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LEBANON

Technology Needs Assessment For Climate Change

In Collaboration with

UNDP

Empowered lives,
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Republic of Lebanon
Ministry of Environment

LEBANON
Technology Needs Assessment Report for Climate Change

Beirut, Lebanon
December, 2012

Project partners

REPUBLIC OF LEBANON MINISTRY OF ENVIRONMENT

UNEP

UNEP RISØ CENTRE ENERGY, CLIMATE AND SUSTAINABLE DEVELOPMENT

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This document is an output of the Technology Needs Assessment project, funded by the Global Environment Facility (GEF) and implemented by the United Nations Environment Programme (UNEP) and the UNEP-Risoe Centre (URC) in collaboration with the Regional Centre ENDA for the benefit of the participating countries. The present report is the output of a fully country-led process and the views and information contained herein are a product of the National TNA team, led by the Ministry of Environment.

Lebanon Technology Needs Assessment Report for Climate Change

Coordinated by

Ministry of Environment

Supported by

Global Environment Facility
United Nations Environment Programme
UNEP Risø Centre on Energy, Climate and Sustainable Development
ENDA-Senegal
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Foreword

As a non-Annex I country to the UNFCCC, Lebanon is not subject to binding greenhouse gas emission reduction commitments under the Kyoto Protocol. Our contribution to global greenhouse gas emissions is, and will remain in the foreseeable future, small. Nonetheless, as a small but vulnerable country to the impacts of climate change, Lebanon takes its responsibilities seriously and it will continue to do its part in the global efforts to address climate change.

The technical and technological development to combat climate change in developing countries is lagging behind and the international cooperative support has been extremely limited. It is therefore essential for the international community to enhance the efforts in this area. With an economy mainly based on fossil fuel energy, Lebanon's key strategy to mitigate greenhouse gas emissions is by improving efficiency in all sectors of the economy, specifically in the power and transport sectors that constitute more than 75% of our national emissions. As a result, this Technology Needs Assessment report has focused its mitigation assessment on these two sectors to shape appropriate national mitigation measures into concrete detailed action plans that can help decision makers to identify, create, and expand the market for clean technologies.

Concurrently, Lebanon is a country that is highly vulnerable to the impacts of climate change whereby facing the growing challenges demands urgent and decisive action. The increasing vulnerability to climate change and climate variability and extreme events remains our biggest challenge. Therefore, we are investing in new capabilities in climate science to achieve a deeper understanding of our vulnerabilities, and develop appropriate adaptation solutions to protect Lebanon against the risks posed by climate change. As a result, this Technology Needs Assessment project also looked into several adaptation technologies related to water and agriculture, the two most vulnerable sectors in Lebanon, and developed concrete action plans to increase the resilience of these sectors in facing the expected adverse effects of climate change.

This Technology Needs Assessment report is yet another attestation of Lebanon's active role in the global fight against climate change. We are committed and we will continue to do our part, despite our limited resources, and we are proud to share with the international audience all our efforts and initiatives in addressing climate change.

H.E. Nazem El-Khoury

Minister of Environment

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Last but not least, we would like to thank the main authors of this report, Dr. Farid Chaaban, Dr. Charbel Mansour and Dr. Jean Stephan for their professionalism, friendship and patience throughout the project process.

The TNA project team.

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List of Acronyms

A	Ampere
AC	Alternating current
ACSAD	Arab Center for the Studies of Arid Zones and Dry Lands
AER	All-Electric Range
AUB	American University of Beirut
BAU	Business As Usual
BDL	Banque Du Liban
BEV	Battery Electric Vehicle
BRT	Bus Rapid Transit
CA	Conservation Agriculture
CAS	Central Administration of Statistics
CBA	Cost Benefit Analysis
CCGT	Combined Cycle Gas Turbine
CDM	Clean Development Mechanism
CDR	Council for Development and Reconstruction
CEDRO	Country Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon
CGIAR	Consultative Group on International Agriculture Research
CHP	Combined Heat and Power systems
CNG	Compressed Natural Gas
CNRS	National Council for Scientific Research
DCT	Dual Clutch Transmission
DGLMT	Directorate General of Land and Maritime Transport
DGUP	Directorate General for Urban Planning
DLE	Dendro Liquid Energy

List of Acronyms

DO	Diesel Oil
DSM	Demand Side Management
ECA	Energy Conversion Agreements
EDL	Electricite du Liban
EFL	Environmental Fund for Lebanon
EPA	Environmental Protection Agency
ESCO	Energy Service Company
ESCWA	Economic and Social Commission for Western Asia
EU	European Union
EWS	Early Warning System
EWS-ICT	Early Warning System - Information and Communication Technologies
EWS-SPM	Early Warning System through Snowpack Monitoring
EWUIS	Efficient Water Use Irrigation System
FAO	Food and Agriculture Organization
FCA	Fuel Cost Adjustment
FIT	Feed- in tariff
GAP	Good Agriculture Practices
GBA	Greater Beirut Area
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIZ	Gesellschaft für Internationale Zusammenarbeit
GJ	Giga Joules
GoL	Government of Lebanon
GPS	Global Positionning System

List of Acronyms

GWh	Gigawatt-hour
Ha	Hectare
HEV	Hybrid Electric Vehicle
HFO	Heavy Fuel Oil
ICARDA	International Center for Agricultural Research in the Dry Areas
ICE	Internal Combustion Engine
ICT	Information and Communication Technologies
ICTSD	International Center for Sustainable Development
IEA	International Energy Agency
IFAD	International Fund for Agriculture and Development
II	Index Insurance
INC	Initial National Communication
IPCC	Intergovernmental Panel on Climate Change
IPM	Integrated Pest Management
IPP	Integrated Production and Protection
IPP	Independent Power Producer
IPR	Intellectual Property Rights
KEC	Kadisha Electricity Company
KW	Kilowatt
kWh	Kilowatt-hour
LARI	Lebanese Agriculture Research Institute
LAU	Lebanese American University
LBP	Lebanese Pounds
LCC	Lebanese Commuting Company
LCEC	Lebanese Center for Energy Conservation

List of Acronyms

LNG	Liquified Natural Gas
LPA	Logical Problem Analysis
LPG	Liquified Petroleum Gas
LRA	Litani River Authority
LT	Long Term
LU	Lebanese University
MCA	Multi-Criteria Analysis
MJ	Mega Joules
Mm^3	Million Meters cube
MMI	Mobility Monitoring Indicators
MoA	Ministry of Agriculture
MoE	Ministry of Environment
MoET	Ministry of Economy and Trade
MoEW	Ministry of Energy and Water
MoF	Ministry of Finance
MoIM	Ministry of Interior & Municipalities
MoJ	Ministry of Justice
MoPWT	Ministry of Public Works and Transport
MW	Megawatt
MWh	Megawatt-hour
NEAP	National Environmental Action Plan
NEEAP	National Energy Efficiency Action Plan
NEEREA	National Energy Efficiency and Renewable Energy Account
NG	Natural Gas
NGO	Non-Governmental Organization

List of Acronyms

NGV	Natural Gas Vehicle
O&M	Operations and Maintenance
OCFTC	Office des Chemins de Fer et des Transports en Commun
OCGT	Open Cycle Gas Turbine
OEM	Original Equipment Manufacturers
Pass	Passenger
PHEV	Plug-in Hybrid Electric Vehicle
PPA	Power Purchase Agreement
PPP	Private Power Producers
PTW	Pump-To-Wheel
PV	Photovoltaic
R&D	Research and Development
RCPS	Risk Coping Production Systems
RE	Reciprocating engines
RPTA	Railway and Public Transport Authority
RWHG	Rainwater Harvesting from Greenhouse tops
RWHH	Rainwater Harvesting from Hill lakes
RWHR	Rainwater Harvesting from Roads
SA	Soilless Agriculture
SAVR	Selection of Adapted Varieties and Rootstocks
SI	Spark ignition
SNC	Second National Communication
SPM	Snow Pack Monitoring
SUV	Sport Utility Vehicle
TAP	Technology Action Plan

List of Acronyms

TMO	Traffic Management Organization
TNA	Technology Needs Assessment
UTP	Union for Public Transport
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention Climate Change
UPOV	Union of Protection of New Varieties of Plants
URC	UNEP RISOE Center
USAID	United States Agency for International Development
USD	United States Dollar
USEK	Université Saint-Esprit de Kaslik
USJ	Université Saint Joseph
UTWWI	Use of Treated Wastewater in Irrigation
VoLL	Value of Loss of Load
WB	World Bank
WTP	Well-To-Pump
WTW	Well-To-Wheel
WUA	Water Users' Association
YMCA	Young Men Christian Association

Introduction

1.1 General Project Framework

Lebanon ratified the United Nations Framework Convention on Climate Change (UNFCCC) in 1994 by virtue of Law 359, with a primary objective of achieving the stabilization of greenhouse gas (GHG) concentrations in the atmosphere at a level that would prevent dangerous anthropogenic activities from interfering with the climate system.

In terms of Articles 4.1(c), (j) and 12 of the Convention, countries are periodically required to submit reports to the Conference of Parties on various topics regarding their attempts to address climate change. In order to fulfill these requirements, Lebanon has submitted its Initial National Communication (INC) in 1999, and its Second National Communication (SNC) in 2011 through funding from the Global Environment Facility (GEF), management of the United Nations Development Programme (UNDP), and execution by the Ministry of Environment (MoE). National Communications established Lebanon's national inventory of greenhouse gases from 1994 to 2004, assessed and updated Lebanon's vulnerability to climate change, and proposed appropriate mitigation and adaptation measures Lebanon has also prepared its first national report on Technology Needs Assessment (TNA) and Technology Transfer (TT) in 2002.

UNFCCC Decision 2/CP4 requested GEF to provide funding to developing country Parties to enable them to identify and submit to the COP their prioritized technology needs. Following a first round of Technology Needs Assessments conducted from 2000 to 2004 in 92 countries, the GEF allocated USD 50 million to support 35 to 45 countries to carry out improved Technology Needs Assessments within the framework of the UNFCCC. Lebanon has been selected to take part of this exercise, in order to complement the findings and proposals resulting from the SNC, and to build on the momentum that was created through this period on climate change issues.

This project comes to complement all the efforts the government of Lebanon is undertaking to combat climate change and aims at providing new and additional information that responds to concerns, generates new findings for policy reform and shapes action plans for intervention.

1.2 Objectives of the TNA Project

The Technology Needs Assessment project, funded by the Global Environment Facility ,managed by United Nations Environment Programme RISOE Center (URC) and executed by the Ministry of Environment (MoE), aims at assisting Lebanon in identifying and analysing priority technology needs to mitigate GHG emissions and reduce the vulnerability of sectors and livelihoods to the adverse impacts of climate change and to form the basis for a portfolio of Environmentally Sound Technology projects and programmes.Technical support for the implementation of the project is provided by Environment and Development Action (ENDA)-Senegal.

The main objectives of the project are:

- To identify and prioritize through country-driven participatory processes, technologies that can contribute to mitigation and adaptation goals of Lebanon, while meeting the national sustainable development goals and priorities;
- To identify barriers hindering the acquisition, deployment, and diffusion of prioritized technologies;
- To develop Technology Action Plans (TAP) specifying activities and enabling frameworks to overcome the barriers and facilitate the transfer, adoption, and diffusion of selected technologies in Lebanon;
- To develop proposals/concept notes for selected technologies in prospect for future funding.

1.3 TNA relevance to national development priorities

The TNA project is being undertaken to introduce technologies that could improve Lebanon's developmental and environmental integrity. The main

objective is to identify and assess environmentally sound technologies that have synergies between reducing the impact of climate change and the rate of GHG emissions and Lebanon's national development objectives. The resulting TNA and TAP report will be used to:

- Identify a portfolio of technologies that have the potential to combat climate change, reduce environmental pollution, and contribute to Lebanon's sustainable development
- Communicate Lebanon's climate change technology requirements to the global community
- Facilitate the access to international sources of funding for the implementation of mitigation and adaptation activities
- Support Lebanon's position in climate change negotiations in the area of technology transfer

1.4 Lebanon's institutional response to climate change

Lebanon, like other developing countries, faces the dual challenge of protecting the environment while pursuing economic growth in a sustainable manner. All development paths induce an increase in levels of GHG emissions, which impose stresses on the human and natural systems. In this way, mitigation and adaptation strategies are dynamically connected to sectoral development plans. Numerous activities have been conducted recently by the Lebanese Government, intergovernmental agencies and non- governmental organizations not only to reduce emissions and increase the adaptive capacity of socio-economical systems but also to tackle specific national environmental problems such as air pollution, urban sprawl, traffic and electricity shortages. The following is a non-exhaustive list of direct climate change related projects/activities that are being or have been implemented in the country:

- The National Action Plan (NAP) for combating desertification: the plan was developed in 2003 by the Ministry of Agriculture (MoA) and submitted to the United Nations Convention to Combat Desertification (UNCCCD). The plan is expected to help reduce GHG emissions and increase resilience of the sector through the promotion of sustainable agriculture, improved rangelands management and soil conservation practices.
- Sustainable Land Management Programme for Livelihood Development in Lebanon: the programme established at the Ministry of Agriculture assists the Lebanese Government in reducing land degradation and achieving sustainable land management through assessing alternatives in agricultural production to enhance market linkages and expand the agri-business and local SMEs.
- HASAD project : the Hilly Areas Sustainable Agriculture Development (HASAD) Project is a large scale water capturing programme at the Ministry of Agriculture funded by a loan from IFAD which promotes water and soil conservation (water harvesting, irrigation networks, technical assistance for improved soil and water conservation practices) and provides technical support to farmers (creation of Farmer service centers, marketing support, etc) in the desertification prone areas of Lebanon.
- National Water Sector Strategy (NWSS): the NWSS was officially launched in 2012 aiming to ensure water supply, irrigation and sanitation services through 16 initiatives involving institutional & organizational reforms as well as financial, commercial and environment initiatives such as modifying Law 221, refining climate change knowledge on water sector and preparing the sector for private sector participation.
- Lebanese Center for Energy Efficiency and Conservation: : the LCEC, established at the Ministry of Energy and Water is working on promoting the energy efficiency market, particularly in the industrial and domestic sector, through private Energy Saving Companies (ESCOs). Technical capacity building programmes, national energy saving

Introduction

campaigns and financial mechanisms are being implemented to encourage demand-side management especially that the Government pays a high subsidy cost for electricity. the LCEC serves as a national advisory unit on energy conservation that lobbies for energy efficiency at the policy-level while pushing the local market towards increasing demand-side management.

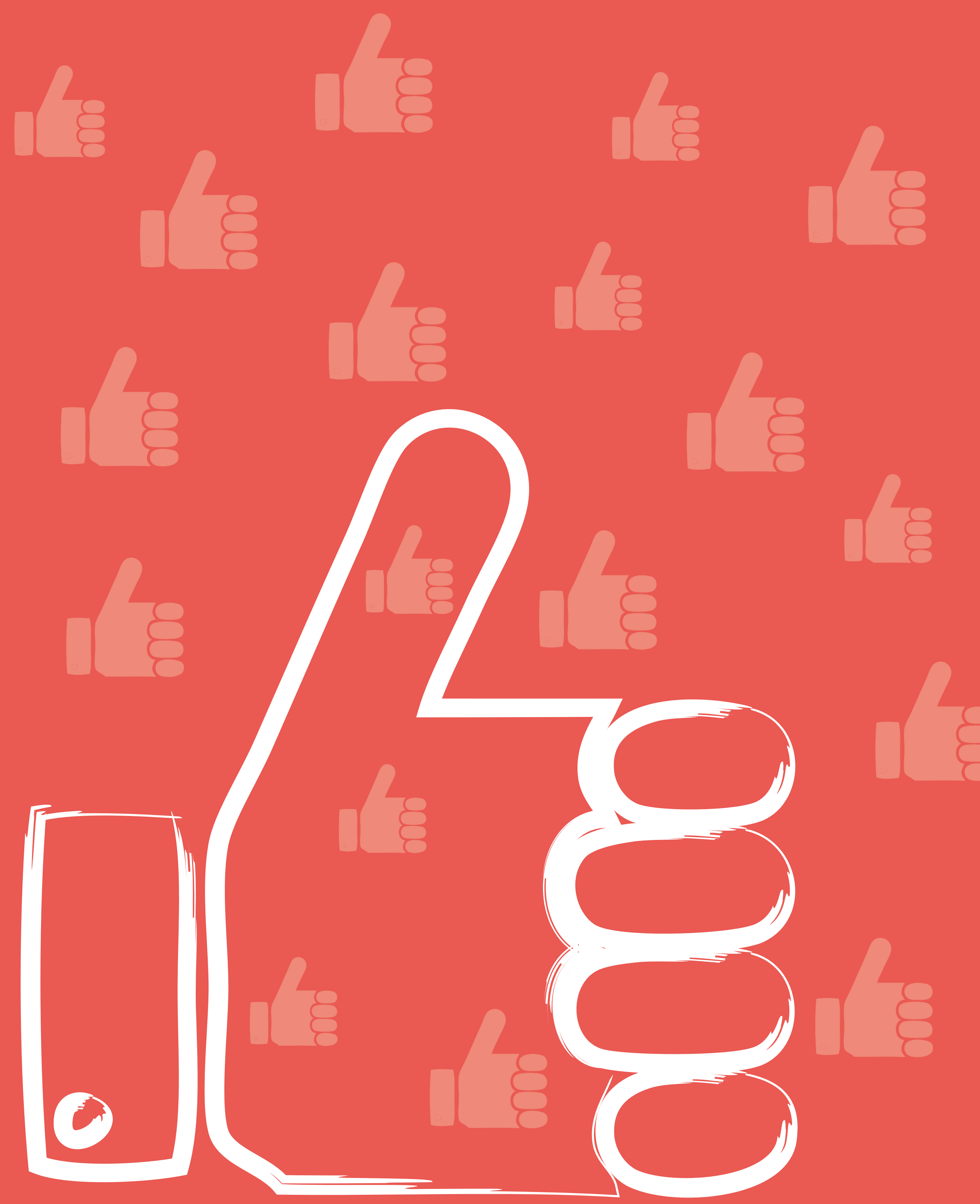
- Community Energy Efficiency and Renewable Energy Demonstration Project for the Recovery of Lebanon (CEDRO): The project is supporting early recovery activities by installing energy efficiency and renewable energy equipment in selected public buildings and facilities (schools, hospitals, municipal street lighting, etc.) in highly affected areas by the July 2006 conflict. The project also monitors the direct impacts of the installed equipment on the beneficiaries› energy bills to set the basis for future national sustainable energy strategies. CEDRO published in 2011 Lebanon's wind atlas which measures the wind potential in Lebanon and identifies potential hot spots for wind harnessing. It also published in 2012 Lebanon's bioenergy resource assessment which assesses the biomass potential in the country , identifies the most suitable conversion technologies and formulates Lebanon's National Bioenergy Strategy.

