HYDROPOWER FROM NON-RIVER SOURCES: THE POTENTIAL IN LEBANON

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LEBANON

- UNSTABLE POLITICAL AND SECURITY SITUATIONS
- ELECTRICITY SHORTAGES
- 75% OF ELECTRICITY FROM HYDRO BEFORE 1975
- ABUNDANT WATER RESOURCES
- NEED FOR ANY TYPE OF ELECTRICITY PRODUCTION
- COMMITMENT OF 12% TARGET

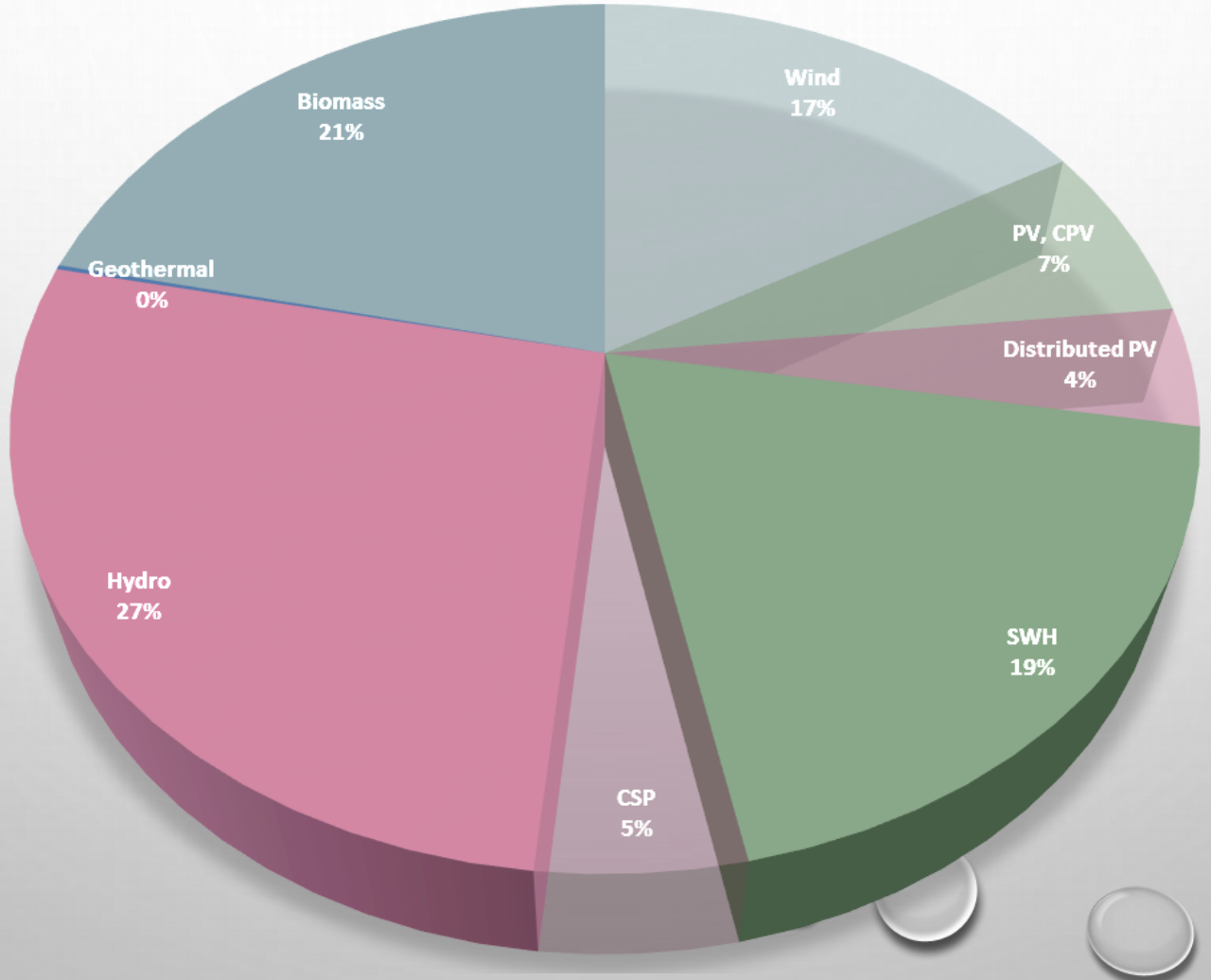
HYDRO ELECTRICITY IN LEBANON: INSTALLED CAPACITY

RIVER STREAM	ESTABLISHMENT	PLANT NAME	YEAR	INSTALLED CAPACITY	MW	REMARKS
LITANI AWALI RIVERS	LITANI WATER AUTHORITY	MARKABI	1961	1 x 17.9 MW + 1 x 19 MW	199	In Service - Will be affected by Conveyor 800 Project
		AWALI	1964	3 x 37.76 MW		
		JOUN	1967	2 x 24.65 MW		
NAHR IBRAHIM RIVER	SOCIETE PHOENICIENE DES FORCES DE NAHR IBRAHIM DES EAUX ET ELECTRECITE	CHOUANE	1961	2 x 7.5 MW	32	In Service - Needs Rehabilitation / Upgrade
		YAHCHOUCH	1955	2 x 4.984 MW + 1 x 2.464 MW		
		FITRI	1951	3 x 1.664 MW		
WADI KADISHA	LA KADISHA - SOCIETE ANONYME D'ELECTRECITE DU LIBAN NORD S.A.L. (EDL OWNED)	BECHARE	1924	2 x 0.82 MW	21	In Service - Needs Rehabilitation / Upgrade
