidized tariff system does not motivate private sector to participate in the sector. Tariff restructuring or removing the subsidies strategy will include the amendments of the national energy pricing system through a number of measures which reduces the economic burden of the power sector and allows eventual private power producers to sell their electricity at higher tariff. EDL must calculate the revenue requirement tariff to break even and thus calculate the yardstick tariff. Consequently, a modern tariff structure is to be proposed and implemented, preferably including the following criteria:

- Categorize customers based on voltage level and the type of consumer (residential, commercial, etc.)
- Introduce the time of use of energy
- Add Fuel Cost Adjustment formula (FCA)

It is worth noting that the tariff structure also heavily depends on the metering and billing philosophy.

According to a new structure, independent power producers will submit a tender through and international bidding round (transparent) where the winner will be the one with the lowest life time cycle cost – levelized cost (including or excluding fuel, this depends on the type of the contract).

Provision of financial incentives: Financial incentives should be provided to encourage investments in the infrastructure needed for the import, storage, and distribution of natural gas in the country. These projects are characterized by high capital cost and therefore both economic and fiscal incentives are required to support the deployment of CCGT.

Incentives or financial risk reduction may come in several forms that would encourage the private sector to bid in Lebanon. Risks that need to be carefully considered and mitigated to attract the private sector:

1. The political risk: will increase price by increasing the rate of return to recap the investment as soon as possible.
2. The credit risk: The dire financial situation of the power sector makes it non-creditworthy for potential investors and lenders.
3. Fuel supply: Fuel procurement is currently undertaken by EDL and paid for by the Government to a large extent, it is the reason of 90% value of the subsidy. In this context, a private investor in new generation capacity may prefer to have an Energy Conversion Agreements (ECAs) instead of a PPA. The substantive difference between these is that a PPA has a fuel component while an ECA does not. Under an ECA, the investor is responsible for converting provided fuel into electricity and any potential fuel interruption is outside of the responsibility of the investor. It is important to note however that it is not necessary to have a fuel component (as in a PPA) to hold investors responsible for the plant heat rate (i.e., the efficiency of fuel usage). In international experience, PPAs are much more common than ECAs, but ECA are used where fuel supply is under a monopoly and/or the risk of fuel supply is considered to be better managed by the public entities. In any event, all power plants that are constructed in Lebanon should be dual-fired otherwise the non-availability of gas would threaten the sustainability even of an ECA.
4. The regulatory risk: it is important that the Government finalize the arrangements and establishes the planned Energy Regulatory Authority as soon as possible. The existence of a regulatory agency would also help strengthen the transparency and accountability of power sector regulation and provide sector leadership in events of changes in government and in Energy Ministers in particular.
5. Foreign-exchange risk: The mismatch therefore between the revenue currency and the currency of financing of sector investment by the private sector in a context of weak macroeconomic prospects as perceived by lenders is a major issue for raising private financing for the power sector.

Institutional reforms: This includes amending Law 462, and setting the platform for fruitful collaboration amongst the governmental entities. Electricity Law 462 calls for the unbundling of Lebanon's power sector and the creation of a regulatory authority. Several amendments to the law 462 are being currently discussed to allow for future plan expansions, make provisions for the feed- in tariff for co-generation, and call for the introduction of a transition period during which the corporatization of EDL will take place. It shall also call for the gradual introduction of the private sector into EDL through service providers law and new independent power producer (IPP) to build and operate new CCGT units.

Awareness initiatives: International organizations such as UNDP, have already implemented projects with a main objective of conducting awareness campaigns and capacity building activities. The private sector should be targeted to promote the benefits and profits that could be obtained from the participation in establishing and operating new CCGT power plants. The private sector could also participate in the infrastructure for the import and storage of natural gas.

Technological development: In order to engender substantial reduction in the operation and maintenance costs of the CCGT technology and hence encourage its market development, small industries should be supported to manufacture spare parts and components for the CCGT. Some demonstration projects have already been initiated and supported in order to shape domestic technology expertise, link suppliers to the industry, and to create examples of best practice.

4.4.3 Action Plan for the deployment of Combined-Cycle Gas Turbines

Target for Technology Transfer and Diffusion

CCGT is considered by GoL as an economically feasible option for generation expansion and GHG mitigation, especially with the high potential of extracting natural gas in marketable quantities from the Lebanese territories in the Mediterranean. The target is to operate the Zahrani and Beddawi plants using CCGT instead of the current use of Diesel by 2015.

The measures identified in this process could be distributed as shown in Table 13.

Table 13 - Technology Action Plan for CCGT

	Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost USD	Potential Donors
General Measures	Gradual increase in tariff through fuel subsidies removal until it reaches 50% in 2015	1	- To avoid distorting effects of energy pricing. - To remove financial burden from EDL. - To enhance the marketability of CCGT.	The Department of Investment at MoEW	EDL Private Power producers	0-3 years	- MoEW decisions and governmental decrees. - Periodical EDL reports.	2,000,000 for preparation of economical study to determine appropriate tariff.	World Bank, UNDP, USTDA, EU.
	Low interest loans offers by the banking sector	2	- To encourage investments in CCGT infrastructure.	Banking sector	Private power producers	0-5 years	- Reports by stakeholders that cover financial Information, comparison of actual financial outputs with forecasts, and project financial statements.	0	NEEREA, Commercial banks. New Market Mechanisms Arab funds.
	Tax exemptions on imported technologies	2		GoL				0 Assuming that the amount of the tax reduced is added to the tax of fuel based technologies.	
Specific Measures	Provision of Natural gas	1	- To run new and re-furbished power plants on NG. - Fuel diversification.	GoL	EDL Private power producers Industries	0-2 years	- Imports statistics. - Energy bill. - Plants running on NG.	500,000,000 cost breakdown as follows: 1. Gas Pipeline connection: 200,000,000. 2. FSRU as an LNG import terminal: 250,000,000. 3. Administrative, consultancy, supervision and logistics: 50,000,000.	International donors, Private sector.