- Copenhagen Declaration: at the COP15 in Copenhagen, the Government of Lebanon has committed itself to voluntary introduce 12% renewable energy in its energy mix by the year 2020. Lebanon's Copenhagen Declaration, which was later noted by the Policy Paper of the Energy Sector and adopted by the Council of Ministers in 2010.

- Policy Paper of the Ministry of Energy and Water: The MoEW has prepared and issued in 2010 a new plan for the reform of the electricity sector in Lebanon. While it primarily aims at increasing power generation, the plan is based on the use of renewable sources of energy, which can significantly reduce Lebanon's national emissions. An increase in generation capacity is planned to reach 4000MW by 2014, and 5000MW after 2015. This additional capacity will be supplied through the construction of new power plants, dams, wind farms and waste-to-energy plans. The fuel sourcing will be mainly on natural gas (66%) with multiple sources of supply, and 12% on renewable energies. In addition, energy saving laws such as encouraging the use of CFL bulbs, solar water heaters, and public light saving mechanisms will be prepared and issued by MoEW.

- National Energy Efficiency Action Plan (NEEAP): the National Energy Efficiency Action Plan (NEEAP) for the years 2011-2015 was developed and adopted by the government in 2011, and provides Lebanon's strategy in energy efficiency and renewable energy through 14 national initiatives that contributes in achieving the national target of 12% renewable energy by 2020.

Stakeholders engagement



2.1 Institutional arrangements and stakeholder consultation process

Since the TNA project directly followed the preparation, submission and public dissemination of the Second National Communication report, the same institutional structure and stakeholder consultation process was followed to maintain the momentum created by the SNC activities and ensure sustainability of the process.

The TNA project is a country driven process where a wide variety of stakeholders have been involved in the identification and prioritization of sectors and technologies and in the preparation of comprehensive action plans for the acquisition, diffusion and deployment of technologies. The stakeholders engagement plan was designed to reach high level decision makers as well as technical experts, academicians, NGOs in order not only to validate the results of the project but also to answer to the needs of the specific sectors and to fill a gap to build an integrated strategy to combat climate change. This was achieved through the use of the following communication tools:

- Expert consultations in the preparatory phase: during the initiation and planning phases of the project, sectoral experts related to climate change issues were consulted during the inception workshop, through a series of meetings or through digital communication in order to identify sectoral needs and gaps and determine their expectations from the TNA project. These expert consultations were used to select the priority sectors, to confirm the choice of the initial list of technologies and to validate the information presented in the factsheets before their dissemination to a wider audience.
- Expert consultations workshops: 2 expert consultation workshops were prepared first to prioritize technologies then to identify barriers and enabling framework for the selected technologies, during which stakeholders had the opportunity to review factsheets and draft reports and to elaborate problem and objective trees.
- Individual meetings: in order to make sure that the right people are involved in the process and to overcome the absence of some key stakeholders in workshops, individual meetings were organized with ministers' advisors, technical public servants, data providers, private companies, economists and lawyers to collect data or endorse results. These meetings were crucial to build or maintain a personal contact with stakeholders, mainly during the preparation of action plans and the conceptualization of project proposals.
- Official communication: in the case were the response rates of some institutions was low, draft reports and documents were sent through official channels (Minister to Minister) requesting review and validation.
- Public project visibility: the TNA project's objectives, procedure, methodology, and preliminary results were presented on many occasions during seminars, conference and related events in order to reach out to a wider spectrum of people and to receive feedback and recommendations from a other perspectives.

The adoption of these different communication approaches ensured to the extent possible the proper engagement of stakeholders which has lead to transfer of new knowledge, especially local knowledge, and insights on specific technology challenges and opportunities that might otherwise have been missed. In addition, special attention was attributed throughout the project to ensure that the TNA process does not duplicate work and only tackles issues that are currently under-assessed in the country or that are of high development interest to decision makers.

The stakeholders were identified according to their expertise, decision making positions, involvement and knowledge of the selected sectors and capability to influence the implementation of the proposed TAP. Most of the stakeholders have already been involved in the SNC process, which has created a common knowledge base and has built strong inter-institutional and interpersonal relations (Annex 1).

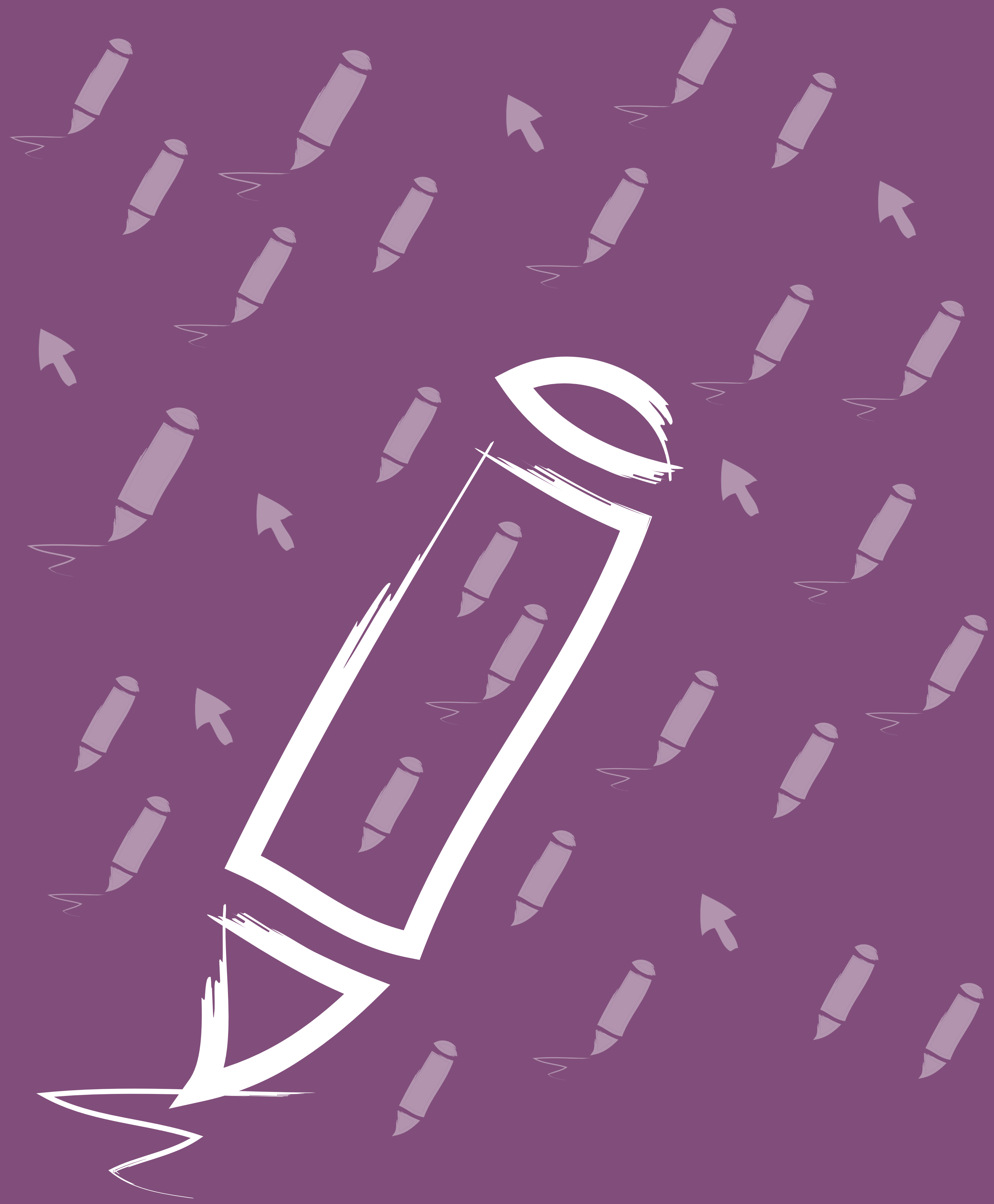
Communication with stakeholders varied with the type of institution they belong to. A significant number of individual or group meetings were conducted to discuss in depth specific topics or to develop a specific action plan or project proposal. This personalized approach increased the involvement of the different actors in the process and the ownership of the results which facilitates in the future the quick adoption of the project outcomes in sectoral development.

Stakeholders are divided into 4 groups, as indicated in the following Table:

Table 1 - Stakeholders categorization

Category	Name	Representation
Ministries and governmental institutions	Ministry of Energy and Water Ministry of Interior and Municipalities Ministry of Public Works and Transport Ministry of Environment Ministry of Economy and Trade Ministry of Finance Ministry of Agriculture Order of Engineering and architects Lebanese Agricultural Research Institute Council for Development and Reconstruction Litani River Authority Electricite du Liban Strategic Planning Unit Industrial Research Institute Green plan	High level officials Technical experts
Private sector	Association of Lebanese Industrialist Private industries Car importers	Upper management Technical experts
Academic/ research sector	American University of Beirut Universite Saint Joseph Universite Libanaise National Center for Scientific Research	Technical experts
Projects	CEDRO Lebanese Center for Energy Conservation HASAD Hilly Areas Sustainable Agricultural Development Project Environment Fund for Lebanon /CDR	Technical experts
IGOs	Economic and Social Development Commission in Eastern Asia World Health Organization Food and Agricultural Organization International Center for Agricultural Research Development for the Dry Areas United Nations Development Programme	Technical experts
NGOs	Indyact Greenpeace Greenline	

Sector prioritization



Sector Prioritization

3.1 An overview of sectors, and projected climate change and the GHG emission status and trends

Lebanon's Second National Communication to the UNFCCC (SNC) has served as the baseline for the selection of the priority mitigation and adaptation sectors. The report, which was submitted in February 2011 to the UNFCCC secretariat, presents the country's GHG inventory for the year 2000 with a trend analysis for the period 1994-2004 as well as sectoral mitigation measures to reduce national emissions. The report also presents the climate risks to Lebanon, based on modeled climatic projections and identifies the most vulnerable sectors and proposes adaptation measures. The preparation of the SNC was based on a participatory approach where relevant stakeholders were involved in data collection and validation of methodology, baseline and emission scenarios as well as proposed measures and action plans.

3.1.1 Mitigation sectors

In the year 2000, Lebanon's total GHG emissions recorded 18,507Gg (18.5 Million tonnes (Mt)) of CO_2 equivalent (CO_2eq), the energy sector being the main source of emissions, accounting for 74.86% of the total national emission (53.45% from energy production and 21.41% from transport). Industrial processes and waste sector accounted for 9.62% and 9.40% respectively while emissions from agriculture and land use change and forestry constituted 5.76%, and 0.36% of total CO_2 eq. respectively.

Lebanon's GHG emissions have increased by 27.6% since 1994, when total emissions were approximated to 15,901 tCO_2 eq. This represents an average annual growth rate of 2.77%. As can be seen in Table 2, the fastest rate of growth occurred in the waste sector followed by the energy and industrial sector. A significant decrease in emissions was noted in the Land Use and Forestry sector in addition to a slight decrease in the agriculture sector.

In general, the trend of increase in total GHG emissions closely follows the trend of emissions from the energy sector, which constituted 49 to 58% of total emissions during this period (Fig. 1). This significant growth in emissions reflects the growing demand for electricity, due in part to the changing socio-economic conditions and to the expansion of the national grid. In fact, the sharp increase noticed between the 1994 and 2000 emissions is due to the increase in gas/diesel oil consumption (Fig. 2) that accompanied the installation and operation of the 4 diesel power plants during this period.

Table 2 - Trend of emissions (in Gg CO_2 eq.) during the period 1994-2004

	Total GHG emissions	Energy	Transport	Industry	Agriculture	Land Use Forestry	Waste
1994	15,901	7,743	3,991	1,924	1,130	210	902
2000	18,507	9,892	3,963	1,781	1,066	67	1,739
2004	20,299	10,979	3,976	2,178	925	12	2,227
% change 1994-2004	27.66%	41.79%	-0.39%	13.19%	-18.12%	- 94.42%	146.99%
Average % change/year	2.77%	4.18%	-0.04%	1.32%	-1.81%	-9.44%	14.70%

Source: (MoE/UNDP/GEF, 2011)

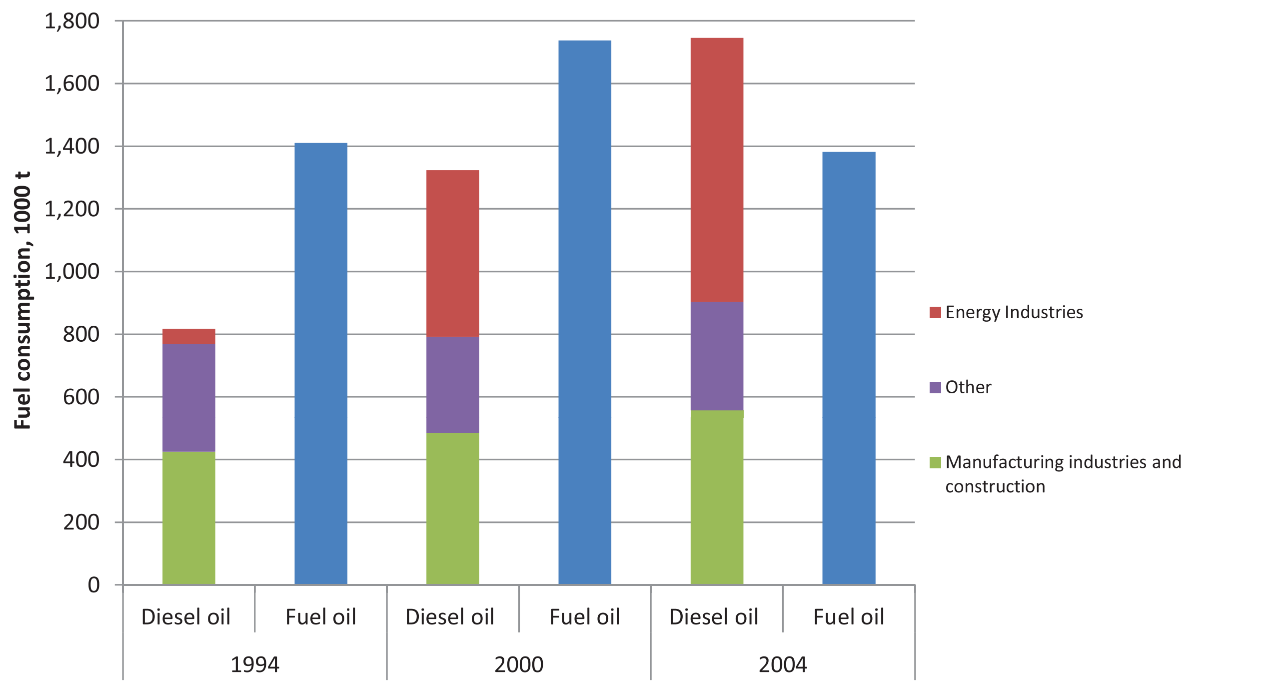


Fig. 1- Trend in emissions

Source: (MoE/UNDP/GEF, 2011)