		MAR LICHA	1957	3 x 1.04 MW		
		BLAOUZA II	1961	3 x 2.8 MW		
		ABU-ALI	1932	2 x 2.72 MW + 1 x 2.04 MW		
NAHR AL BARED	AL BARED CONCESSION	AL BARED 1	1936	3 x 4.5 MW	17	In Service - Needs Rehabilitation / Upgrade
		AL BARED 2	1936	1 x 1.2 MW + 1 x 2.5 MW		
SAFA SPRING	ELECTRECITE DU LIBAN	RICHMAYA - SAFA	1931	2 x 3.1 MW + 1 x 6.8 MW	13	In Service - Needs Rehabilitation / Upgrade
				TOTAL INSTALLED CAPACITY	282	MW

HYDRO ELECTRICITY IN LEBANON: SHARE OF ELECTRICITY

Plant	Net Installed Capacity MW	Current Yearly Production GWh	Rehabilitated Plant Yearly Production GWh
Zouk	607	1,897	3,164
Jieh	327	1,218	1,704
Deir Ammar	450	2,977	3,275
Zahrani	450	2,984	3,283
Baalbek	64	166	186
Tyr	72	187	209
Hrayche	70	200	364
Total Thermal	2,040	9,629	12,185
Kadisha Hydro	21	72	82
Litani	199	680	775
Nahr Ibrahim	32	92	105
Bared	17	54	62
Richmaya	13	20	23
Total Hydro	282	918	1,047
Total Thermal & Hydro	2,322	10,547	13,232
% of Hydro Energy		8.70%	7.91%