4.5 Analysis of Technology: Wind Power

The wind farm concept is yet to be deployed in the country. According to the wind atlas for Lebanon recently published by CEDRO, the potential for wind power generation is estimated at around 6.1 GW including offshore facilities, with the northern regions of Akkar being the most appropriate in terms of wind availability.

Lebanon used to have a strong wind measurement system, but it was mostly destroyed and the records lost during the civil war. As of November 2007, there were seven complete synoptic stations for meteorological measurement, all reporting wind speeds and directions, but the equipment lack proper calibration and their locations are affected by various construction that affect the accuracy of the readings (CEDRO, 2011).

4.5.1 Identification of Barriers

Some of the generic barriers identified in Table 12 are more significant with regards to the deployment and diffusion of the wind technology, namely:

Initial capital cost: The initial capital cost of wind power is generally higher than conventional energy sources, resulting in cost-driven decisions and policies that may renounce the technology as a mitigation strategy. A true comparison must be made on the basis of total lifecycle costs that account for initial capital costs, future fuel costs, future operation and maintenance costs, decommissioning costs, and equipment lifetime. Large subsidies for fossil fuels can significantly lower final energy prices, putting renewable energy at a competitive disadvantage if it does not enjoy equally large subsidies. The capital cost for the installation of wind turbines in Lebanon is estimated at USD 1.9 Million/MW.

Absence of feed-in tariffs: Due to the high capital cost of renewable energy technologies, the private sector is not encouraged to be involved in the deployment of such technologies. With most of the country connected to the national grid, PV is not economical compared to the grid produced electric energy at the present low tariff. PV energy is only competitive when compared to private generation that uses diesel oil. The electricity tariff is still low and is actually below the average production cost of electricity. A feed-in tariff has not yet been in place that can stimulate the market and encourage investments in RE.

Restrictions on siting and construction: Wind turbines and large scale farms may face building restrictions based upon height, aesthetics, noise, or safety, particularly in urban and semi-urbanized areas. Wind turbines have faced specific environmental concerns related to siting along migratory bird paths and coastal areas.

Absence of transmission access for independent power producers: Transmission access is necessary for private power producers because some renewable energy resources, mainly the potential sites in Akkar are somehow far from population centers.

Lack of expertise: Potential private wind power producers may be ignorant of the technology potential and benefits. They may also be faced with conflicting information and data about the wind regime in the country, leaving them with decisions not in preference to the new alternative. Consumers, managers, engineers, architects, and other stakeholders still lack information about wind despite the recently published wind atlas.

Lack of local spare parts manufacturing industries: Little incentives have been developed to promote the manufacturing of RE systems and products. The companies that provide services in RE are numerous but not all of them are experienced. Equipment suppliers currently import all kind of products without quality control and taxes on the imports of RE products and systems have not been waived yet

Fig. 6 shows results of the root cause analysis for wind power. Common causes and impacts of renewable technologies have been identified earlier.