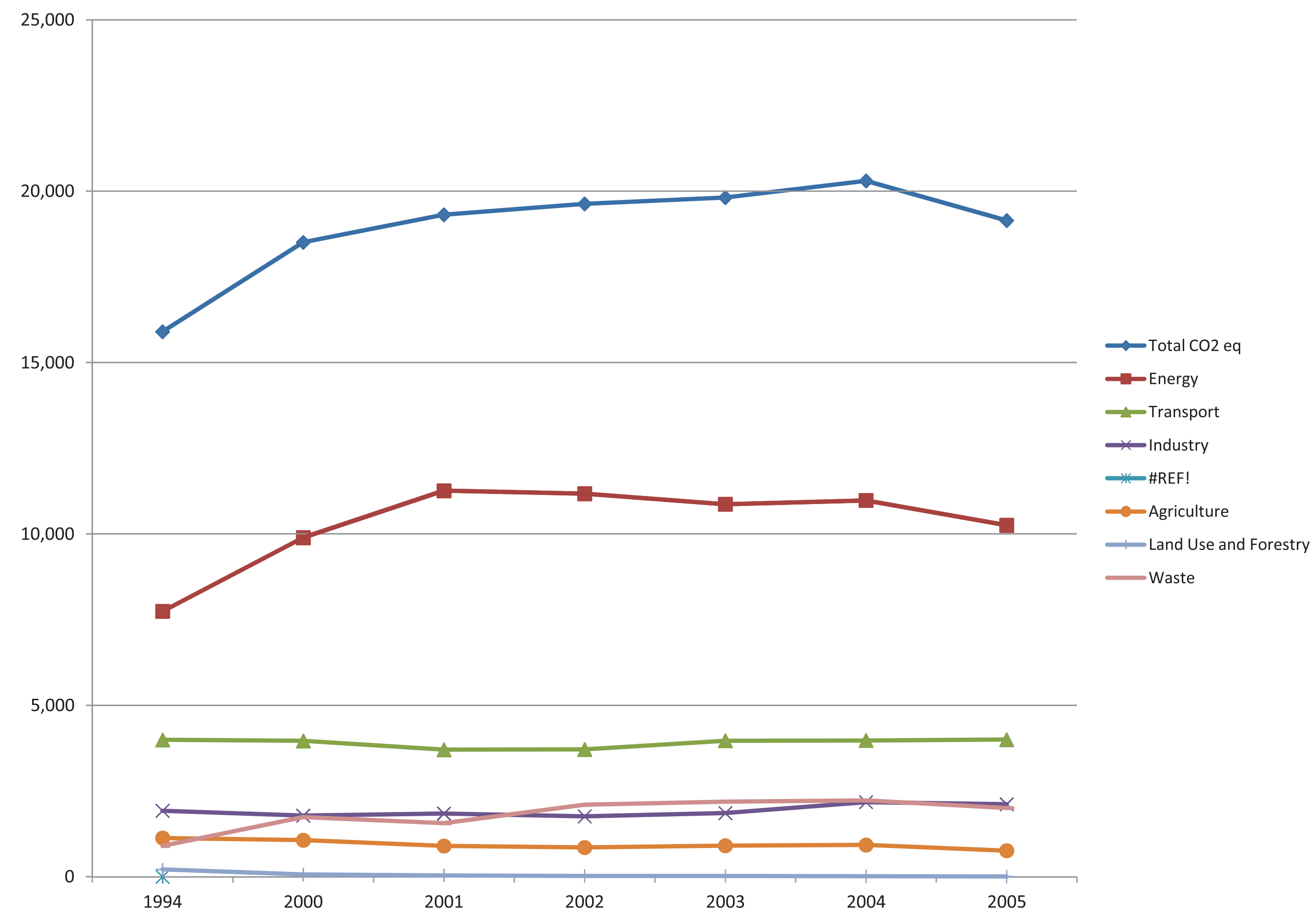


Fig. 2 - Consumption of fuel and diesel oil in the power sector

Source: (MoE/UNDP/GEF, 2011)

As for the transport sector, GHG emissions have conserved a steady state throughout the 1994-2004 period. Despite a vehicle fleet increase during this period, the increased efficiency in fuel consumption of new cars, the ban to import cars older than 8 years that was introduced in Lebanon and the inspection system that was established in Lebanon in 2001 contributed to the stabilization of the emission trend from the transport sector.

Emissions from the industrial sector increased during this period by around 13.19%., and namely due to the increase in cement and lime production while emissions from the waste sector increased by 147% from the 1994 values. With an increase in population, in waste generation and in percent of waste deposited in landfills, methane emissions from solid waste disposal on land have increased by 135% despite the flaring that was introduced in 2000 with the establishment of the Naameh landfill.

As for agriculture and land use change and forestry, emissions decreased by 18% and 94.44% respectively, mainly due to a decrease in the population of livestock and decrease in forest fires from 1994 to 2004.

3.1.2 Adaptation sectors

Analysis of historical climatic records of Lebanon from the early 20th century with future emissions trajectories indicates that the expected warming in Lebanon has no precedent. Annual average temperatures are projected to increase by 1 to 2°C above the current levels by the year 2040, and 3 to 5°C by 2090. In addition, rainfall is projected to decrease by 10-20% by 2040, and by 25-45% by the year 2090, compared to the present. This combination of significantly less wet and substantially warmer conditions will result in an extended hot and dry climate. Temperature and precipitation extremes will also intensify with additional 50 “hot summer days” and 34 “tropical nights” by the end of the century, causing the seasonal prolongation and geographical expansion of drought periods (MoE/UNDP/GEF, 2011).

Such changes in climate are expected to have diverse implications on Lebanon’s environment, economy, and social structure. The fragile biodiversity, ecosystems, and natural habitats will be threatened by increased forest fires, pest outbreaks and sea level rise. The findings from the vulnerability assessment do not single out one specific vulnerable sector, but identifies the agriculture, forestry, water resources, human health, coastal zone, and tourism sectors as most vulnerable with distinctive social, economical and environmental implications.

Lebanese agriculture may experience a decrease in productivity for most of the crops and fruit trees especially for wheat, tomatoes, cherries, apples, olive and grapes, despite some transient benefits from the expansion of the coastal plantations such as banana and tomatoes. Furthermore, changes in precipitation and, subsequently water management are particularly critical factors affecting the future productivity of the Lebanon’s agriculture. The declines in precipitation will also exacerbate existing challenges to water availability and quality for agriculture as well as for commercial and residential uses. Climate change will induce a reduction of 40% to 70% of the snow cover of Lebanon with an increase of 2°C to 4°C respectively, a shift of elevation of snow from 1500 m to 1900 m and a decrease in snow residence time from 110 days to 45 days. This will have adverse impacts on rivers and groundwater recharge, and will affect water availability during the summer season and in drought periods.

Coastal zones may be affected by increases of sea level rise and sea level temperature, which will have an impact on sand beaches and coastal natural reserves. This may also lead to seawater intrusion into aquifers and cause coastal flooding and inundation during storms.

As for forests, they will be adversely affected by climate change, especially that forest stands suffer from fragmentation, pest outbreaks, forest fires and unsuitable practices that already challenge their capacity to survive and develop.

Finally, the effects of climate change on public health include the outbreak of infectious diseases from changing temperatures, increased morbidity and mortality from heat and other extreme weather events, malnutrition from droughts and floods and other water-borne, rodent-borne diseases and vector-borne diseases.

3.2 Process and criteria of prioritization

An inception and sector prioritization workshop was held to introduce the project in its global and national context and to clarify the role of the stakeholders in the process. The process of the TNA project was presented in terms of objectives, planned activities, number of expected national workshops, and overall project expectations.

The workshop also served as a sector prioritization session where all relevant sectors in mitigation and adaptation were presented, described in terms of emissions and vulnerability and analyzed for the selection of the priority sectors.

Mitigation prioritization was based mainly on the findings of the national GHG inventories that indicate that energy, both in terms of power production and transport, is the sector that contributes the most to GHG emissions. The selection criteria were:

- GHG reduction potential
- Availability of technologies
- Potential in attracting investment
- Potential of market penetration
- Cost of mitigation

The discussion lead to an unanimous agreement that the energy and transport sectors are indeed considered as priority development sectors in the country, as it is reflected in every ministerial declaration and in all development plans. The consensus resulting from the workshop was to focus on soft and hard technologies related to power production from public utilities and private generators as well as the transport management in terms of mass public transport and individual commutation.

As for adaptation prioritization, a Multi-Criteria Analysis (MCA) exercise was conducted using a scoring of 0 to 5, with 0 being “not important” and 5 being “extremely important” to rank the 6 most vulnerable sectors (agriculture, forestry, water, public health, coastal zone and, tourism) according to the following selection criteria:

- Vulnerability to climate change
- Adaptive capacity
- National priority based on development plans
- Socio-economic importance
- Extent to which change can be inflicted
- Technological availability
- Cost of adaptation

The exercise revealed a general consensus on the assessment of the water and agriculture sectors (average score of 32 for water and 27 for agriculture) followed by coastal zones (average score 20) and the public health sector (average score 19) (see Table 3).

Table 3 - Ranking of adaptation technologies through MCA

	Score	Agriculture	Forestry	Water	Public health	Coastal zones	Tourism
Vulnerability to climate change	1: low 5: high	4	3.7	4.5	2.5	4	2
Adaptive capacity	1: high 5: low	3.7	2.5	4.2	2.4	3.5	1.5
National priority	1: low 5: high	3.8	2.7	5	1.8	2.3	1.5
Socio-economic importance	1: low 5: high	4	2.4	4	4.5	3.7	3.8
Extent to which change can be inflicted	1: low 5: high	3.5	1.9	4.5	1	1.5	2.3
Technological availability	1: low 5: high	4.1	2.5	4.7	3.6	1.8	2
Cost of adaptation	1: high 5: low	3.8	2.3	5	3	3.5	1.8
TOTAL	26.9	18	31.9	18.8	20.3	14.9	
RANK	2	5	1	4	3	6	

3.3 Mitigation and adaptation prioritized sectors

3.3.1 Mitigation sectors

According to the sector prioritization exercise, and confirmed by the latest national GHG inventory results, the TNA project will assess the specific technology needs of the power and the transport sectors.

Although the government has been significantly active in initiating and implementing activities related to the power sector through relevant ministries, national and international organizations, the private sector and other partners, it was decided through the sector prioritization workshop to concentrate the work on power production from the supply side and not to tackle the demand side. Indeed, Demand Side Management is a topic that is intensively being dealt with in Lebanon and that the TNA project would not be much of an added value to it.

Contrarily to the power sector, the transport sector is unfortunately under-assessed at the national level, being confounded in political conflicts and being tore apart by overlapping of responsibilities between ministries and public agencies. The sector is characterized by a major lack of data, rare sound research and an uncooperative first circle of stakeholders. However, since it negatively impacts a large proportion of the population on the social and economical level, transport has raised to become one of the priority areas in the country's race to development needing urgent interventions.

3.3.2 Adaptation sectors

Based on the results of the vulnerability assessment published in the Second National Communication, and according to the prioritization exercise undertaken by stakeholders, the TNA project will assess the agriculture and water sectors in term of technologies identification and preparation of action plans.

Although these sectors have already been tackled numerous times as priority development areas, the TNA Project offers an opportunity to complement government efforts in these sectors and to propose specific targeted solutions to increase their resilience to the adverse impacts of climate change

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.
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)

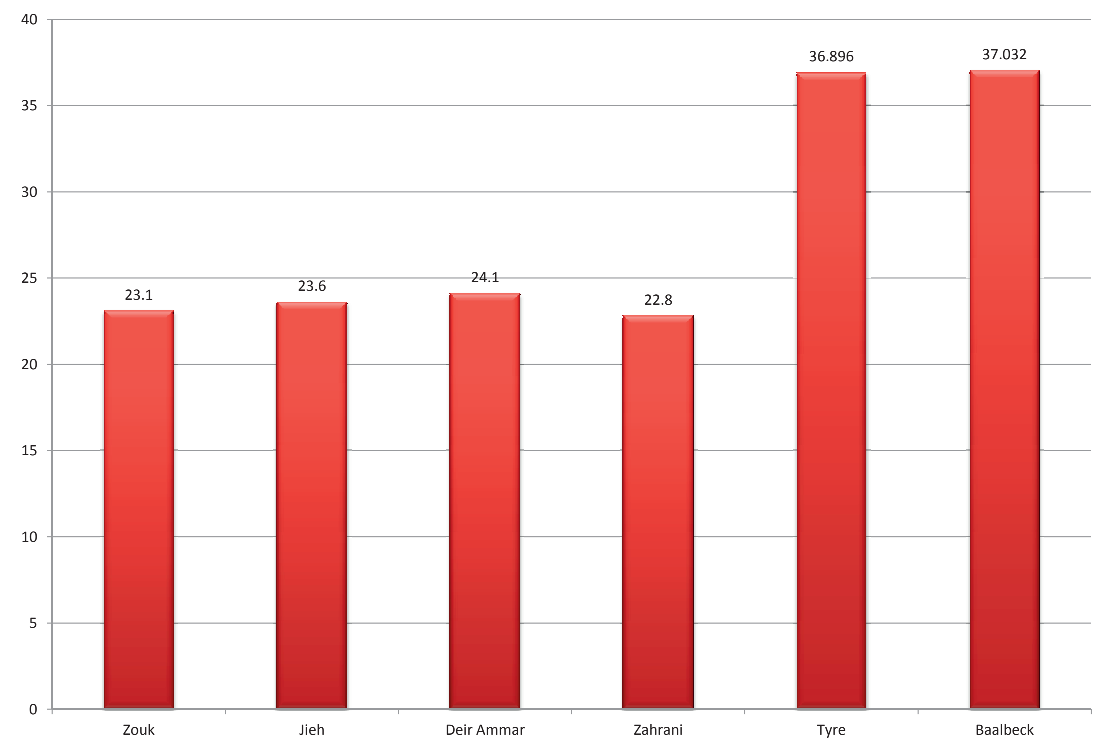


Fig. 3 - Levelized costs of existing power plants

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	Fuel cost*	Capital cost	Additional O&M costs	Option sustainability**	Societal and economic benefits**
	Tonnes CO_2	USD/MWh	10^6/MW	USD/MW	Average score	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.

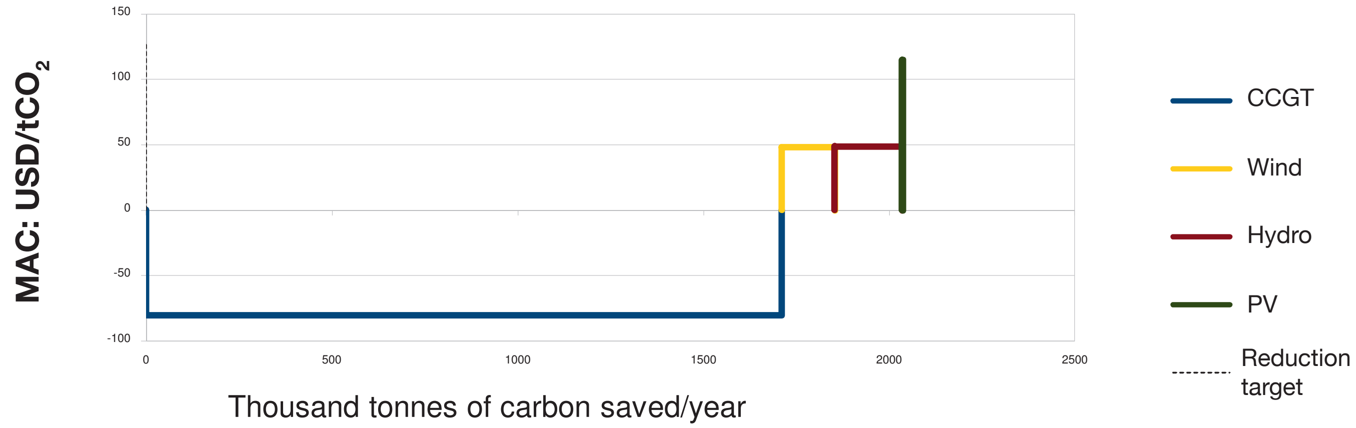


Fig. 4 - Marginal Abatement Cost of the 4 prioritized technologies

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
Institutional	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
Financial	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
Financial	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
Economic	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
Technological	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
Technological	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
Political	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.