NREAP: 12% TARGET IN 2020

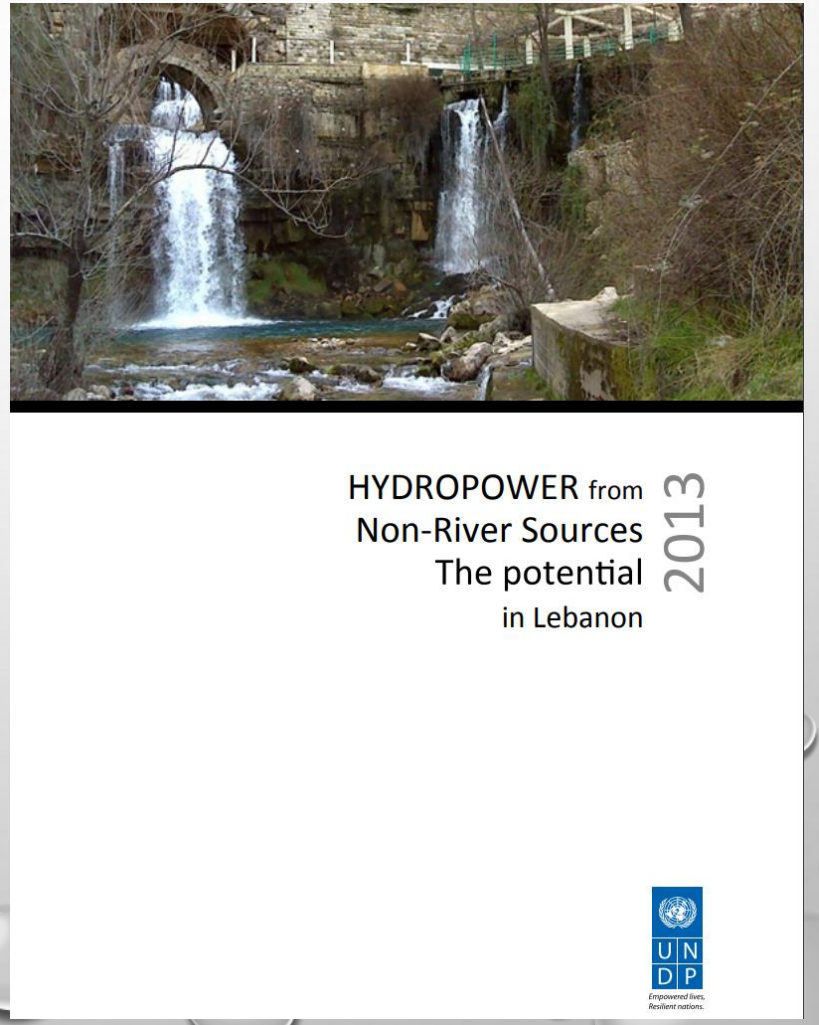


EXAMPLE OF THE WATER-ENERGY NEXUS IN LEBANON

- CONVEYOR 800 PROJECT: SUPPLIES OVER 90 VILLAGES AND APPROXIMATELY 15.000 HA OF POTENTIALLY PRODUCTIVE FARMLAND WITH WATER FROM THE NEARBY LITANY RIVER AND QARAOUN DAM
- THE PROJECT WILL BRING 110 MILLION M3 OF WATER A YEAR FROM THE LITANY RIVER – THE NATION'S LARGEST SOURCE OF FRESH WATER
- 52 KM LONG MAIN CONVEYOR 800, WITH SOME 60 KM OF SECONDARY CONVEYORS (BOTH GRAVITY AND PUMPED) TO TRANSPORT THE WATER TO THE HEAD OF THE INDIVIDUAL IRRIGATION PERIMETERS
- WILL REDUCED HYDRO ELECTRIC PRODUCTION OF EXISTING POWER PLANT SUBSTANTIALLY

HYDROPOWER FROM NON-RIVER RESOURCES: THE STUDY

- STUDY CONDUCTED IN 2013 BY UNDP CEDRO PROJECT
- PART OF THE RENEWABLE ENERGY POTENTIAL ASSESSMENT
- ADOPTED BY THE NREAP
- PART OF THE 12% TARGET SET BY THE LEBANESE GOVERNMENT
- IDENTIFIED AROUND 5 MW OF POTENTIAL



STUDY METHODOLOGY

- INSPECTION OF AROUND 20 SITES ALL OVER LEBANON
- AS A RESULT, 7 SITES HAVE BEEN FOUND NOT TO QUALIFY FOR FURTHER ACTION: THESE SITES EITHER HAVE ONLY MINOR POTENTIAL (WITHIN THE RANGE OF PICO-HYDRO) OR THEY ARE TECHNICALLY NOT FEASIBLE.
- THE REMAINING 13 SITES SELECTED FOR FURTHER ACTION HAVE BEEN EVALUATED FROM A TECHNICAL AND ECONOMIC PERSPECTIVE