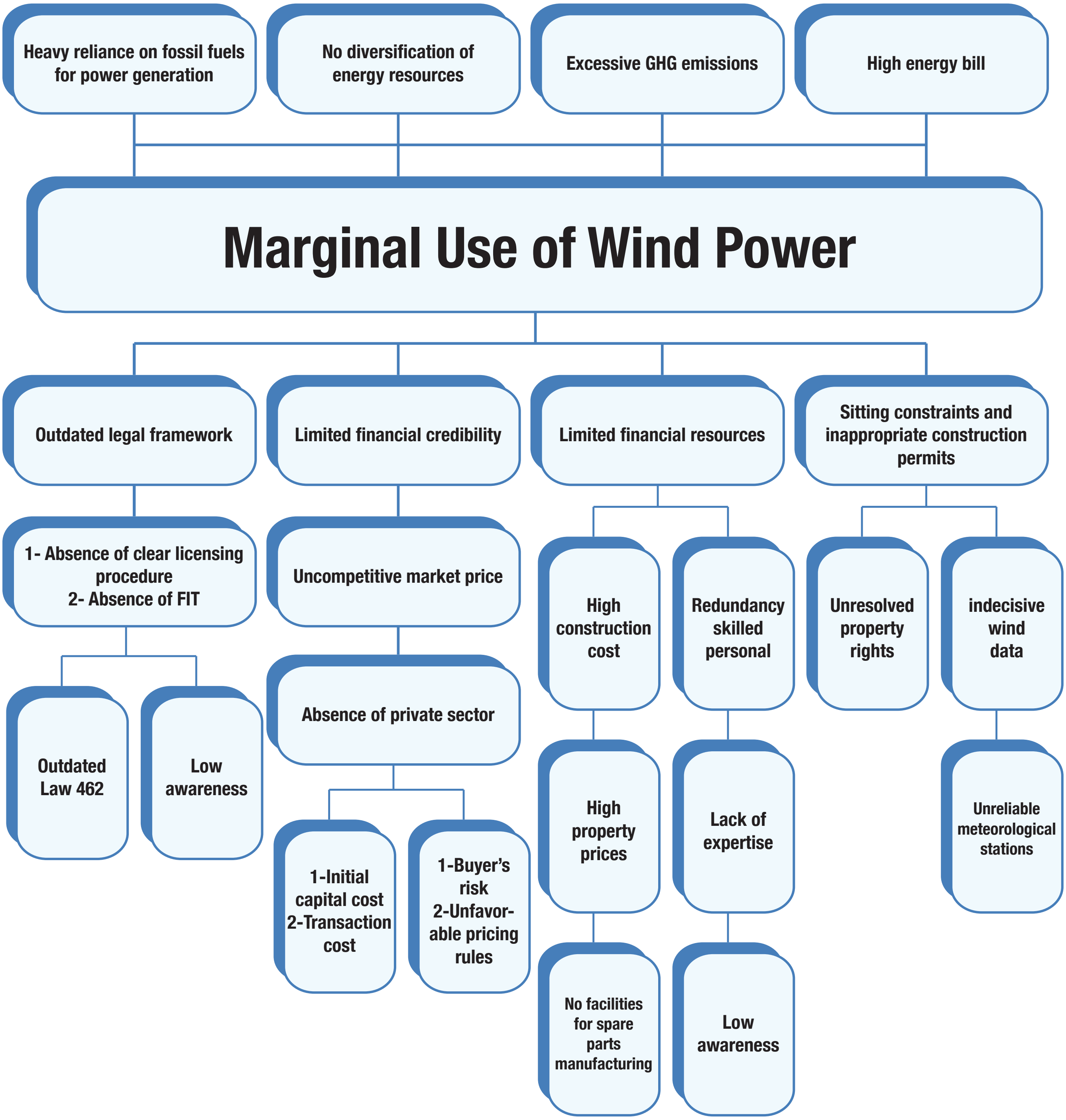

Fig. 6 - Root cause analysis for wind power

4.5.2 Identification of measures

Among the generic measures proposed in Table 12, price reforms would produce much substantial motivation to industrial end-users and household consumers to invest and to ensure the system operated as efficiently as possible. Significant measures for the deployment of wind technology include:

Removal of subsidies on fuel: The current electricity tariff needs to be revised to reflect the actual cost of electricity production and distribution and to subsequently encourage the use of renewable energy technologies. Until the tariff is adjusted, it is very hard to see private investments in RE. The projects already taking place stem from the desire to overcome electricity rationing and are not based on economic merit. The main objectives of tariff restructuring are to minimize the financial burden on EDL through the removal of subsidies and to ensure an adequate impact of future policies for promoting alternative and cleaner energy technologies that are currently at a cost disadvantage. Gradual tariff adjustment by GoL is expected to reach around 50% increase by 2015. This will also allow private power producers to sell at higher profit-making tariff. Moreover, tariff restructuring will lead to more rational use of electricity in the long-run leading to substantial reduction in GHG emissions

Provision of financial incentives: Financial incentives need to be set by the banking sector to encourage investments in the renewable technologies market in the country.

Feed-in tariffs: When the average tariff of the utility is corrected and set at the yardstick tariff to achieve a break even for the utility, then several RE technologies will become economically viable especially if feed-in tariff with incentives is further adopted for RE suppliers.

Institutional reforms: The environment needed to accelerate the penetration of any Renewable Energy into the market has not been installed yet. The Law 462 which was recently amended to facilitate the introduction of RE has not been approved by the Cabinet of Ministers and so it may be long before it is ratified by the Parliament. Several amendments to the law 462 are being currently discussed to allow for future plan expansions, and for the penetration of renewable energy technologies. The amended law is expected to make provisions for the feed- in tariff for co-generation, and should call for the introduction of a transition period during which the corporatization of EDL will take place.

Technological development: Small wind power- related industries should be established and supported to manufacture spare parts and components for wind power in order to compete with imported spare parts leading to substantial reduction in the operation and maintenance costs. This can be achieved by exchange of experience and capacity building with neighboring countries and other industrialize countries with relevant experience in the field. Facilities such as permitting privileges and easy credit access should be put in place in close collaboration with the Ministry of Industry to encourage the establishment of such industries.

4.5.3 Action Plan for the deployment of Wind Power

Target for Wind Technology Transfer and Diffusion

The policy paper has set a target of up to 100MW wind power production to be financed by the private sector by 2015. The capital cost is estimated around USD 1,950/kW, whereas the additional cost due to its implementation as a mitigation technology is around USD 950/kW. The consultation meetings with stakeholders revealed a significant interest in wind power in the private sector.

The main identified measures as obtained from the stocktaking process are presented in Table 14.

Table 14 - Technology Action Plan for Wind Power

	Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Potential Donors
General Measures	Gradual increase in tariff through fuel subsidies removal until it reaches 50% in 2015	1	- To avoid distorting effects of energy pricing system. - To remove financial burden from EDL. - To enhance the marketability of wind power.	The Department of Investment at MoEW	- EDL through improved financial balance. - private producers	0-3 years	- MoEW decisions and governmental decrees. - Periodical EDL reports. - Windmill generators operating in the country.	2,000,000 for preparation of economical study to determine the appropriate tariff.	World Bank, UNDP, USTDA, EU
	Low interest offers by the banking sector	2	To encourage investments in wind power	Banking sector.	Private power producers	0-5 years	Reports by stakeholders that cover financial Information, comparison of actual financial outputs with forecasts, and project financial statements.	0	NEEREA, Commercial banks. New Market Mechanisms Arab funds
	Tax exemptions/ reduction on imported technologies	2		GoL				0 Assuming that the amount of the tax reduced is added to the tax of fuel based technologies.	
Specific Measures	Feed- in- Tariff	1	- To facilitate power purchase from private producers. - To attract the private sector.	GoL MoEW	- EDL - Private power producers	1-3 years	- New tariff structure. - Number of windmill projects by private sector.	15,000 for economic feasibility of the energy purchase prices.	NEEREA, EU

4.6 Analysis of Technology: Photovoltaic cells

The manufacturing of photovoltaic (PV) cells has grown and advanced considerably in recent years on global scale, up to a total capacity of 40 GW at the end of 2010, distributed in more than 100 countries (REN21, 2011). This growth has been accompanied by a significant drop in the material and electronic system cost. In Lebanon, The UNDP-CEDRO project has managed to complete the installation of 126 kW for schools, municipalities and community centers. Such a progress may trigger additional penetration of PV into the Lebanese market if supported by other initiatives. The Lebanese territory is rich in solar radiation, and therefore with proper policies and incentives, paralleled with global drop in manufacturing cost could witness widespread outside major cities. Like wind power, PV cells are expected to replace or supplement the operation of diesel private generators mainly in the residential sector.