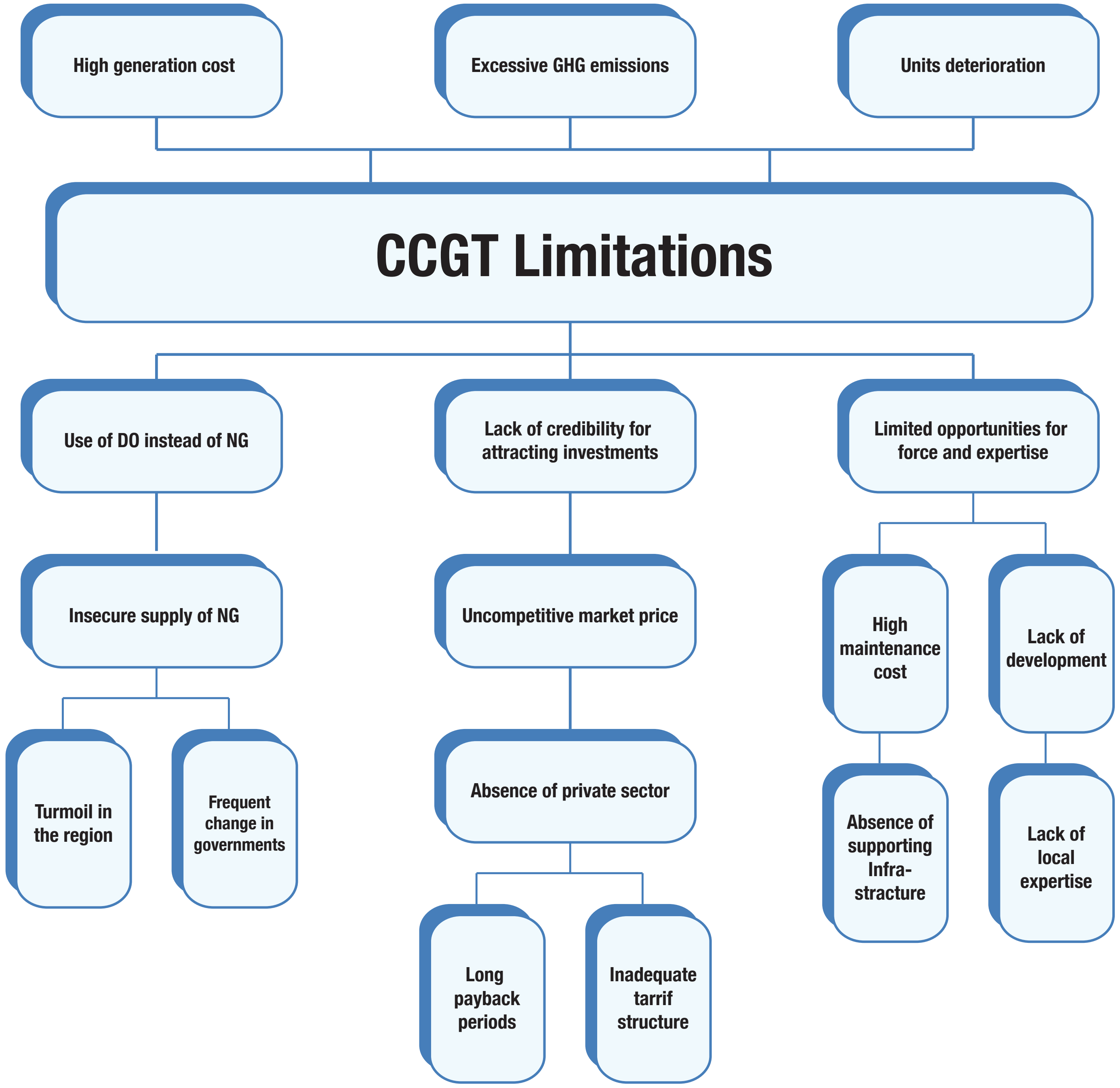


Fig. 5 Root cause analysis for CCGT.

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.

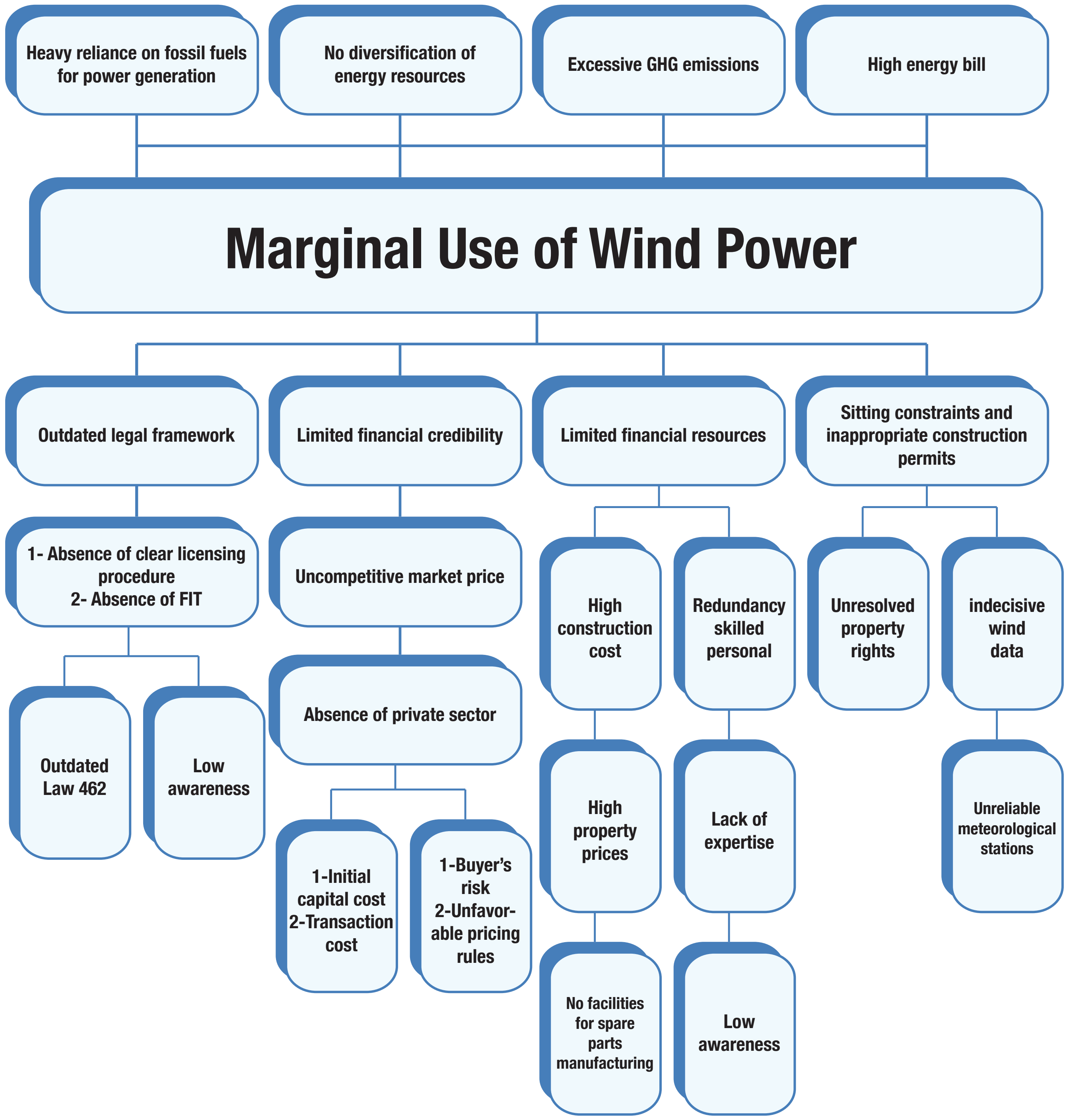


Fig. 6 - Root cause analysis for wind power

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.

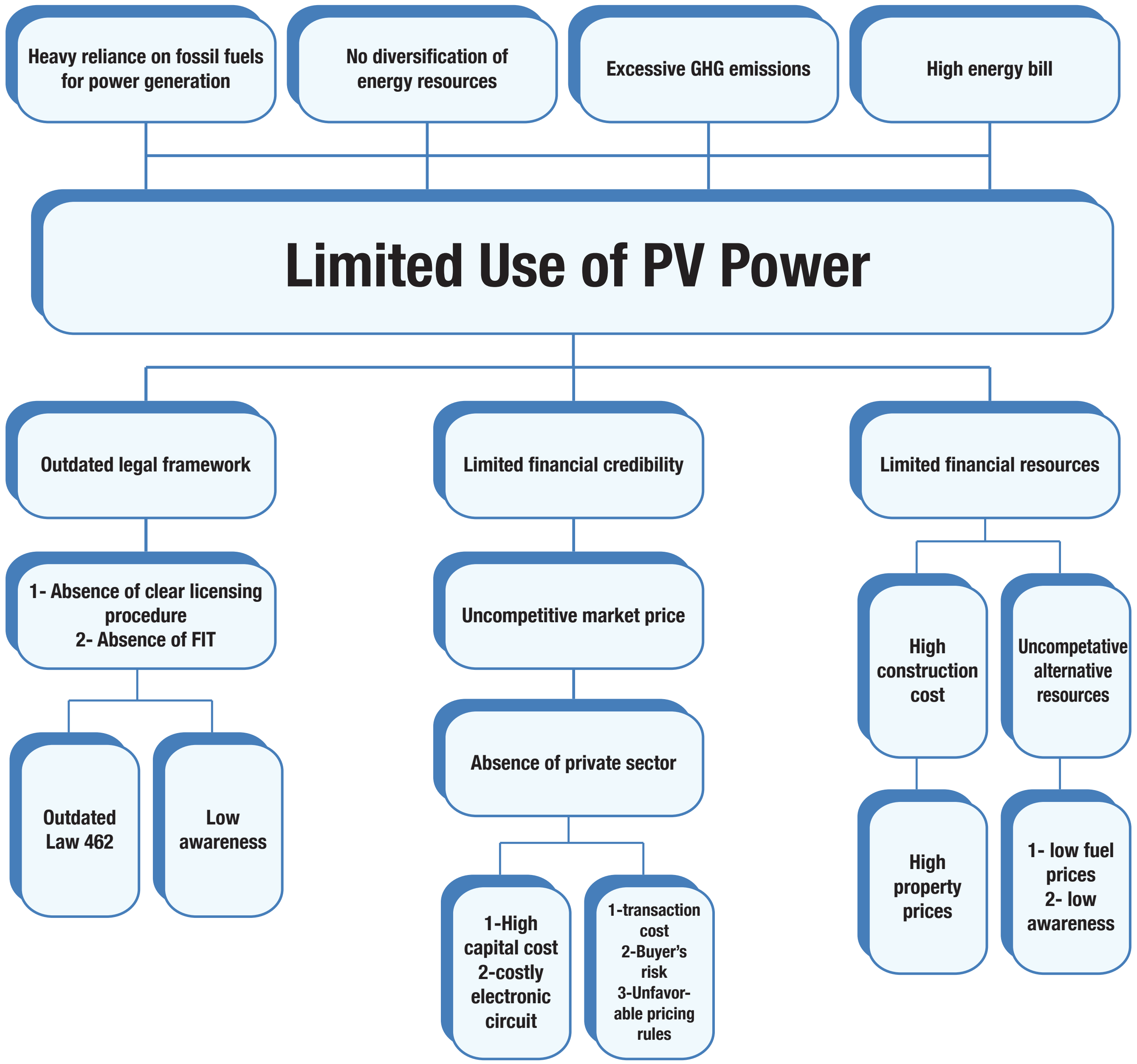


Fig. 7 - Root cause analysis for PV cells

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 the 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

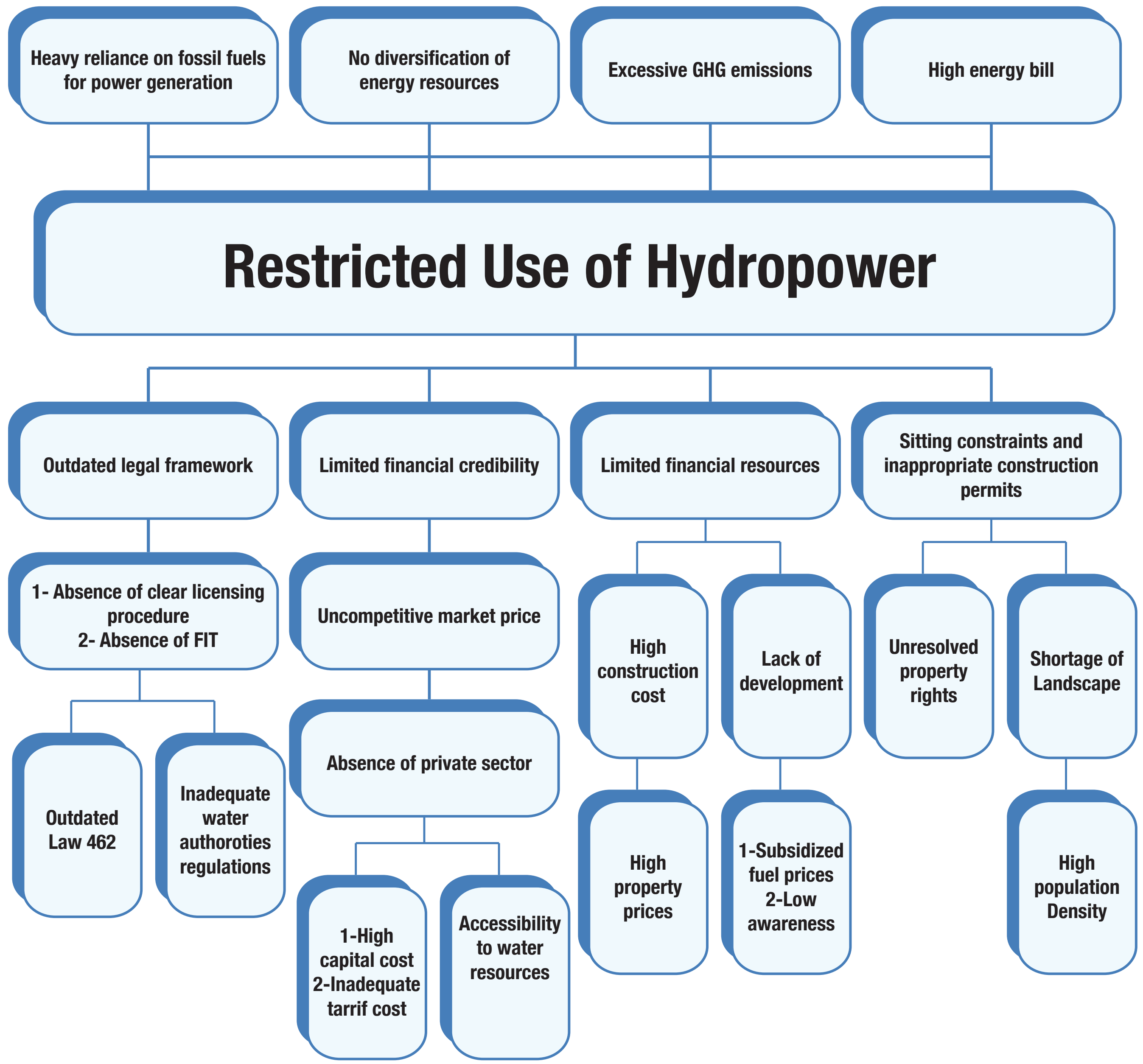


Fig. 8 - Root cause analysis for hydropower

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.

Levelized Cost of Production per Unit (US¢/kWh)

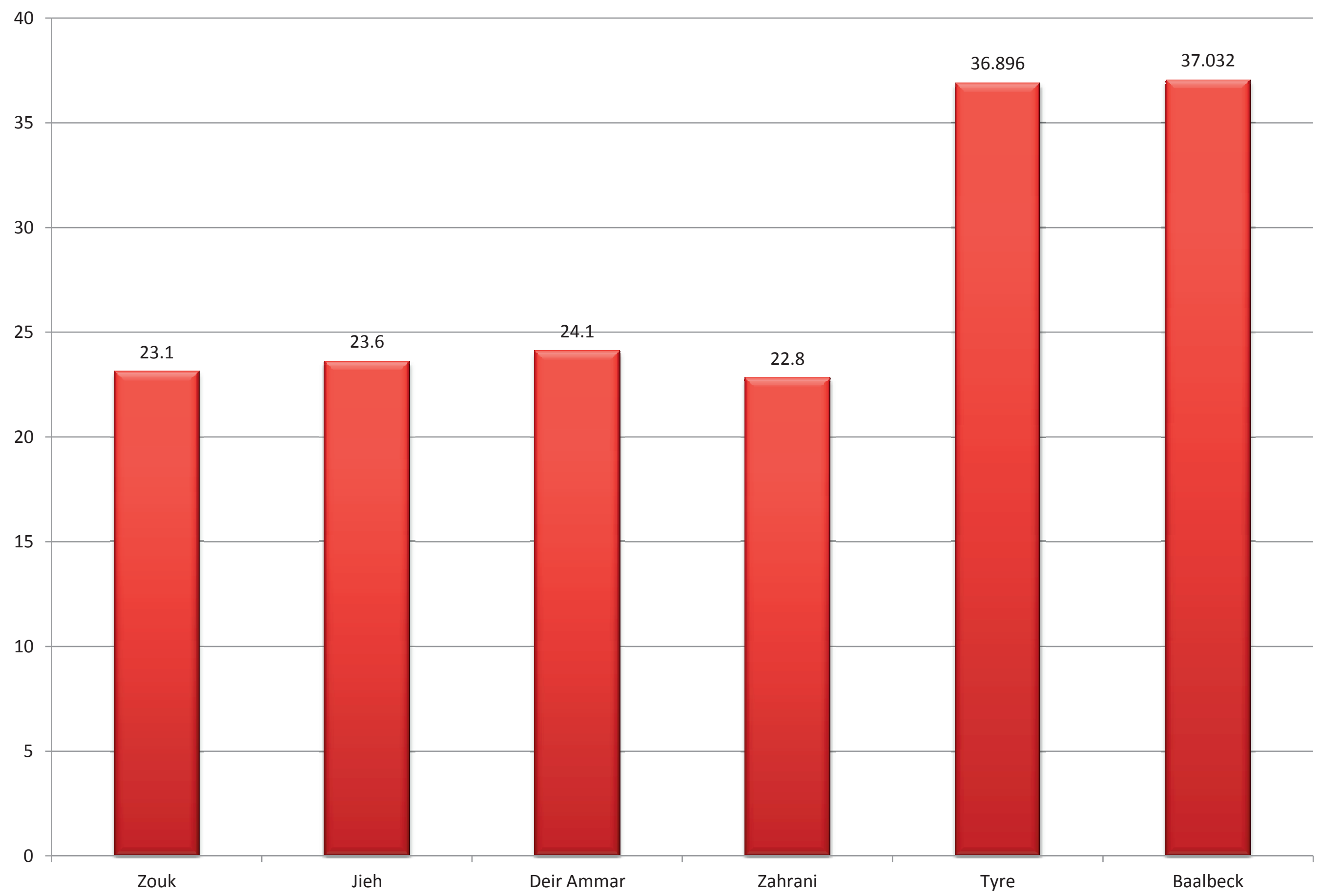


Fig. 9 - Levelized costs of existing thermal power plants

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.