STUDIED RESOURCES

- FOUR TYPE OF RESOURCES STUDIED:
  - IRRIGATION CHANNELS AND CONVEYORS
  - WASTE WATER TREATMENT PLANTS
  - ELECTRIC PP OUTFALL CHANNELS
  - MUNICIPAL WATER DISTRIBUTION NETWORKS

IRRIGATION CHANNELS AND CONVEYORS

- THE PRIMARY FUNCTION OF THIS SOURCE IS IRRIGATION, WHICH NEEDS TO BE MAINTAINED AT THE REQUIRED MINIMUM PRESSURE AND FLOW.
- THE PRODUCTION OF ELECTRICITY IS ONLY RANKED SECOND AND MUST NOT UNDERMINE THE PRIMARY FUNCTION IN ANY WAY.
- THE HYDROPOWER PLANT HAS TO BE DESIGNED IN A WAY TO MAKE OPTIMUM USE OF AVAILABLE HEAD AND FLOW AT DIFFERENT IRRIGATION REGIMES.

WASTE WATER TREATMENT PLANTS

- THERE ARE TWO POSSIBILITIES FOR USING THE HYDROPOWER POTENTIAL IN SUCH SYSTEMS
- ONE IS TO INSTALL A TURBINE AT THE INLET OF THE WASTEWATER TREATMENT PLANT, USING UNTREATED WASTEWATER.
- THE OTHER IS TO USE THE POTENTIAL OF THE TREATED WASTEWATER BEFORE IT IS RETURNED INTO THE RECEIVING WATER.

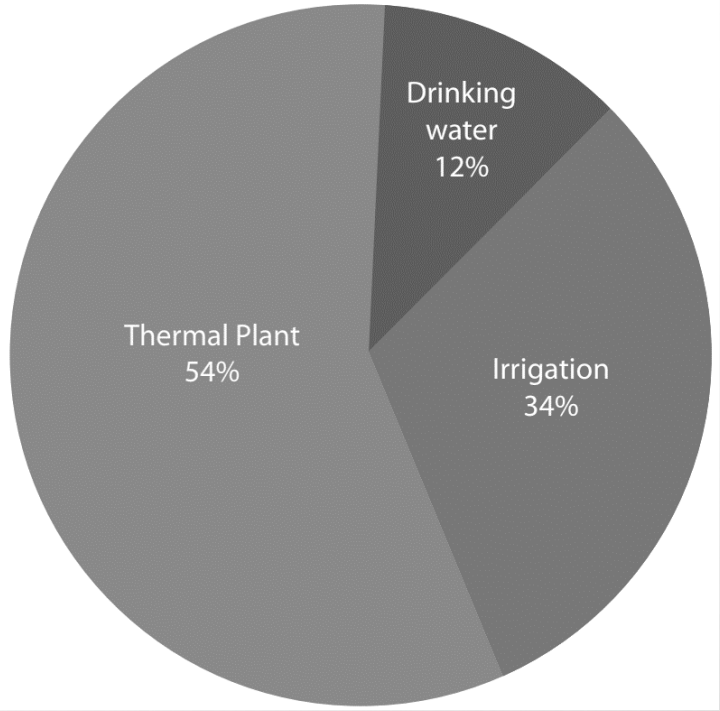
ELECTRIC PP OUTFALL CHANNELS

- LARGE THERMAL POWER PLANTS REQUIRE SIGNIFICANT AMOUNTS OF COOLING WATER.
- COOLING WATER IS NORMALLY TAKEN FROM THE SEA, PUMPED TO A HEAT EXCHANGER, AND RETURNED VIA THE OUTFALL PIPES TO THE SEA.
- THE AVAILABLE HYDROPOWER POTENTIAL DEPENDS ON THE SPECIFIC SITUATION AND TOPOGRAPHY AT THE RESPECTIVE THERMAL POWER PLANT.
- FOR EXAMPLE, A TURBINE CAN BE INSTALLED AT THE OUTLET OF THE DISCHARGE COOLING WATER SYSTEM AT A THERMAL POWER PLANT.