4.6.1 Identification of barriers for PV cells

The policy paper for the electricity sector did not include energy production from PV technology but it committed to start a pre-feasibility study on PV farms. The reason could be due to the high capital cost, low efficiency of PV systems and the false belief that PV cannot make a contribution if widely implemented in decentralized mode along with the new concept of net-metering in Lebanon. With most of the country connected to the national grid, PV is not economical compared to the grid produced electric energy at the present low tariff. However, the PV produced energy is competitive when compared to private generation that uses diesel oil.

Some of the generic barriers identified in Table 12 are more significant with regards to the deployment and diffusion of the PV technology, namely:

High capital cost: The initial capital cost of PV cells and supplementary technologies is substantially higher than conventional energy sources, resulting in cost-driven decisions and policies that may discriminate against PV cells as an economically feasible mitigation strategy. Moreover, large subsidies for fossil fuels do significantly lower final fuel- driven energy prices, putting renewable energy, mainly PV cells, at a competitive disadvantage if it does not enjoy equally large subsidies. In addition to the subsidies barrier, renewable energy investments from the private sector generally may face high taxes and import duties on the components. Although capital cost has been declining over the past years, the current price is still the highest of all alternative technologies, estimated at USD 4 Million/MW.

Inadequate tariff structure: The current tariff structure of electricity is very low and does not represent even the actual cost of energy production. Until the tariff is adjusted, it is very hard to see private investments in RE. The projects already taking place stem from the desire to overcome electricity rationing and are not based on economic merit. Even with tariff adjustment, there is an urgent need to introduce feed-in tariff to encourage investments in the field of RE.

Inadequate net metering system: The already introduced net-metering scheme has to be updated so as to allow for income making from the sale of RE to the grid. As it stands now, the users can benefit from bill reduction when injecting energy into the grid. However, if energy sale exceeds the energy purchased from the grid, the customer cannot cash the balance. Until there is a reliable electricity supply, net metering will continue to suffer from the inability to inject continuously into the grid (when rotating outages are in place) and hence to utilize the energy produced, storage batteries are necessary. Such storage increases considerable the cost of RE systems.

Restrictions on siting and construction: PV installations may face building restrictions based upon height, space availability on building facades, or safety, particularly in multi-store buildings in urban areas.

Absence of transmission access: Transmission access is necessary for private PV power producers because some sites of potential PV plants may be located in remote or semi- urbanized regions and to allow direct third-party sales between the renewable energy producer and a final consumer.

Low awareness: Most decision makers are not aware of the social, economical and environmental benefits of that renewable technologies and do not consider them as high priorities in the development plans. In addition, although many citizens and institutions support the development of RE but many of them do so without being backed by the minimum level of awareness and education about the characteristics of those products

Root cause analysis results are shown in the below figure.