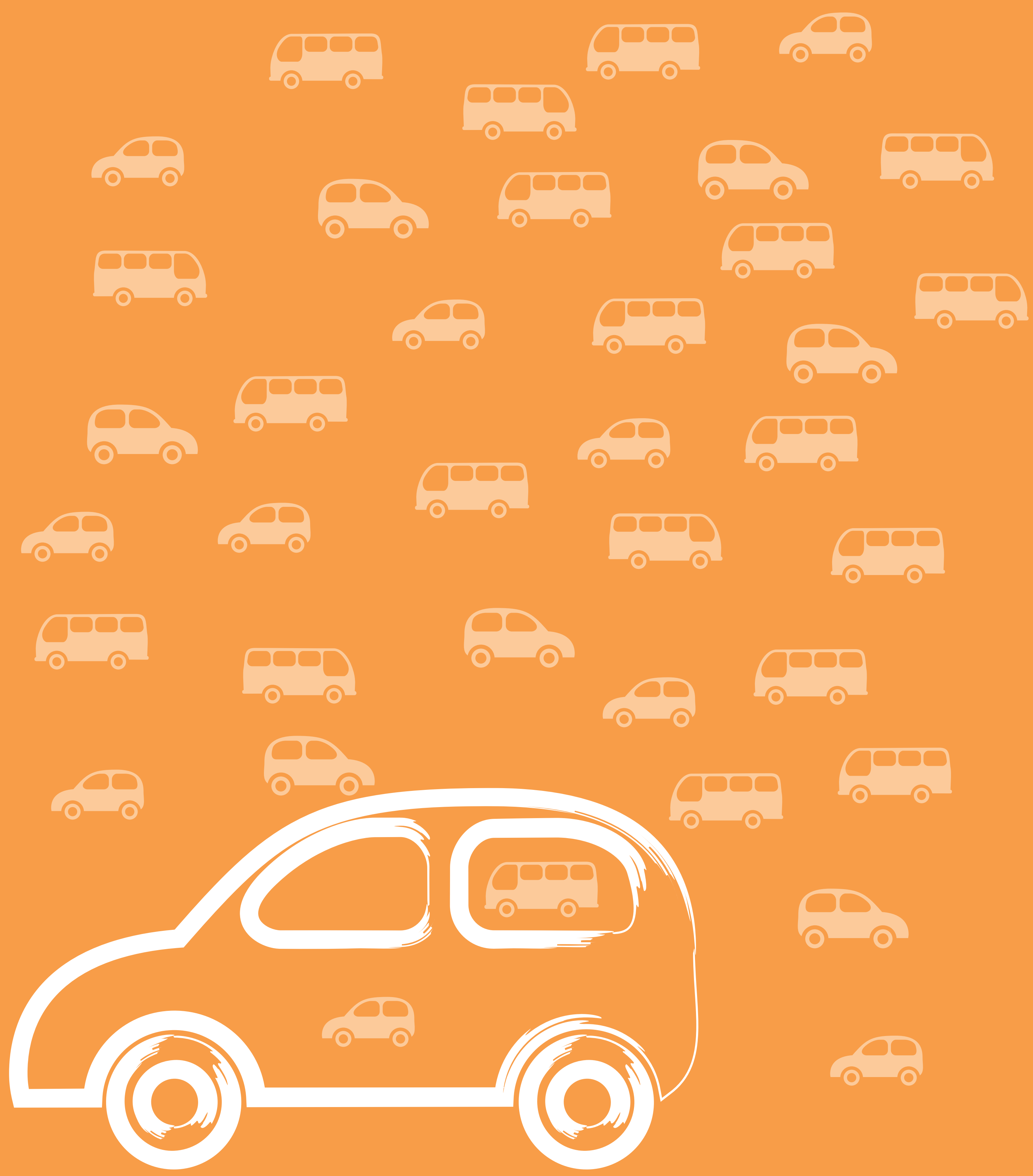
3. Benefit from New Market Mechanisms

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.

The Transport Sector



5.1 Sector overview

5.1.1 Scope of work

The scope of work in this TNA project embraces the road passenger transport sector, since it dominates all modes of transport in Lebanon and consumes the most energy produced by petroleum products. According to statistics from the International Energy Agency in 2008, the oil consumption of the road transport sector constituted more than 60% of the total oil consumption, 99.2% of which is gasoline (IEA, 2008). In terms of emissions, it accounts for nearly 21.4% of Lebanon's GHG emissions for the year 2000, and it is the main source of CO, NO_x and NMVOC emissions, with 94%, 59% and 66% respectively (MoE/UNDP/GEF, 2011).

The scope of this TNA project includes the road passengers' transport while freight, maritime and air transport are left out due to data unavailibility.

5.1.2 Road passengers' transport sector existing conditions

Reviewing past and current mobility assessments for the Lebanese road transport sector, passengers' mobility demand has experienced a real explosion since 1990, particularly in Greater Beirut Area (GBA), and the trend is strongly upward over the decade to come. This growth is mainly attributed to the raise of daily passenger trips and the increase of car ownership.

Traffic volume growth

GBA, which extends from Nahr-el-Damour south to Nahr-el-Kalb north, encloses more than 40% of the population of Lebanon, and 1.5 million of daily passenger trips estimated in 1994, expected to reach 5 million in 2015 (MoE/UNDP/GEF, 2011). Traffic conditions in GBA can be described as mostly congested, with a daily traffic volume of 230,000 passenger-car-unit crossing the north coastal highway and 85,000 the southern highway (Afif, 2012; Waked et al., 2012), and delays at some intersections ranging from 5 to 30 minutes (MoE, 2005).

Vehicle fleet overview

The current land transportation system mainly rely on vehicles, particularly private passenger cars that share in 2007 around 80% of the 1.55 million vehicles of the Lebanese car fleet, as indicated in Table 19. The rate of car ownership is estimated to be 3 persons per car in 2002, and the trend is to increase in the next decade with an annual rate of 1.5%.

Table 19 Lebanese vehicle fleet composition in 2007

Passenger cars	1,247,572
Red plate cars	47, 707
Heavy duty vehicles	183,428
2/3-wheelers	70,699
Agriculture vehicles	210
Total	1,549,616

Source:(MoE/UNDP/GEF, 2011)

The passenger cars fleet is old with an average age exceeding 13 years. 63% of the fleet is older than 20 years and 90% older than 10 years as indicated in Fig. 10. Moreover, the vehicle engine distribution shows that the fleet is mostly inefficient, since 60% of the cars have engine displacements exceeding 2.0 liters, while only 8% have engines less than 1.4 liters (Fig. 11).

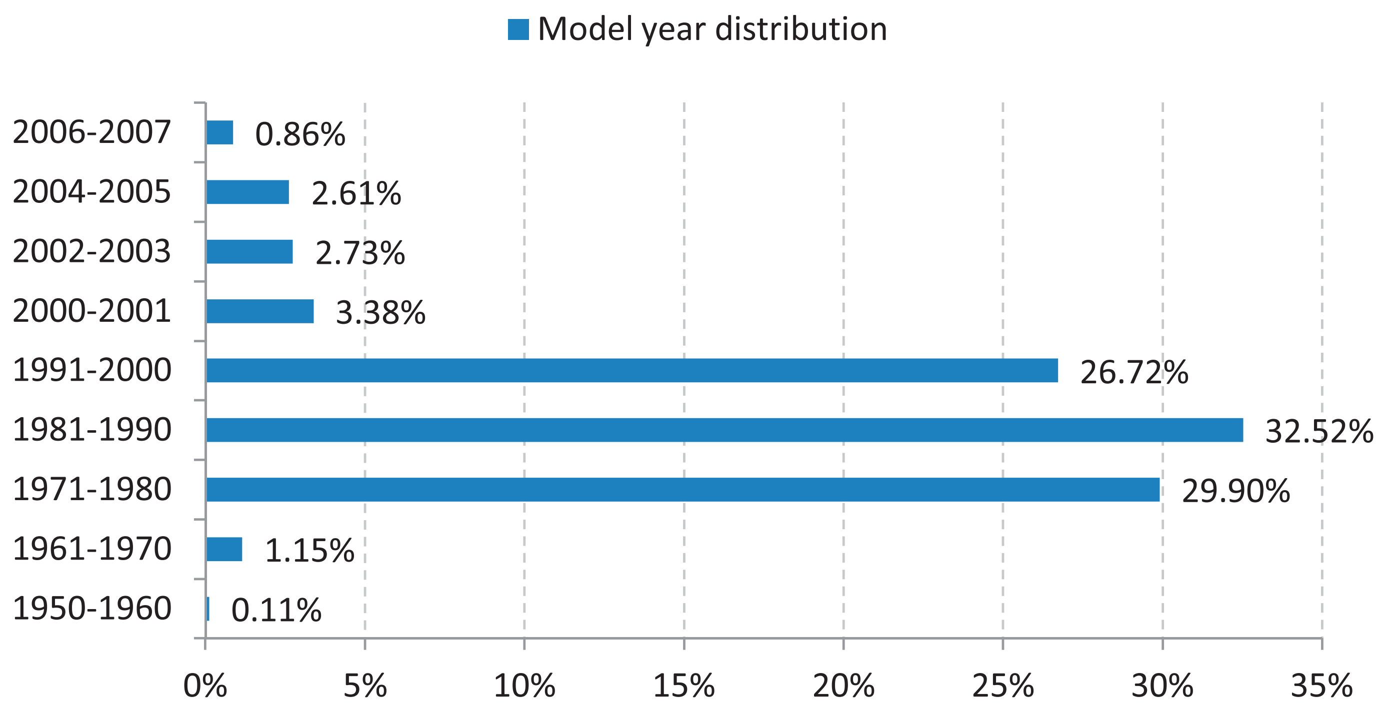


Fig. 10 - Lebanese vehicle fleet age structure in 2007.

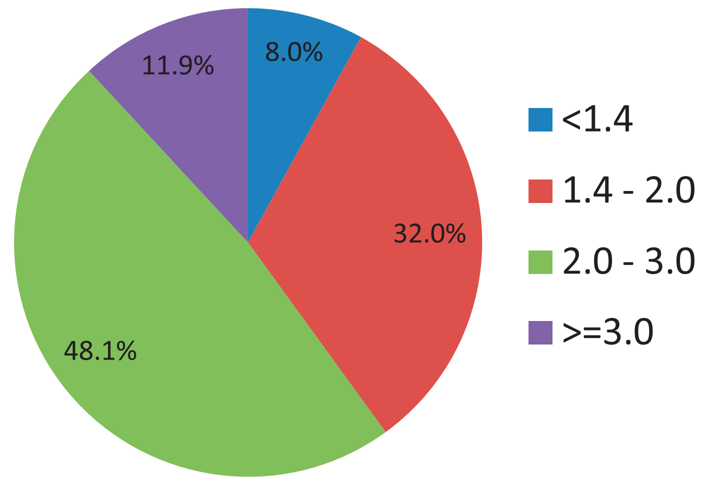


Fig. 11 - Engine displacement distribution of the Lebanese car fleet in 2007.

Public transport overview

Mass transport systems in Lebanon are generally characterized by being inefficient, unreliable and cost-ineffective. It relies on public and private buses, private vans and minibuses, and exclusive and shared ride taxis, operating without any coordination. In 2002, the mass transport market share in GBA was 31%, split between modes as illustrated in Fig. 12 (MoE, 2005). In 2007, the database of registered vehicles shows that the number of mass transport vehicles registered is 55,875, with 47,707 exclusive and shared taxis.

Contrary to the high number of mass transport vehicles, occupancy rate of mass transport systems is low, as indicated in Table 20.

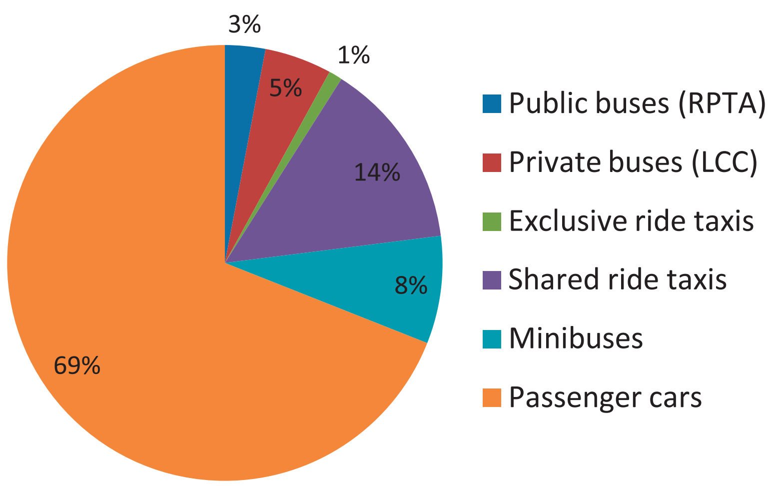


Fig. 12 - Market share of transport systems in GBA in 2002

Source: (MoE, 2005)

Table 20 - Vehicle occupancy in GBA in 2008

	Vehicle occupancy (passengers excluding driver)
RPTA buses	15.1
LCC buses	11.2
Exclusive ride taxis	1.18
Shared ride taxis	1.18
Red plate vans	5.93

Source: (Team International, 2010)

Driving conditions overview of passenger cars in GBA

Based on collected data from on-road measurements in GBA through GPS survey with different drivers, the GBA driving conditions in 2011 are characterized by the following:

- 50% of total trips have a total distance lower than 5 km and 75% lower than 12 km, with an average trip distance of 9.6 km.
- 25% of stops are below 2 seconds and 75% below 10 seconds.
- Stop time corresponds to more than 15% of travel time.

This statistical survey reflects the low driving range in GBA with high rate of congestion and high rate of short time stops. Moreover, the speed acceleration frequency distribution presented in Fig. 13 shows that the acceleration rates are significant at very low speed, which result in an inefficient operation of internal combustion engines; thus leading to a high rate of fuel consumption and pollutant emissions in conventional gasoline powered vehicles.

All these existing conditions have led the road passengers' transport sector to have a high passenger transport energy intensity in 2007, estimated at 3.08 MJ/passenger-kilometer (Fig. 14), in addition to having a high energy demand of 15.06 GJ/capita, exceeding the world average (Fig. 15).

As a result, GBA passengers are suffering from high budget required for transport, high dependence on fossil fuels, in addition to alarming pollution rates particularly in urban areas. Therefore, road passengers' transport is a key sector for reducing the total fuel consumption and emissions of Lebanon.

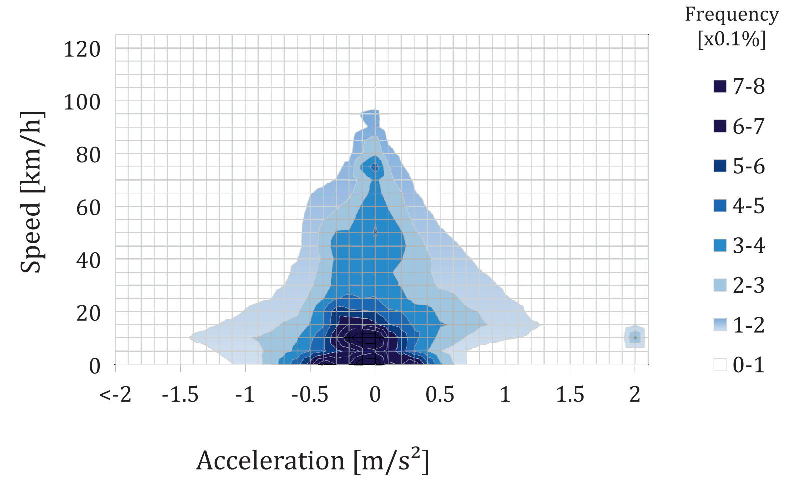


Fig. 13 - Speed-acceleration frequency distribution

Source: (Mansour and Zgheib, 2012)

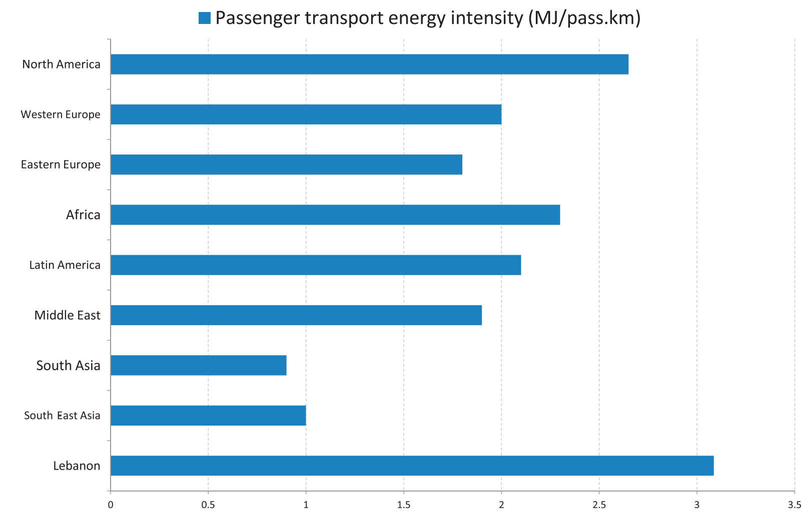


Fig. 14 - Transport energy intensity (2007 for Lebanon and 2005 for the rest of regions)

Source: (Electris et al., 2009).