MUNICIPAL WATER DISTRIBUTION NETWORKS

- THE PRIMARY FUNCTION OF THESE SYSTEMS IS TO SUPPLY DRINKING WATER TO THE CONSUMERS AT A SPECIFIED SUPPLY PRESSURE.
- WHERE THERE IS A NEED FOR PRESSURE REDUCTION, THE EXCESS PRESSURE CAN BE USED TO DRIVE A HYDROELECTRIC SYSTEM.
- THERE ARE DIFFERENT POSSIBILITIES TO PRODUCE ELECTRICITY WITHIN DRINKING WATER SYSTEMS.
- ONE CONCEPT IS TO INSTALL A TURBINE AT THE ENTRANCE OF THE RESERVOIR OR THE STORAGE TANK AT THE WATER DISTRIBUTING STATION.
- ANOTHER OPTION IS TO INSTALL IT WITHIN THE SUPPLY NETWORKS. IN THAT CASE, NORMALLY A CERTAIN RESIDUAL PRESSURE - AS REQUIRED FOR THE DISTRIBUTION NETWORK - HAS TO BE MAINTAINED

NON RIVER POTENTIAL

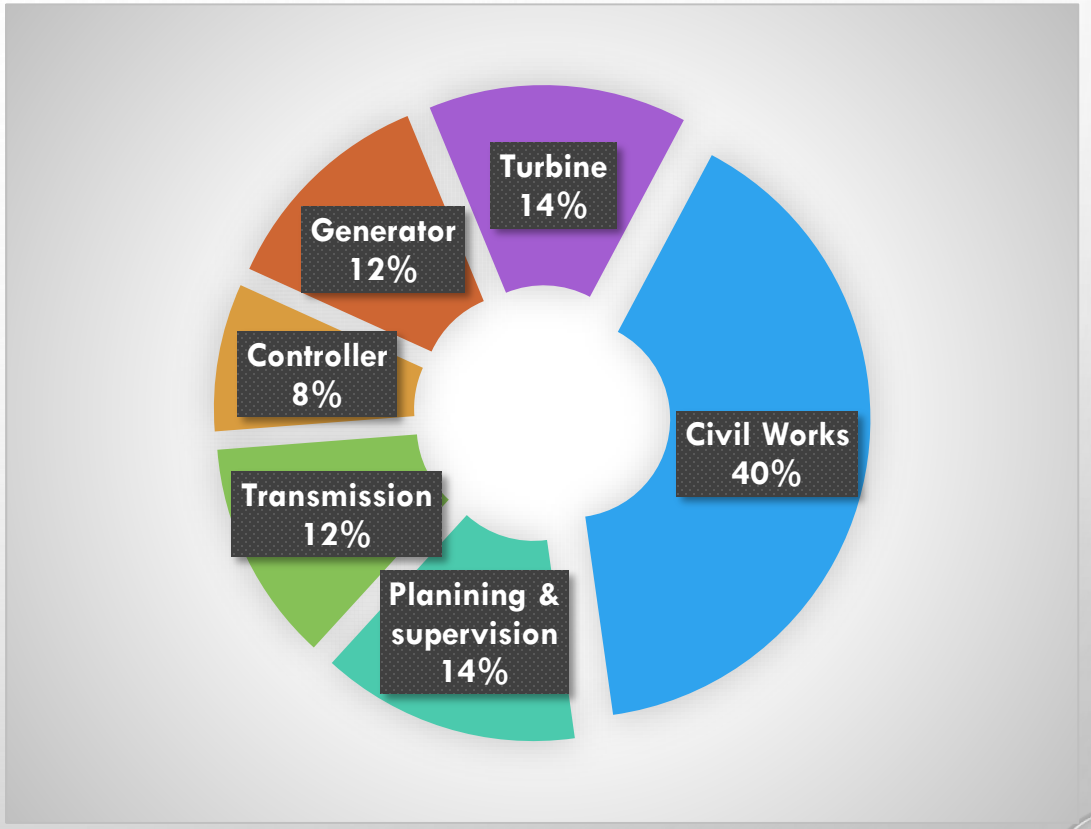


Total of around 5 MW

Micro-Hydro Stream	Public Institution	Number of Studied Sites	Potential Capacity (MW)
Irrigation Channels and Conveyors	All Water Establishments, Ministry of Agriculture	4	1.270
Waste Water Treatment Plants Intakes and Outfalls	All Water Establishments, CDR	1	0.123
Electric Power Plants Outfall Channels	EDL Electric Power Plants	5	3.421
Municipal Water Distribution Networks	All Water Establishments, Municipalities	4	0.144
Total Capacity			4.958

FINANCIAL ANALYSIS

- AVERAGE PRODUCTION COST AROUND 0.19 USD/KWH WHEREAS SELLING AVERAGE PRICE AROUND 0.094 USD/KWH
- IN THE STUDY, NO DETAILED ENGINEERING HAS BEEN CARRIED FOR THE VISITED SITES SO THAT ACTUAL COSTS CANNOT BE CALCULATED
- AVERAGE COST DISTRIBUTION OF MICRO-HYDRO SYSTEMS ADOPTED FROM INDONESIA EXPERIENCE



FINANCIAL ANALYSIS: COST PER MW