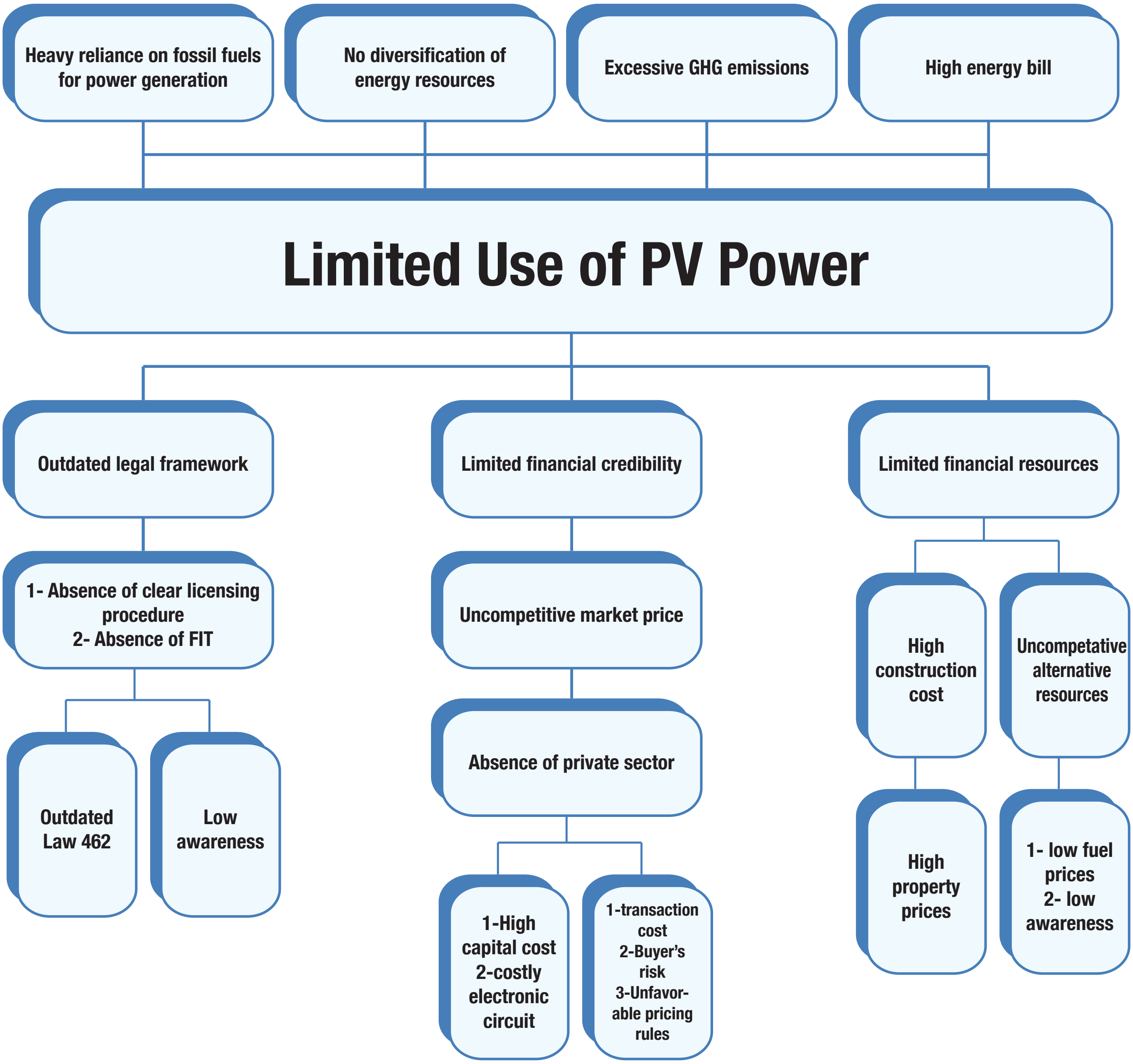

Fig. 7 - Root cause analysis for PV cells

4.6.2 Identification of measures

Knowing that PV cells currently have the highest capital cost of all listed renewable technologies, then price reforms certainly provide high motivation for private industrial end-users and household consumers to invest and to ensure that their investments will be economically feasible. Among the generic measures proposed in Table 12, financial and technical support are the most significant, and they include:

Removal of subsidies on fuel: The main objectives of tariff restructuring are to minimize the financial burden on EDL through the removal of subsidies and to ensure an adequate impact of future policies for promoting alternative and cleaner energy technologies that are currently at a cost disadvantage. Gradual tariff adjustment by GoL is expected to reach around 50% increase by 2015. This will also allow private power producers to sell at higher profit- making tariff. Moreover, tariff restructuring will lead to more rational use of electricity in the long-run leading to substantial reduction in GHG emissions.

Provision of financial incentives: Economic and fiscal incentives can be used to encourage investment. Significant support so far has been focused on promoting solar hot water heating systems, a proven technology that can make a useful contribution to GHG reduction. LCEC has been active in promoting solar thermal water heaters in the Lebanese market, providing advice on technical issues, communication and marketing. A similar momentum should be created to the PV systems. CEDRO has carried out a project for the deployment of PV cells for street lighting and for a number of schools in different regions of Lebanon.

Feed-in tariffs: For a power grid operator, PV renewable energy technology is of much higher capital cost, and therefore must be subsidized if it is to be developed by private industry in a competitive market. Even with tariff adjustment, there is an urgent need to introduce feed-in tariff to encourage investments in the field of RE. Investors need to have the opportunity to sell excess energy to the grid and consequently cash the balance.

4.6.3 Action plan for the Deployment of Photovoltaic cells

Target for Technology Transfer and Diffusion

In Lebanon, the CEDRO project has started installing PV cells in around 25 public schools and community centres in different parts of the country with a total capacity estimated between 1.2 and 1.8kW.The Council for Development and Construction is developing a pilot project farm with nominal capacity ranging between 1 and 5MW (MoEW, 2012). In conducting the generation capacity expansion till year 2015, a total of 1MW of PV cells has been considered.

The stocktaking process has identified the measures for PV technology as listed in Table 15

4.7 Technology Analysis: Hydropower

Hydropower is a combustion- free energy resource which is well established on global scale, and in Lebanon. Hydroelectric power plants have long economic lives, with some plants in Lebanon still in service for 50–100 years. Hydropower could, therefore, provide a feasible mitigation option for a limited replacement of fuel- driven thermal units since the hydro power capacity in the country could be increased by around 40MW. Hydro power has been established in Lebanon for a long time, since the 1960s, and therefore, unlike other renewable resources, local expertise is already available in hydro projects like Abdel Al and others.

4.7.1 Identification of barriers

Some of the generic barriers identified in Table 12 are more significant with regards to the deployment and diffusion of the hydropower technology, namely:

High capital cost: The capital cost for building the infrastructure needed for a hydro power plant could be very high compared to other conventional energy sources, resulting in cost-driven decisions and policies that may renounce hydro power as an economically feasible GHG mitigation strategy. The investment cost is further inflated by the rising trend of property prices in the country. The capital cost for hydropower has been estimated to USD 3.5 million in Lebanon.

Outdated legal framework: Renewable energy sources feeding into an electric power grid may not receive full credit for the value of their power. Renewable energy resources such as hydro power are often regarded as an intermittent discontinuous source whose output level depends on water availability that cannot be entirely controlled. Therefore utilities tend to regards these renewable resources are not reliable and hence reduce their purchase prices.

Inadequate water authorities regulations: In Lebanon, all water resources and rivers are considered to be a state property. In these circumstances, and in the absence of a legal framework, independent power producers will not have enough incentives and motivation to invest in hydro power facilities.

Unresolved property rights and shortage of landscape: Unresolved property rights in many regions of the country, state ownership for rivers and water resources, and dams for hydro power, may lead to restrictions on implementing such projects. Current city planning regulations may not allow for private hydro power production amongst water resources. Also they may not have established procedures for dealing with siting and permitting. Competition for land use with agricultural, recreational, scenic, or development interests, accompanied by substantial increases in property prices and scarcity of water for several months every year, can also be a barrier for the wide spread of hydro power. Fig. 8 shows the results of the root cause analysis for hydro power.