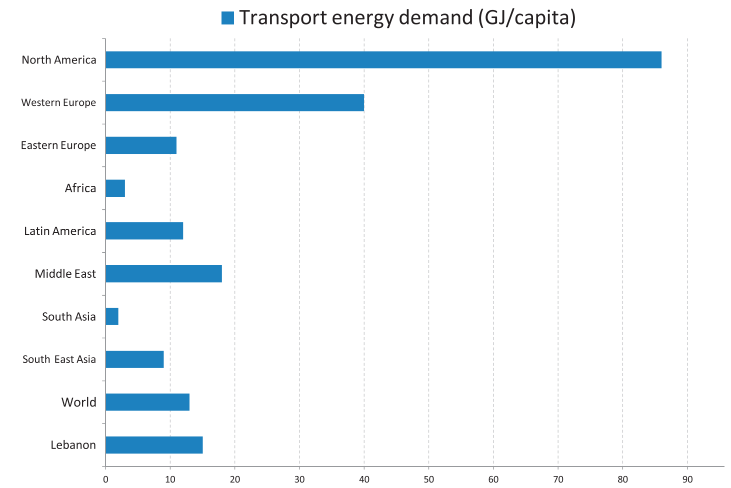


Fig. 15 - Passenger transport energy demand per capita. (2007 for Lebanon and 2005 for the rest of regions)

Source: (Electris et al., 2009).

5.1.3 Actions at sectoral level

Existing policies and Measures

The main existing transport legislation relevant to the mitigation of GHG emissions comprises:

Rules/Policies/Regulations	Description
Decree No. 124/2003	Specifications of motorcycles and engines, and allowed time to drive, applied in all areas of Lebanon.
Decree No. 8243/2003	Mandatory Annual vehicle inspection.
Decree No. 11244/2003	Set up Traffic Management Organization (TMO) which has yet to carry out a technical traffic management role rather than just an administrative one.
Decree No. 7858/2002	• Incentives to renew the fleet such as exempting new cars, 5 years old cars, public transport cars, and buses of no more than 24 passengers from import tax, and registration, and inspection fees. • Compensate owners of private cars, public transport cars, and buses which would convert to gasoline engines with amounts ranging from 1,000,000 to 13,000,000 L.L depending on the year of manufacture. • Ban the use of private and public cars of diesel engines starting from 15/6/2002. • Ban the use of private and public transport autobuses of diesel engines starting from 15/7/2002. • Ban the use of public buses of 16 to 24 passengers of diesel engines starting from 31/10/2002. • Designate the port of Beirut and Tripoli for collecting the replaced engines until they are exported outside Lebanon.
Decree No. 8442/2002	Specifications of fuel motor vehicle; diesel oil and gasoline 92, 95 and 98 octane.
Law 341 (6/08/2001)	The law lays the legal framework for reducing air pollution from the transport sector and encouraging the use of cleaner sources of fuel. Specifically, the law bans the import of minivans operating on diesel engines, as well as old and new diesel engines for private passenger cars and minivans. The law empowered the GoL to retrieve 10,000 public license plates operating on diesel.
Council of Ministers decision 9, on 5/4/2000	The decision calls for the reform and reorganization of the Land Public Transport Sector in Lebanon and the reduction of the number of public transport vehicles from 39,761 to 27,061 vehicles.
Decree 6603 (4/4/1995)	It defines standards for operating diesel trucks and buses, as well as the implementation of a monitoring plan and permissible levels of exhaust fumes and exhaust quality (particularly for CO, NO_x ,hydrocarbons and TSP).

5.1.4 Mitigation strategies

Based on the prevailing conditions in the Lebanese road transport sector, reducing GHG and pollutant emissions from passengers' transport means (per passenger-kilometer) has become a must, which implies reducing the dependence on fossil fuels. The objective of this TNA report is to identify and prioritize technologies that contribute to mitigating emissions and fuel consumption in road passengers' transport.

Reviewing the existing conditions in the passenger transport sector, several factors need to be considered for mitigation: (1) reduce the number of passenger cars, (2) reduce the number and length of trips, (3) increase the vehicle occupancy rates, (4) increase mass transit means, (5) improve the vehicle efficiency, (6) increase the use of low carbon fuels, (7) increase urban average traffic speed.

Based on these mitigation factors, it is clear that no single measure will provide the solution and that action is needed simultaneously through different mitigation strategies. The priority strategies identified for consideration in Lebanon seek to:

- Revitalize the public transport systems
- Renew the existing car fleet through a scrappage programme
- Optimize the use of existing and planned road networks

However, the implementation of these strategies won't be successful without the adoption of enforcing strategies and policies:

- A well defined transport demand management system, based on shifting demand toward low carbon modes through pricing incentives and disincentives
- Legislative reforms regarding urban planning laws, expropriation laws, taxes and tariffs, traffic and driving laws

Fig. 16 reviews the process for reaching the objective of reducing the GHG and pollutant emission levels from transport sector.

Many ongoing projects aim at improving road networks, particularly the Urban Transport Development Plan for the city of Beirut, implemented by the Council for Development and Reconstruction (CDR). It consists of implementing a traffic management system, an on-street parking management system, a corridors improvement programme, and an establishment of the Traffic Management Organization (TMO) (MoE, 2005). Hence, the mitigation strategies to be considered in this TNA will focus on the remaining two strategies: revitalizing the public transport and renewing the existing car fleet.

The associated mitigation technologies to each of the two strategies are illustrated in Fig. 17, classified under "bus technologies for public transport", "advanced powertrains for passenger cars" and "alternative fuels for passenger cars".

5.2 Possible mitigation technology options in the transport sector and their mitigation benefits

This section highlights the characteristics of the identified mitigation technologies presented in Fig. 17, in addition to their energy consumption savings and environmental benefits comparing to Business As Usual (BAU). Two reference scenarios are considered in the analysis: the Lebanese average fuel consumption of its passenger cars fleet in 2007 under GBA driving conditions (11.16 l/100km) (Mansour et al., 2011) and the world average feul consumption of new car fleet in 2005 (8.07 l/100km) (IEA, 2011). The objectives are to identify the benefits relative to the existing conditions in GBA and its old fleet, in addition to highlighting the benefits relative to a complete new vehicle fleet with recent technologies dating 7 years.

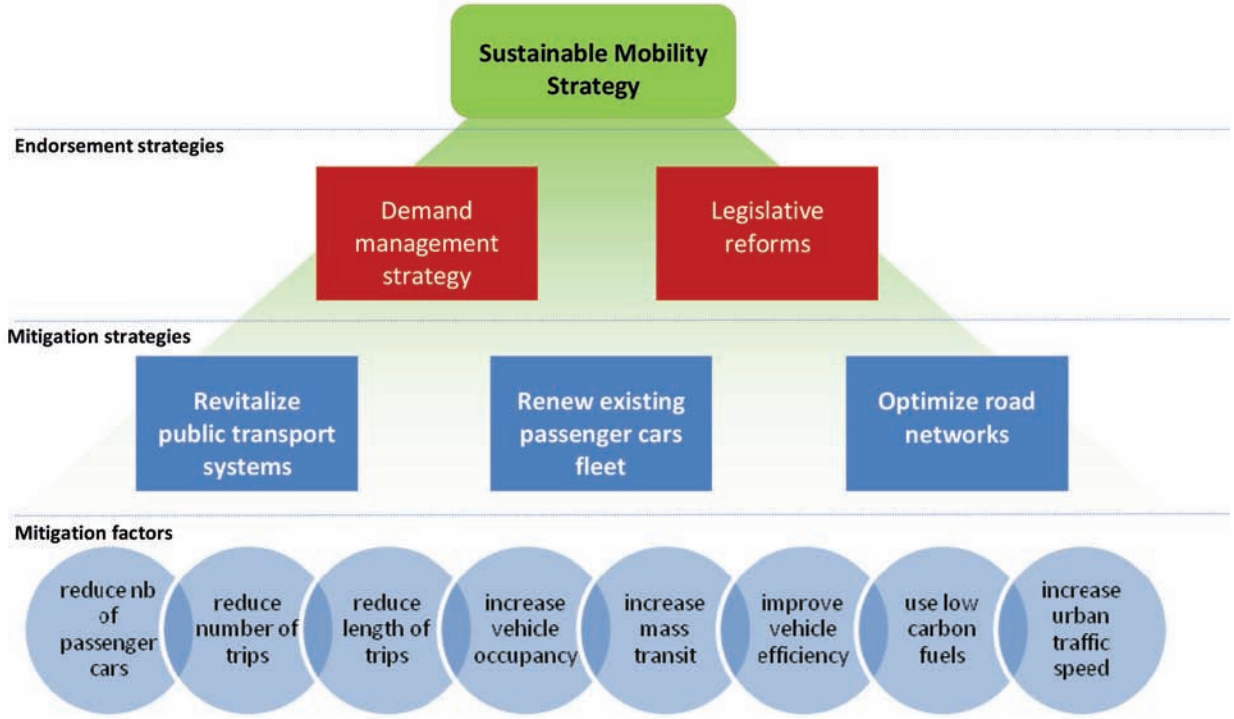


Fig. 16 - Process for reducing emissions from transport sector.

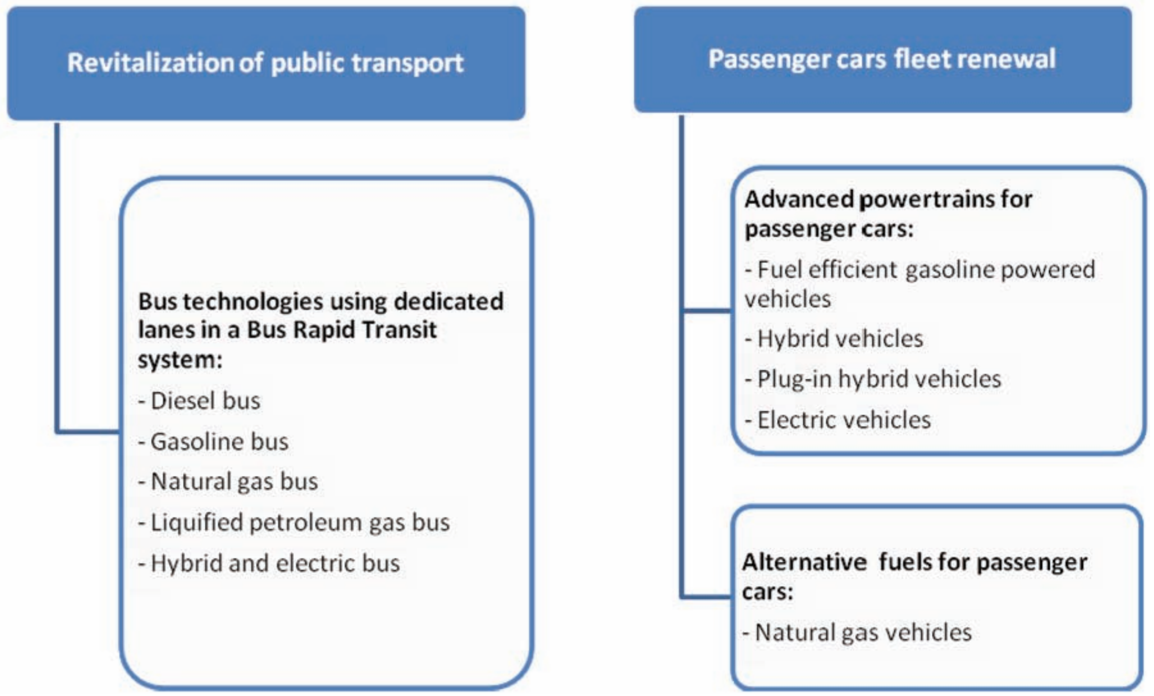


Fig. 17 - Mitigation technologies to be prioritized for each mitigation strategy.

5.2.1 Assessment methodology

In the context of assessing energy consumption and emissions savings of the identified mitigation technologies relative to the existing Lebanese road passenger transport means, results from end-of-life on-road measurements have been used, in addition to simulation results from specific powertrain simulation and life-cycle-analysis tools. These tools were used in order to bypass the complexity of real world measurements and obtain results reflecting the Lebanese existing conditions. Specific models are developed and validated for the purpose of this TNA and adapted to the existing conditions of road passengers' transport in GBA.

In fact, different variables need to be considered for assessing the consumption and emissions in real driving conditions, such as road gradient, stop duration, use of accessories, driver behavior, routes length, driving situation chronology and weather condition (Zgheib, 2009). Moreover, the variables in driving conditions are unique for every geographical area because of the variation of the road network topography, traffic congestion, car fleet composition and driving behavior in the underlying region (Andre, 2004). Accordingly, specific driving cycles emulating the Lebanese driving conditions in GBA are built for the purpose of this TNA, based on on-road measurements through GPS data logging (Mansour et al., 2011; Mansour and Zgheib, 2012).

Consumption results have served in assessing the operating costs of each of the technologies, according to its associated energy price. Other cost assessment issues such as maintenance and additional purchase costs have been determined from the literature and market review.

5.2.2 Bus technologies

Technology characteristics

Though diesel buses are still the most used bus technology worldwide, several bus technologies have made a breakthrough in public transport services, relying on different sort of fuels other than diesel. Among them are alternative fuel buses operating on CNG, LNG and LPG, and electric driven buses.

Bus public transport is a real mean to short-term solution to the environmental pollution issues in Lebanon, particularly when bus technologies are coupled to a well designed transport demand management system and dedicated lanes, like the Bus Rapid Transit (BRT) system.

Bus public transport with dedicated lanes contribute to the following aspects of sustainable developments: (1) improvement of air quality, (2) reduction of GHG emissions, (3) congestion reduction, (4) increase in energy supply security due to reduction of imported oil, (5) social equality and poverty reduction by providing affordable transport

with lower operating costs than passenger cars per passenger-kilometer, (6) economic prosperity by reducing travel times and congestion. However, bus technologies not coupled to dedicated lanes and a well-defined demand management strategy lead to negative impacts on the environment and the traffic, case of the current conditions of public transport in GBA.

Fuel consumption and GHG emissions reduction potention

The passenger-kilometer efficiency of bus technologies is higher than that of the passenger cars, which is the main reason why public transport can lower the GHG and pollutant emissions of road traffic and reduce the total energy use. Nevertheless, this efficiency differs largely with the type of fuel used and the bus occupancy. Fig. 18 and Fig. 19 illustrate the passenger-kilometer efficiency and CO_2 emissions of different bus technologies as function of their occupancy. Results are compared to the average efficiency of the Lebanese car fleet in 2007, with 1, 1.5, 2 and 3 pass/veh.

In Lebanon, passenger cars occupancy is estimated to be lower than 2. Therefore, diesel, gasoline, CNG and electric driven buses would present a better efficiency and lower CO_2 emissions as their occupancy exceeds 10 to 15 pass/veh. 40.9 and 80.3% of CO_2 savings are observed with diesel buses with occupancy of 10 and 30 pass/veh respectively, comparing to Lebanese passenger cars fleet of 2007, under GBA driving conditions.

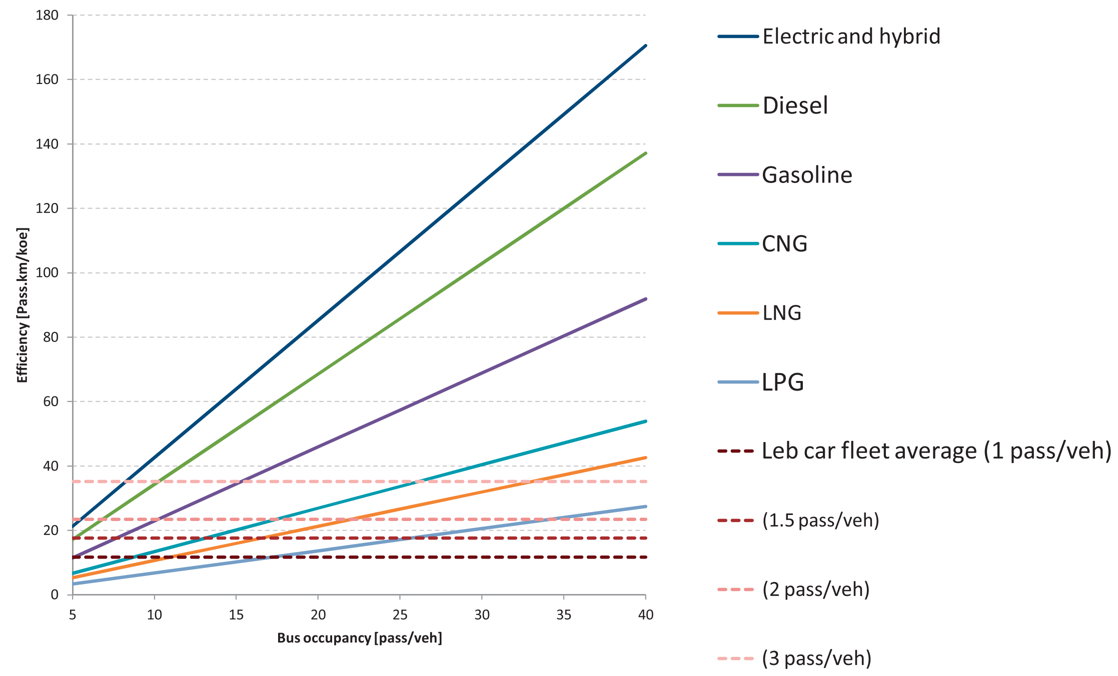


Fig. 18 - Efficiency of bus technologies as function of bus occupancy, relative to the Lebanese average passenger cars efficiency, with 1, 1.5, 2 and 3 pass/veh occupancy.