- THE APPROXIMATED FIXED COSTS FOR THE PROPOSED SYSTEMS ARE ABOUT 4,000 USD/INSTALLED KW.
- DEPENDING ON THE DIFFICULTY AND COMPLEXITY OF THE SPECIFIC SITE A CORRECTION FACTOR (CF) WAS INTRODUCED TO ESTIMATE THE INDIVIDUAL SPECIFIC CONSTRUCTION COSTS FOR EACH SITE.
- THE CORRECTION FACTOR IS A ROUGH ESTIMATE OF A PERCENTAGE INCREASE OF THE SPECIFIC INVESTMENT COST.

Site Name	Sym	Correction factor (Cf)	USD / kW
Naher el Bared lake	A	10%	4,400
Ain Leghwaibe (b)	A	5%	4,200
Qasimia Irrigation System	A	10%	4,400
Falouss Irrigation System	A	10%	4,400
Zahrani Power Plant	C	15%	4,600
Zouk Power Plant	C	35%	5,400
Jieh Power Plant	C	35%	5,400
Deir Ammar (Beddawi) Power Plant	C	10%	4,400
Hrayche Power Plant	C	15%	4,600
Saida water station (a)	D	10%	4,400
Saida water station (b)	D	10%	4,400
Kaa el Rim	D	5%	4,200
Ain Leghwaibe (a)	D	10%	4,400

FINANCIAL ANALYSIS: STUDY PARAMETERS

Hydropower plant in…	Plant capacity factor
Irrigation system	25%
Thermal power plant	80%
Drinking water system	50%
Other inputs	Value
Discount rate (nominal)	7%
Inflation rate	5%
Interest rate	3%
Loan duration	5 years
Service life	20 years
Operation & maintenance cost	5 % of investment cost

FINANCIAL ANALYSIS: SELLING TARIFF

- THE ANALYSES ARE MADE FOR TWO "ENERGY SALES OPTIONS" (TARIFF FOR ENERGY SALES TO THE GRID):
  - ELECTRICITY TARIFF $¢9.4/KWH (= SUBSIDIZED SALES PRICE IN LEBANON)
  - ELECTRICITY TARIFF $¢19/KWH (= REAL PRODUCTION PRICE IN LEBANON)
- FOR BOTH OPTIONS, A TARIFF INCREASE OF 5% PER YEAR IS ASSUMED WHICH APPROXIMATES THE GENERAL ANNUAL INFLATION RATE.