Table 15 - Technology Action Plan for Photovoltaic cells

	Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Potential Donors
General Measures	Gradual increase in tariff through fuel subsidies removal until it reaches 50% in 2015	1	- To remove financial burden from EDL. - To enhance the marketability of PV technology	The Department of Investment at MoEW	- EDL through improving the financial balance - private producers	0-3 years	- MoEW decisions and governmental decrees. - Periodical EDL reports.	2,000,000 for preparation of economical study to determine appropriate tariff.	World Bank, UNDP, USTDA, EU
	Low interest offers by the banking sector	2	- To encourage investments in PV technologies.	Banking sector	Private power producers	0-6 years	Reports by stakeholders that cover financial Information, comparison of actual financial outputs with forecasts, and project financial statements.	0	NEEREA, Commercial banks, New Market Mechanisms
	Tax exemptions/ reduction on imported PV technologies	2		GoL				0 Assuming that the amount of the tax reduced is added to the tax of fuel based technologies.	
Specific Measures	Feed- in- Tariff	1	- To facilitate power purchase from private producers. - To attract the private sector.	GoL MoEW	- EDL - Private power producers	1-3 years	- Updated Law 462. - New tariff structure. - Number windmill projects by private sector.	15,000 for economic feasibility of the energy purchase prices.	NEEREA, EU
	Updated buildings code	2	- To stimulate wide integration of PV units in buildings.	- Urban Planning Authority - Order of Engineers and Architects	-Building sector	0-2 years	- Updated building code decrees. - PV units installed in the building sector.		NEEREA EU

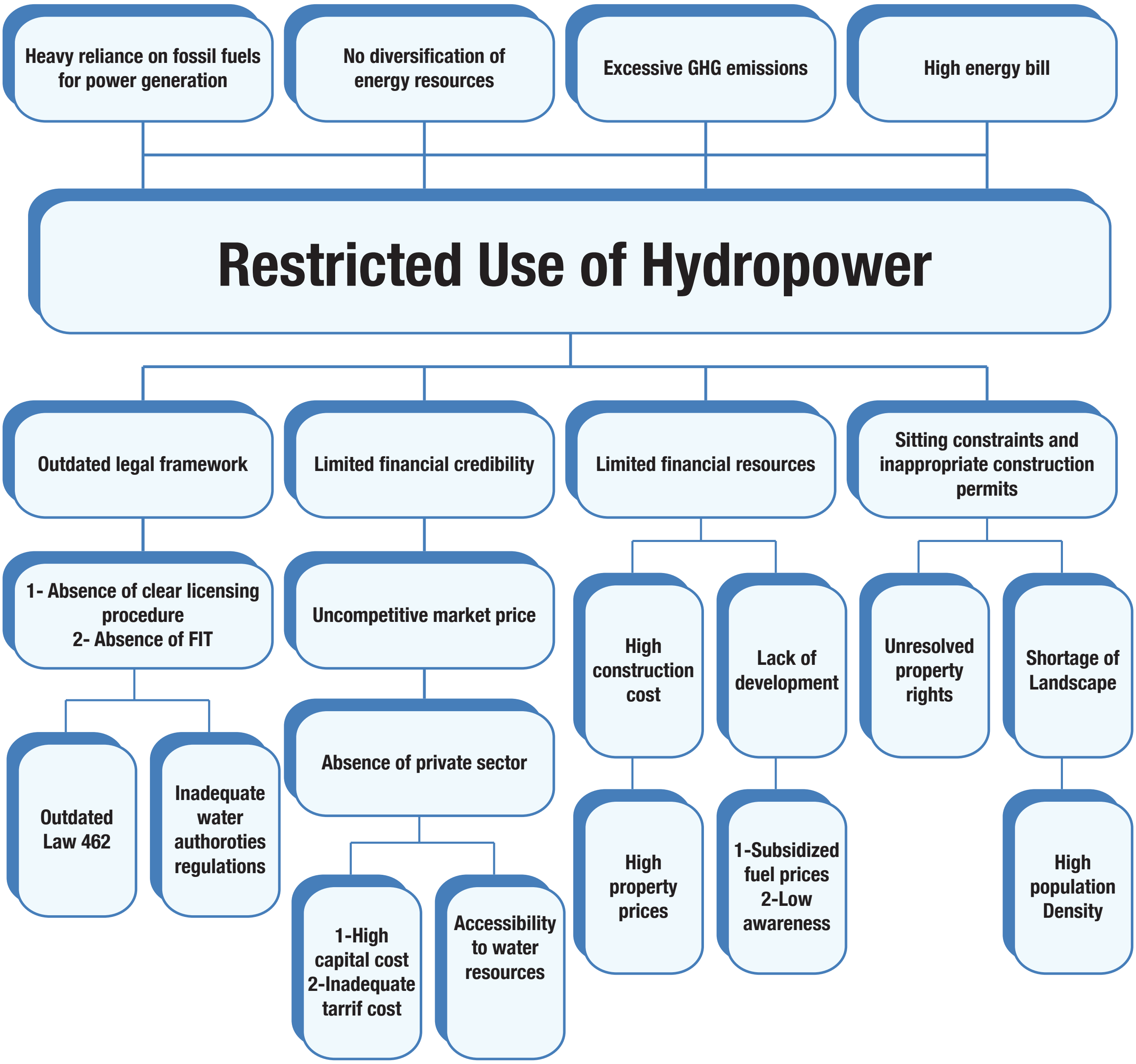

Fig. 8 - Root cause analysis for hydropower

4.7.2 Identification of measures

Among the most important measures are price reforms that would produce much substantial motivation to industrial end-users and household consumers to invest and to ensure the system operated as efficiently as possible. Measures for financial support and other measures have been discussed in Table 12, and they include:

Removal of Subsidies on Fuel: The current electricity tariff needs to be revised to reflect the actual cost of electricity production and distribution and to subsequently encourage the use of Hydropower energy technologies.

Feed-in Tariffs: due to the high capital cost of renewable energy technologies, the private sector should be encouraged to be involved in the deployment of such technologies.

Institutional reforms: they include the establishment of a clear energy strategy, clarification of roles and responsibilities of all involved entities and amend Law 462. It also includes the enforcement of safety standards, city planning intervention for setting property rights throughout the country and setting clear procedure for licensing and assessment.