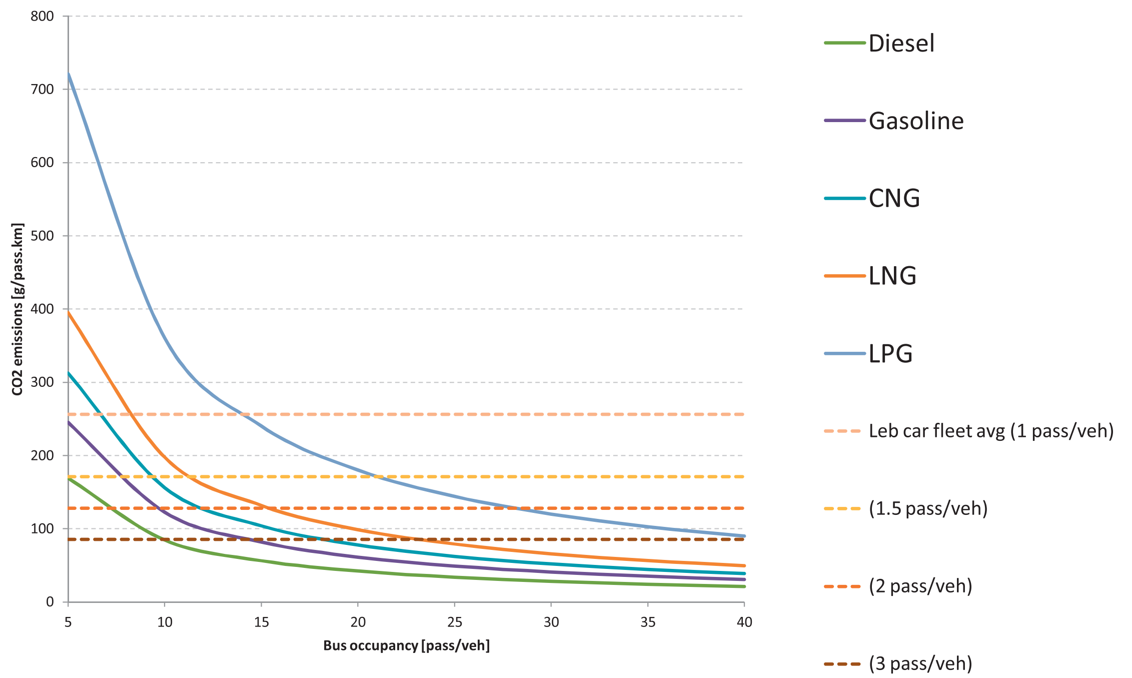


Fig. 19 - CO_2 emissions of bus technologies as function of bus occupancy, relative to the Lebanese average passenger cars CO_2 emissions, with 1, 1.5, 2 and 3 pass/veh occupancy.

5.2.3 Fuel efficient gasoline powered vehicles

Technology characteristics

Fuel efficient vehicles are commonly known by conventional gasoline powered vehicles with low consumption (estimated lower than 6.5 l/100km). These vehicles are equipped with advanced technologies and present advantages of consumption and emissions reduction comparing to similar gasoline vehicles within same vehicle segment (two-seaters, subcompact, compact, mid-size, full-size, station-wagon).

The advanced technologies are classified as passive and active systems, illustrated in Fig. 20. Passive systems have indirect impact on reducing fuel consumption, such as reducing the vehicle weight; and active systems have direct impact on consumption reduction such as engine downsizing, idle stop/start systems and continuous variable transmissions.

Fuel efficient gasoline powered vehicles are characterized by the following:

- No major modifications within the power train (similar to conventional vehicles); hence, drivers don't have to adapt their driving techniques to these new technologies.
- Technologies can be applied on the basis of modular flexibility where different combination of features (listed in Fig. 20) can be observed.
- With the addition of stop/start systems, combinations of technologies and the use of turbo charging technology to downsize the engine lead to 15-25% improvement compared to current gasoline engines.
- Additional costs are observed according to the added features, but remains cheaper than alternative technologies like hybrid vehicles.

Potential for reducing fuel consumption and GHG emissions

Considerable consumption and CO_2 emissions savings are observed with fuel efficient vehicles for all vehicle segments, as indicated in Table 21. These savings range from 10 to 50% comparing to the world average new cars fleet of 2005, and from 35 to 64% comparing to the Lebanese average consumption of the passenger cars fleet in 2007 under GBA driving conditions.

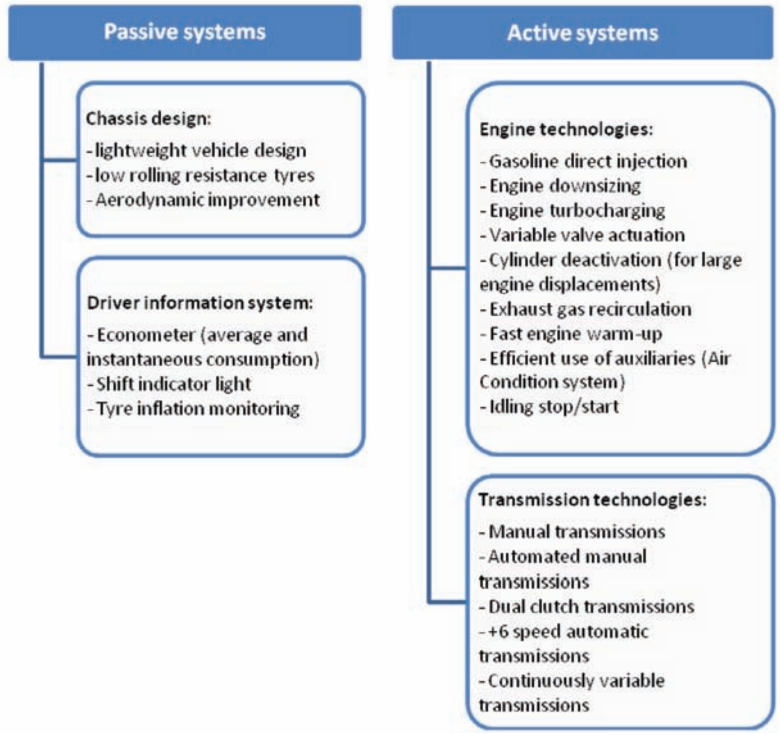


Fig. 20 - Passive and active system technologies of fuel efficient gasoline powered vehicles.

Table 21 - Fuel consumption and CO_2 emissions of fuel efficient gasoline powered vehicles, compared to Lebanese average existing cars fleet (in 2007) and to world average new cars fleet (in 2005).

Vehicle segment	Fuel efficient gasoline powered vehicles 2011	Fuel consumption on combined cycle (l/100km)	CO_2 emissions (g/km)	Fuel and CO_2 savings relative to world average 2005	Fuel and CO_2 savings relative to Lebanese fleet 2007
Two-seaters	45 kW - Manual 5spd	4.2	97	48.0%	62.7%
Mini-compact cars	63 kW - Manual 5spd	4	92	50.4%	64.7%
Sub-compact cars	74 kW - Manual 6spd	5.2	120	35.6%	53.9%
Compact cars	73 kW - Manual 6spd	5.8	135	28.1%	48.1%
Midsize cars	90 kW - Manual 6spd	6.7	155	17.0%	40.5%
Large cars	115 kW - Manual 6spd	7.3	168	9.5%	35.5%
Station-wagons	90 kW - DCT 7spd	6	139	25.7%	46.6%
Average CO_2 emissions of the Lebanese existing fleet in 2007 is estimated 260.4 g/km under GBA driving conditions. Average CO_2 emissions of the world new cars fleet in 2005 is estimated 188.3 g/km.					

Source : (ADEME, 2011; Mansour et al., 2011).

5.2.4 Hybrid electric vehicles

Technology characteristics

Hybrid electric vehicles (HEV) combine an electric motor and battery pack to the internal combustion engine (ICE) found in conventional vehicles. Three powertrain configurations are observed: parallel, series and series/parallel. HEVs are also classified as micro-hybrid, mild-hybrid, full-hybrid, plug-in hybrid and range-extender electric vehicles. They are differentiated by the fraction of electric power added onboard; consequently, the ability to achieve more hybrid functions. Note that the more electric energy is available onboard, the more fuel reduction will result, at the expense of additional control complexity and additional purchase cost.

HEVs are characterized by the following:

- More economical to run with consumption lower than 5 l/100 km in compact cars.
- High driving range of about 960 kilometers, twice that of conventional vehicles and six times that of electric vehicles.
- Fewer tailpipe pollutants because of their electric powertrains and efficiently-operated internal combustion engines.
- Downsized internal combustion engine, designed to operate efficiently when meeting average power needs because the battery intervenes when extra energy is required. In conventional vehicles, the engine is designed to meet peak power needs, thus it is oversized.
- Lower maintenance costs compared to conventional vehicles, estimated from an end-of-life study between 0.6 and 1.8 US¢/km, where the average maintenance cost for conventional vehicles from the same vehicle segment is 2.6 US¢/km (USDOE, 2011). Note that HEVs may need a battery change over the vehicle life.
- Do not require additional infrastructure investments.

Fuel consumption and GHG emissions reduction potential

Hybrid vehicles present significant fuel and CO_2 savings under current GBA existing conditions, as indicated in Table 22. 40 to 53% savings are observed with small to midsize cars. Moreover, the Table highlights the technology advancement in recent years, since 17 to 35% of savings are achievable comparing to gasoline technologies of 2005. On another note, large hybrid cars and SUVs present consumption figures above the world average, but still lower than comparable gasoline car models.

Table 22 - Fuel consumption and CO_2 emissions of end-of-life hybrid vehicles, relative to Lebanese average of 2007 existing cars fleet and to world average of 2005 new cars fleet

Vehicle segment	Fuel consumption on combined cycle	Fuel and CO_2 savings relative to world average 2005	Fuel and CO_2 savings relative to Lebanese fleet 2007
	(l/100km)		
Sub-compact cars	5.2	35.5%	53.4%
Compact cars	5.3	34.2%	52.4%
Midsize cars	6.7	17.2%	40.1%
Large cars	7.9	2.2%	29.3%
SUV	10.1	-24.6%	9.9%

Source: (USDOE, 2011).

5.2.5 Plug-in hybrid electric vehicles

Technology characteristics

A plug-in hybrid electric vehicle (PHEV) is an extended version of hybrid vehicle, which utilizes rechargeable batteries that can be restored to full charge by connecting a plug to an external electric power source. A PHEV shares the characteristics of both a conventional hybrid electric vehicle and a battery electric vehicle, having a plug to connect to the grid. Therefore batteries of PHEVs have bigger capacities than conventional HEVs.

Regardless of its architecture, a PHEV is capable of charge-depleting and charge-sustaining modes:

- Charge-depleting mode allows a fully charged PHEV to operate on electric power until its battery state of charge is depleted to a predetermined level. This mode is the vehicle's all-electric range mode (AER).
- Charge-sustaining mode is the same operating mode as conventional HEVs.

Once a PHEV has exhausted its AER in charge-depleting mode, it switches into charge-sustaining mode automatically.

PHEVs are characterized by the following:

- Less dependence on fossil fuels: PHEVs are expected to use about 40 to 60% less petroleum than conventional vehicles. The consumption of current prototypes ranges from 2.2 to 4.3 l/100km in combined driving conditions, depending on everyday charging frequency.
- Less GHG emissions: PHEVs emit less GHG than conventional vehicles, but the amount generated depends partly on the fuel used at electrical power plants. Renewable sources are highly recommended rather than the currently used in Lebanon residual-oil-burning power plants, or coal-fired power plants.
- Driving range higher than conventional vehicles, since an engine is still onboard to extend the range of the vehicle once the battery charge is depleted.
- Lower operating costs: though PHEVs will likely cost 5,700 to 7,400 USD more than comparable conventional vehicles, the consumed energy will cost less since electricity is cheaper than gasoline. Incentives will play a decisive role in promoting PHEVs.
- Lower maintenance costs: maintenance costs of PHEVs are similar to HEVs, thus lower than conventional vehicles, due to less use of the engine. However, PHEVs may need a battery change over the vehicle life.

However, serious concerns are faced by PHEVs: the recharging time lasts for 1 to 2 hours and the need of a recharging infrastructure is a prerequisite.

Fuel consumption and GHG emissions reduction potential

Fuel consumption of PHEVs depends on the everyday charging frequency. According to consumption results from on-road measurements on PHEV fleets, around 2.4 l/100km are observed for a charging frequency of 2 times/day and 4.1 l/100km for 1 time/day (Zgheib, 2012). Such results lead to fuel savings up to 78.5% under GBA driving conditions, and up to 55% comparing to their similar HEV versions, as indicated in Table 23.

In terms of CO_2 emissions, the vehicle operation emissions are lowered in the same range of the fuel consumption rates. However, the final CO_2 emission reduction depends strongly on the source of the electricity used. A larger deployment of renewable energy sources would lower the CO_2 emission of the PHEV further.

Table 23 - Fuel consumption of on-road measurement PHEV fleets in Japan and France, relative to Lebanese average of 2007 existing cars fleet and to world average of 2005 new cars fleet

Vehicle segment	Charging frequency	Fuel consumption (l/100km)	Fuel savings relative to world average 2005	Fuel savings relative to Lebanese fleet 2007	Fuel savings relative to simi-lar HEV version
Compact car	2.1 times/day	2.2	70.3%	78.5%	55.1%
	0.9 time/day	4.3	49.2%	63.3%	23.4%

Source: (Zgheib, 2012).

5.2.6 Battery electric vehicles

Technology characteristics

Battery Electric Vehicles (BEV) are propelled by an electric motor, powered by rechargeable battery pack. They derive all the power from the battery pack and thus have no internal combustion engine.

BEV is a real mean to long-term solution to today's environmental and noise pollution issues in GBA. Technological innovations now make it possible to mass market an electric vehicle at reasonable cost. In addition, changes in vehicle use make electric cars ideal for the majority of trips in GBA, since 94% of the trips are lower than 20 km (Mansour et al., 2011).

BEVs offer several advantages compared to conventional vehicles:

- Energy efficient: its electric powertrain converts around 75% of the chemical energy from the batteries to power the wheels, where internal combustion engines only convert 20-30% of the energy stored in gasoline on highways and less than 15% in urban areas.
- Environmentally friendly: BEVs emit no tailpipe pollutants, although the power plant producing the electricity may emit them. Electricity from nuclear, hydroelectric, solar, or wind-powered plants causes no air pollutants.
- Performance benefits: Electric motors provide quiet, smooth operation and stronger acceleration and require less maintenance than ICEs (estimated to be half of an ICE).
- Reduce energy dependence.
- Lower operating costs since electricity is cheaper than gasoline. However, incentives will play a decisive role in promoting BEVs.

However, BEVs face significant battery related challenges:

- Limited driving range to 160 km in current tested vehicles.
- 4 to 8 hours battery recharging time. A "quick charge" to 80% capacity takes 30 min. Note that the concept of quick-drop in battery swap stations is under study.
- High cost of battery since lithium-ion batteries currently range between 800 and 1,000 USD/kWh. However, battery lease programmes are under study by automakers, starting from around 100 USD per month to cover a driving range of 10,000km/year (CAS, 2011).
- The need of a battery recharging infrastructure.

Fuel consumption and GHG emissions reduction potential

The energy efficiency of electric cars is very high compared to their fossil fuel counterparts, which lead theoretically to no GHG emissions. Nevertheless, the actual GHG emissions and total energy use associated with the use of BEVs depend largely on the way the required electricity has been produced. Therefore, the well-to-wheel (WTW) analysis must be considered in this assessment.

The WTW energy use improvements of BEVs comparing to WTW average consumption of the Lebanese cars fleet of 2007 are illustrated in Fig. 21. 7.2% of energy savings are achievable under the current Lebanese electricity mix; however, 33 to 42% of savings will be possible in 2030 if mitigation scenarios of electricity generation mix are adopted. These scenarios are summarized in Fig. 22.

Fig. 23 and Fig. 24 outline the WTW GHG and pollutant emissions change of a typical BEV. Note that these emissions are occurring in the Well-to-Pump (WTP) process, no emissions are observed in the vehicle operation process (Pump-To-Wheel). With the current Lebanese electricity production mix, almost no GHG savings are observed with BEV (-0.2%). However, 39.1% and 52.7% of GHG savings are observed with mitigation scenarios for 2030. In terms of pollutant emissions, BEVs can substantially contribute to improving local air quality in GBA apart from NO_x, as shown in Fig. 24.