FINANCIAL ANALYSIS: IRR

Site Code	Site Name	Sym	IRR (elec. tariff 0.094 $/ kWh)	IRR (elec. tariff 0.19 $/ kWh)
LEB001	Naher el Bared lake	A	0%	3%
LEB004	Ain Leghwaibe (b)	A	0%	4%
LEB007	Qasimia Irrigation System	A	0%	3%
LEB008	Falouss Irrigation System	A	0%	3%
LEB012	Zahrani Power Plant	C	13%	45%
LEB013	Zouk Power Plant	C	9%	35%
LEB014	Jieh Power Plant	C	9%	35%
LEB015	Deir Ammar Power Plant	C	15%	49%
LEB016	Hrayche Power Plant	C	13%	45%
LEB017	Saida water station (a)	D	3%	23%
LEB018	Saida water station (b)	D	3%	23%
LEB019	Kaa el Rim	D	4%	24%
LEB020	Ain Leghwaibe (a)	D	3%	23%

SOCIAL AND ENVIRONMENTAL ASPECTS

Relevant aspects	Irrigation system (A)	Wastewater treatment plant (B)	Thermal power plant (C)	Drinking water system (D)
Land issues	Possible	no	no	Possible
Water right	Possible	no	no	no
Water conflict	Possible	no	no	Possible
Community involvement	Possible	no	no	Possible
Catchment area	Yes	no	no	yes
Fish and aquatic live	Yes	no	no	no
Residual water in river	Yes	no	no	Possible

GENERAL CONCLUSION

- NON-RIVER BASED HYDROPOWER PLANTS HAVE POTENTIAL IN LEBANON, ALTHOUGH THE LACK OF SUFFICIENT DATA SUCH AS, FOR EXAMPLE, THE MAPPING OF WATER SUPPLY NETWORKS, DOES NOT ALLOW THE COMPLETE POTENTIAL TO BE EXACTLY MEASURED.
- DATA AVAILABILITY AND PROPER INFORMATION RECORDING (I.E., DIGITIZING INFORMATION) IS REQUIRED, PARTICULARLY FROM THE NATIONAL WATER AUTHORITIES.
- IN THE PRESENT STUDY, THE MOST INTERESTING SITES ARE RELATED TO THERMAL POWER PLANTS
- INVESTMENT IN HYDROPOWER SYSTEMS WHICH CAN BE INTEGRATED INTO THERMAL POWER PLANTS IN LEBANON WAS FOUND TO BE ECONOMICALLY ATTRACTIVE (MAINLY DUE TO HIGH OPERATIONAL HOURS WHICH TRANSLATE INTO A HIGH LOAD FACTOR AND HIGH AVOIDED COSTS).

GENERAL CONCLUSION

- A WELL-DEFINED FEED-IN TARIFF FOR HYDROPOWER WHICH EXCEEDS THE SPECIFIC PRODUCTION COSTS (PER KWH) WOULD ALSO ENCOURAGE PRIVATE INVESTORS.
- A NEW ELECTRICITY TARIFF FOR HYDROPOWER ELECTRICITY WOULD ENCOURAGE THE INVESTMENT IN DRINKING WATER HYDROPOWER PLANTS.
- HYDROPOWER IN IRRIGATION SYSTEMS IN LEBANON CAN BE UTILIZED WHEN THE OPERATION PERIOD IS, AT LEAST, LONGER THAN 56-MONTHS. IF WATER IS FLOWING ALL YEAR ROUND VIA THE IRRIGATION CHANNEL (IN WET AND DRY SEASONS), HYDROPOWER EXPLOITATION WOULD BECOME EVEN MORE ATTRACTIVE.
- THE ANNUAL SAVING OF OIL, IN ALL CASES, CONTRIBUTES TO THE SAVING OF FOREIGN CURRENCY AND THUS IMPROVES THE TRADE BALANCE.
- AVOIDING GREENHOUSE GAS ACCUMULATION BY A CONSIDERABLE AMOUNT SHOULD ALLOW FOR THE APPLICATION OF A CDM OR EVEN A NEWER NEGOTIATED AGREEMENT.