Technological support: this includes the provision of training for the labor force mainly in O&M in

Table 16 - Technology Action plan for Hydropower

	Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Potential Donors
General Measures	Gradual increase in tariff through fuel subsidies removal until it reaches 50% in 2015	1	- To avoid distorting effects of energy pricing system - To remove financial burden from EDL - To enhance the marketability of hydro power	The Department of Investment at MoEW,	- EDL, - Private producers	0-3 years	- MoEW decisions and governmental decrees - Periodical EDL reports	2,000,000 for preparation of economical study to determine appropriate tariff.	World Bank, UNDP, USTDA, EU
	Low interest offers by the banking sector	2	- To encourage investments in hydro technology	Banking sector	Private power producers	0-7 years	Reports by stakeholders that cover financial Information, comparison of actual financial outputs with forecasts, and project financial statements.	0	NEEREA, Commercial banks, New Market Mechanisms
	Tax exemptions/ reduction on imported technologies	2		GoL				0 Assuming that the amount of the tax reduced is added to the tax of fuel based technologies.	
	Facilitating access to water resources	1	To enable investments in small hydro power projects	MoEW, Ministry of Public Works	Private power producers	0-2 years	Updated 462 law Operating small hydro power projects.	0	
Specific Measures	Feed- in- Tariff	1	To facilitate power purchase from private producers To attract the private sector	GoL MoEW	EDL Private power producers	1-3 years	Updated Law 462 New tariff structure Number of hydropower projects by private sector.	15,000 for economic feasibility of the energy purchase prices.	NEEREA, EU

hydropower, creating incentives to develop local supportive manufacturing facilities and thus reduce cost of import, establishing measurements and testing facilities, and developing codes for installation and standardization and labeling.

4.7.3 Action plan for the deployment of Hydropower

Target for Technology Transfer and Diffusion

The target is to generate additional 40MW from hydro resources by year 2014 and generate up to 30 MW from the rehabilitation of existing hydro plants.

Major measures for the hydro power sector are listed in Table 16.

Table 17 shows a summary of the priority of various mitigation measures for the proposed technologies. “1” indicates highest priority. Removal of fuel subsidies is regarded as a high priority measure for all mitigation technologies. Implementing this measure would facilitate large scale deployment of clean and renewable resources in the country. Also, feed- in- tariff is of high priority for the 3 renewable resources.

Table 17 - Priority of proposed measures for the selected mitigation technologies

Measure	CCGT	Wind	PV cells	Hydro
Removal of Subsidies on Fuel	1	1	1	1
Financial incentives	2	2	1	1
Institutional reforms	2	2	2	2
Raising awareness	3	2	1	3
Technological development	3	3	2	3
Feed- in- tariff	-	1	1	1
Securing NG supply	1	-	-	-

4.8 Cost Benefit Analysis

Fig. 9 shows the levelized production costs of the existing thermal power plant. Evidently, the 66-MW plant of Tyre and the 99-MW plant of Baalbeck, both run on diesel, have by far the highest production costs combined with inefficient generation and excessive GHG emissions.

The baseline scenario presented in the previous part of the report discussed the mitigation options, and the outcomes of implementing these options of the total national GHG emissions. To provide more specific cost analysis, 4 cost benefit scenarios are studied here:

i. Replacing Tyre DO plant with wind power.

ii. Replacing DO with natural gas for running the CCGT units in Beddawi and Zahrani.

iii. Replacing Tyre and Baalbeck DO plants with hydro power.

iv. Replacing Tyre DO plant with PV plants.

The results of the cost benefit analysis, as listed in Table 18 show that all the above scenarios provide a win- win opportunity in leading to saving in the generation cost, coupled with significant drop in GHG emissions.

4.9 Linkages of the barriers identified

Linkages of the identified barriers are being highlighted in the on-going amendments of the law 462 aimed at meeting current national requirements, future plan expansions, and to allow for the penetration of renewable energy technologies. These will include a temporary scheme of licensing the sale of renewable power through the feed- in tariff for co-generation. To constitute an enabling activity, the feed-in tariff has to be above the opportunity cost of electricity. The amended law should also call for the introduction of a transition period during which the corporatization of EDL will take place. It shall also call for the gradual introduction of the private sector into EDL through service providers law and new independent power producer.

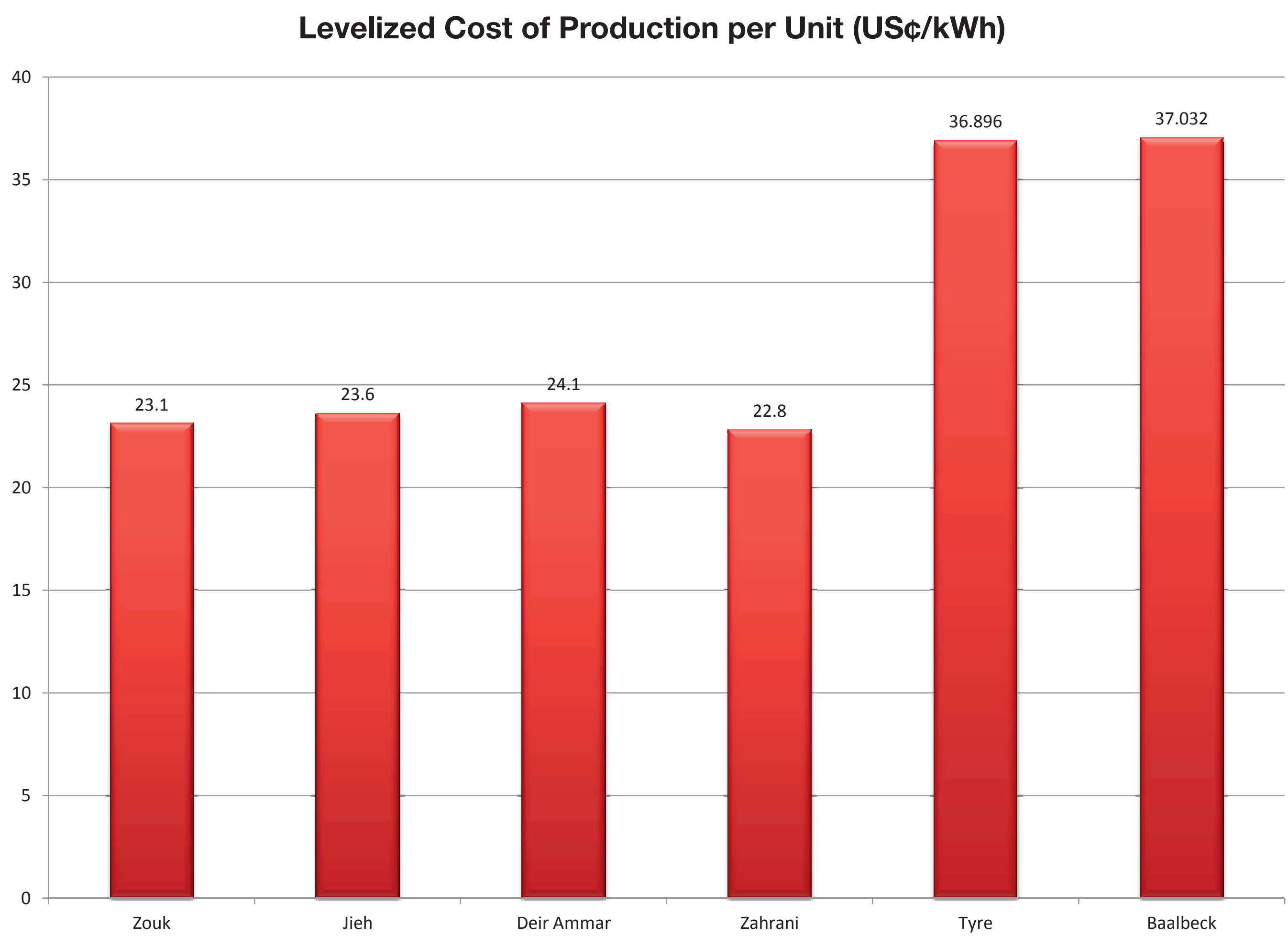

Fig. 9 - Levelized costs of existing thermal power plants

Table 18 - Results of cost benefit analysis.

		Energy (MWh/year)	Emission (gr/kWh)	Tons CO_2/year	Levelized Cost (US¢/kWh)	Cost (USD/Year)
Baseline	Tyre	284,996	778	221,726.89	36.90	105,152,124
Mitigation scenario 1	Wind	284,996	10	2,849.96	11.77	33,532,968
	(Reduction)			***(218,876.93)***	***(25.13)***	***(71,619,156)***
Baseline	CCGT/DO	2,553,888	778	1,986,924.86	23.45	598,886,736
Mitigation scenario 2	CCGT/NG	2,553,888	443	1,131,372.38	9.31	237,715,328
	(Reduction)			***(855,552.48)***	***(14.14)***	***(361,171,408)***
Baseline	Tyre+Baalb	570,047	778	443,496.57	36.90	210,347,343
Mitigation scenario 3	Hydro	570,047	10	5,700.47	12.40	70,685,828
	(Reduction)			***(437,796.10)***	***(24.50)***	***(139,661,515)***
Baseline	Tyre	284,996	778	221,726.89	36.90	105,163,524
Mitigation scenario 4	PV	284,996	32	9,119.87	26.80	76,378,928
	(Reduction)			***(212,607.02)***	***(10.10)***	***(28,784,596)***

4.10 Enabling framework for overcoming the barriers in the Power sector

The enabling framework for overcoming the barriers in the power sector are common for all 4 technologies and include the following:

1. Amended Law 462

Several amendments to the law 462 are being proposed and are currently discussed by the Government to make the law more applicable to present Lebanese conditions, to future plan expansions, and to allow for the penetration of renewable energy technologies. A temporary scheme of licensing the sale of renewable power even for a small- scale generation should be considered.

The amended law is expected to make provisions for the feed- in tariff for co-generation. To constitute an enabling activity, the feed-in tariff has to be above the opportunity cost of electricity. If the feed-in tariff is above the marginal cost of electricity at subsidized fuel prices, but below the opportunity cost then it is simply a regulation to correct the monopoly purchasing power of the network and the distorted fuel prices.

The amended law should also call for the introduction of a transition period during which the corporatization of EDL will take place, It shall also call for the gradual introduction of the private sector into EDL through service providers law and new independent power producer (IPP) to build and operate new CCGT units.

2. Coordination amongst governmental entities

There are several governmental entities involved in planning for the power sector; the MoEW, the Higher Council for Privatization and the Council for Development and Reconstruction (CDR). Decision-making normally proceeds through the general processes available in the executive and legislative branches of the government, and if necessary, will be passed to the Parliament for discussion and approval. These entities should have much closer collaboration for achieving a fruitful and rapid progress in setting the legal reforms needed for the alternative technologies and renewable energy market.

3. Benefit from New Market Mechanisms

The New Market Mechanisms can offer operating support to projects through the provision of a market for the certificates of Carbon Emission Reduction or by providing the opportunity to finance mitigation project though bilateral or multilateral funding. Although still not clearly defined under the UNFCCC, the new market mechanisms can be used through an enhanced post-2012 CDM, or though the preparation and of NAMAs, to support the deployment of clean and alternative technologies in the power sector by either the EDL or by the private sector.

4. Capacity Building

International organizations such as UNDP, have already implemented in Lebanon projects and entities such as the LCEC, with a main objective of conducting awareness campaigns and capacity building activities. Such initiatives have been recently expanded with the clear objective to gradually transfer the responsibility for the implementation and continuation of the campaigns to the Lebanese government. The MoEW policy paper has set a target of having by year 2020, 12% of power generated from renewable resources [NEEAP]. Moreover, the LCEC has published recently the National Energy Efficiency Action Plan (NEEAP), for the upcoming years 2011-2015, that constituted 14 initiatives for the spreading renewable as well as energy efficient technologies. Besides providing awareness for renewable energy and energy efficiency, the campaigns should include capacity building elements, such as training seminars or workshops, to educate officials of relevant Lebanese authorities in designing and implementing effective and efficient policies for renewable energy and energy efficiency.