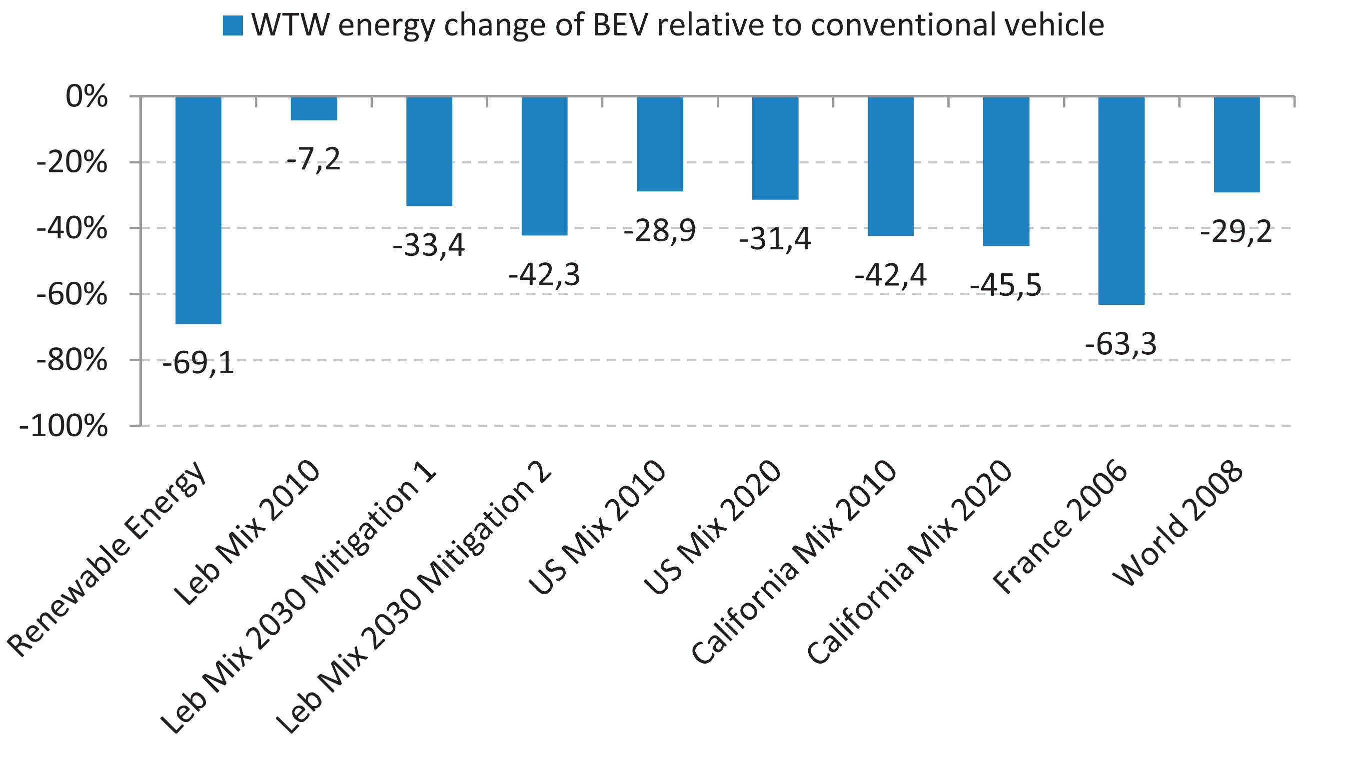


Fig. 21 - WTW energy change of BEV relative to average consumption of the Lebanese cars fleet of 2007.

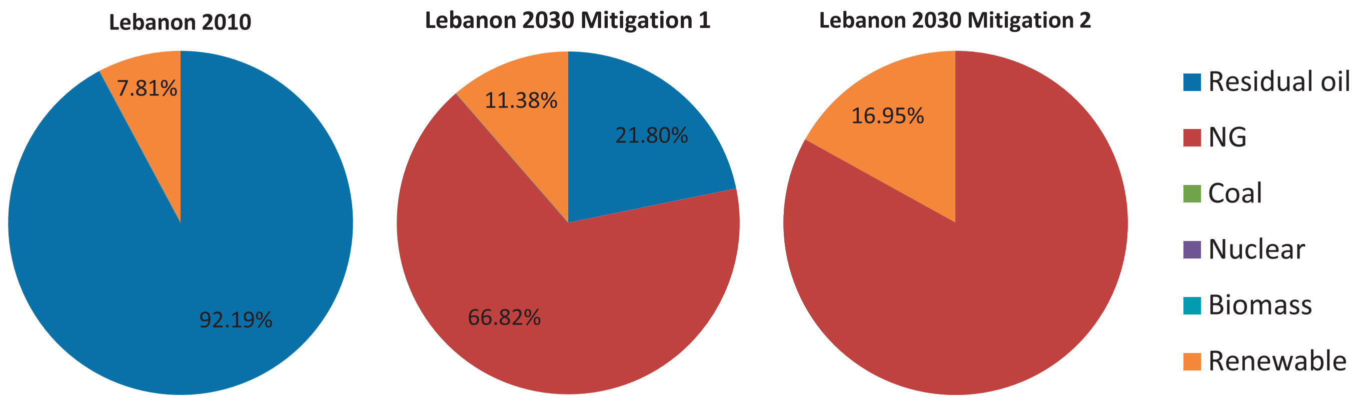


Fig. 22 - Lebanon electricity generation mix

Source: (MOE/UNDP/GEF, 2011)

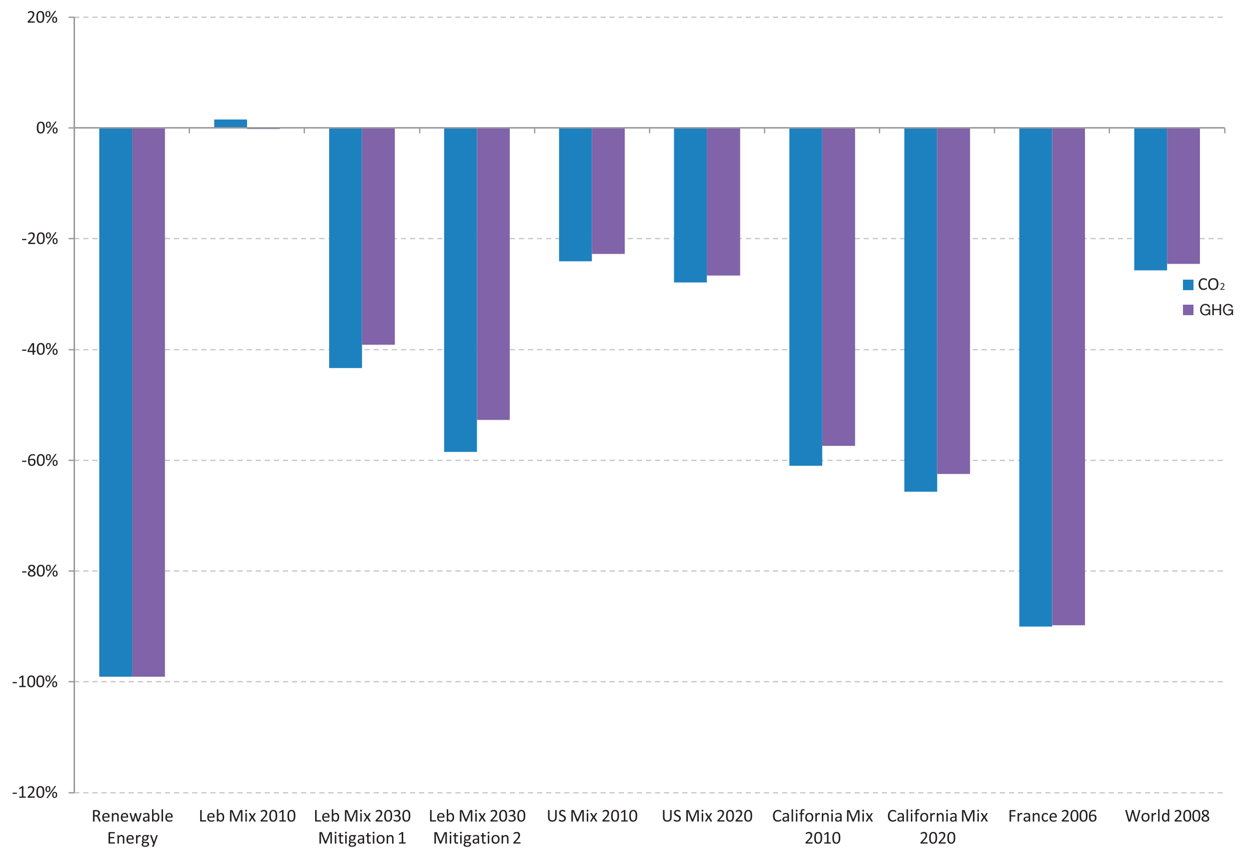


Fig. 23 - WTW GHG emissions change of BEV relative to the Lebanese cars fleet of 2007.

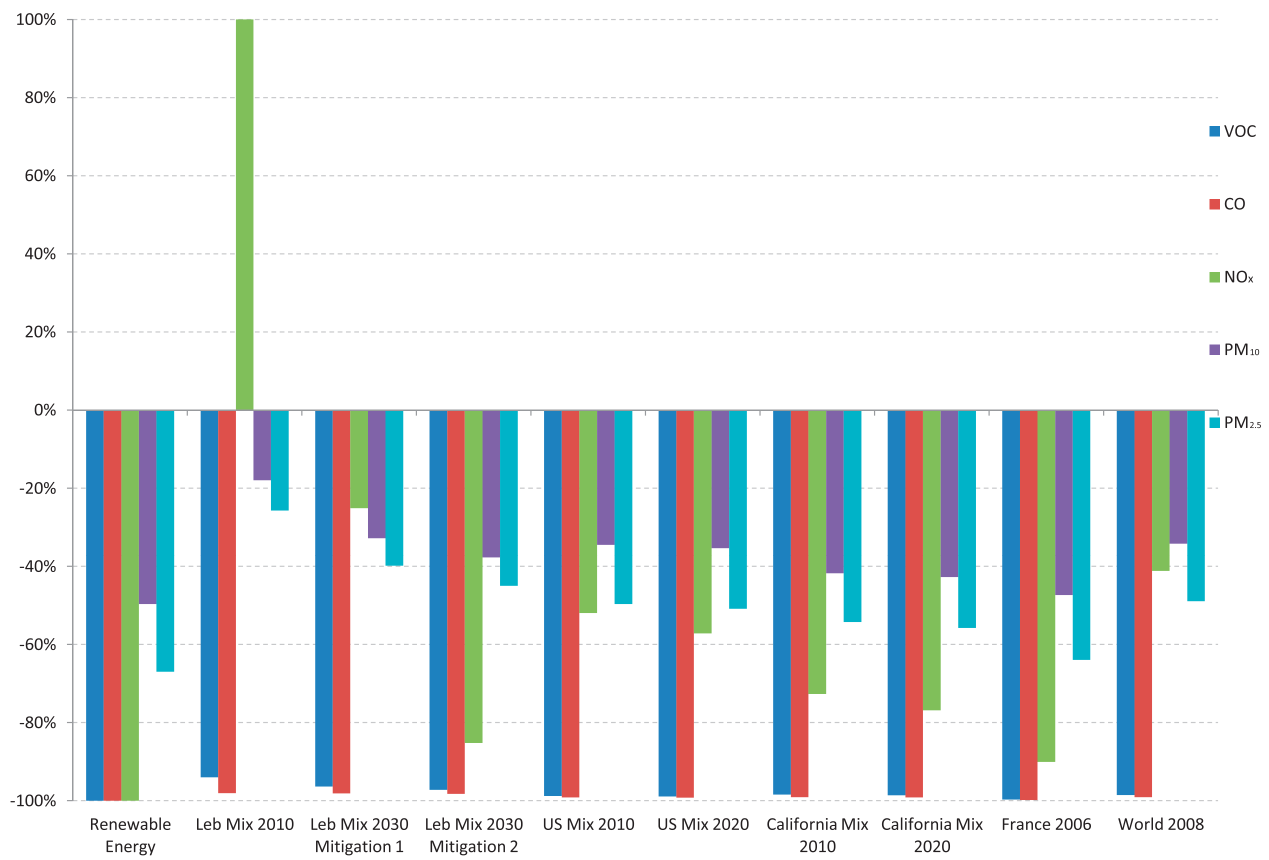


Fig. 24 - WTW pollutants change of BEV relative to the Lebanese cars fleet of 2007 under GBA driving conditions.

5.2.7 Natural gas vehicles

Technology characteristics

A natural gas vehicle (NGV) is an alternative fuel vehicle that uses compressed natural gas (CNG) or liquefied natural gas (LNG) as an alternative to gasoline and diesel. Natural gas is a fossil fuel comprised mostly of methane, and is one of the cleanest burning fuels. In most common applications, it is used in the form of compressed natural gas (CNG) to fuel passenger cars and city buses, and in the form of liquefied natural gas (LNG) to fuel heavy duty trucks. Due to high boil-off evaporative losses, LNG is not recommended for passenger cars and urban buses.

There are both dedicated NGVs which run exclusively on natural gas, and bi-fuel NGVs, which have two separate fueling systems enabling the car to run either on natural gas (CNG) or on gasoline or diesel. Most current CNG passenger cars are bi-fuel vehicles. It is possible to retrofit a gasoline powered vehicle with a natural gas tank. However, these vehicles are not as fuel efficient as OEM (Original Equipment Manufacturers) natural gas powered vehicles. In addition, retrofitted vehicles have higher emissions of NO_x and PM.

NGVs, particularly CNG passenger cars, offer several advantages compared to conventional vehicles:

- CNG vehicles have lower maintenance costs when compared with other fuel-powered vehicles, estimated around 2.1 US¢/km compared to 2.4 US¢/km for similar gasoline vehicles (USDOE, 1999).
- CNG fuel systems are sealed, which eliminates evaporation losses.
- Increased life of lubricating oils, as CNG does not contaminate the engine crankcase oil.
- CNG mixes easily with air, since it is a gaseous fuel, which leads to a clean combustion.
- CNG is less likely to auto-ignite on hot surfaces, since it has a high auto-ignition temperature, which improves the combustion efficiency.
- Less pollution as CNG emits significantly less pollutants such as unburned hydrocarbons, carbon monoxide and particulate matter, compared to conventional gasoline vehicles.

However, CNG vehicles face significant challenges: they have a higher purchase cost estimated at around USD 2,000, a lower driving range and higher gasoline equivalent consumption (110% for bi-fuel CNG and 105% for dedicated CNG and LNG vehicles) due to the inferior energy density of NG compared to gasoline, in addition to the need of an infrastructure for NG transportation and distribution. With NG, transportation is still depending on fossil fuels.

Fuel consumption and GHG emissions reduction potential

The Well-to-Wheel (WTW) energy use change of NGV, gasoline HEV and BEV comparing to the WTW average consumption of the Lebanese car fleet of 2007 is illustrated in Fig. 25. Dedicated and bi-fuel NGV technologies are considered, in addition to two different NG transportation paths: (1) the NG feedstock is transported using LNG, assumed to be the intermediate fuel to bring NG to the stations (shown in the figure under "LNG transport"); (2) the NG feedstock is transported in gaseous form.

Three conclusions are drawn from the figure:

- Dedicated CNG vehicles present better efficiency compared to bi-fuel NGV, as they are optimized to operate solely on NG rather than on two fuel types: gasoline and NG.
- Both technologies present energy consumption exceeding the Lebanese average consumption: 2% to 18% of additional energy is consumed with NGV, whereas electrified powertrains bring remarkable consumption savings, up to 28.6% with HEVs. Such result is expected since NG energy density is lower than gasoline. However, the main advantage of NGVs is expected in reducing air pollutants, due to the clean combustion occurring in the engine.
- NGVs using NG transported in liquid form present higher total energy consumption due to the double gas-liquid conversion losses and to boil-off evaporative losses when NG is transported to stations under LNG.

Fig. 26 and Fig. 27 outline the WTW GHG and pollutant emissions change of NGV, gasoline HEV and BEV comparing to the 2007 Lebanese cars fleet.

Taking into consideration the energy needed to extract and refine the fuels, the corresponding WTW CO_2 emissions of NG are lower than for gasoline. 5% to 20% of CO_2 savings are observed, depending on the powertrain technology and the path for transporting NG feedstock. Nevertheless, considering the rest of GHGs such as CH_4 and N_2O, almost no GHG emissions reductions are observed with NGVs. In contrast, HEV GHG emissions savings can reach 28.4%.

In terms of pollutant emissions, the main pollutant reductions are CO and VOC as NG (methane) has less carbon content and the CNG tanks are sealed, as illustrated in Fig. 27.

Currently, NG is imported in Lebanon from regional countries. Thus, it is convenient to compare also the vehicle operation emissions, as illustrated in Fig. 28. Bi-fuel CNG vehicles present similar CO and VOC emissions comparing to low-emission gasoline vehicles, and much lower than uncontrolled gasoline vehicles. Moreover, dedicated CNG vehicles present even further emissions reduction than low-emission gasoline. However, the uncertainty remains on the NO_x emissions level. According to the literature, NO_x emissions from bi-fuel NGVs, particularly converted CNG vehicles, may be higher or lower than comparable gasoline vehicles, depending on the engine technology. NO_x emissions from NGVs are more difficult to control using three-way catalysts.

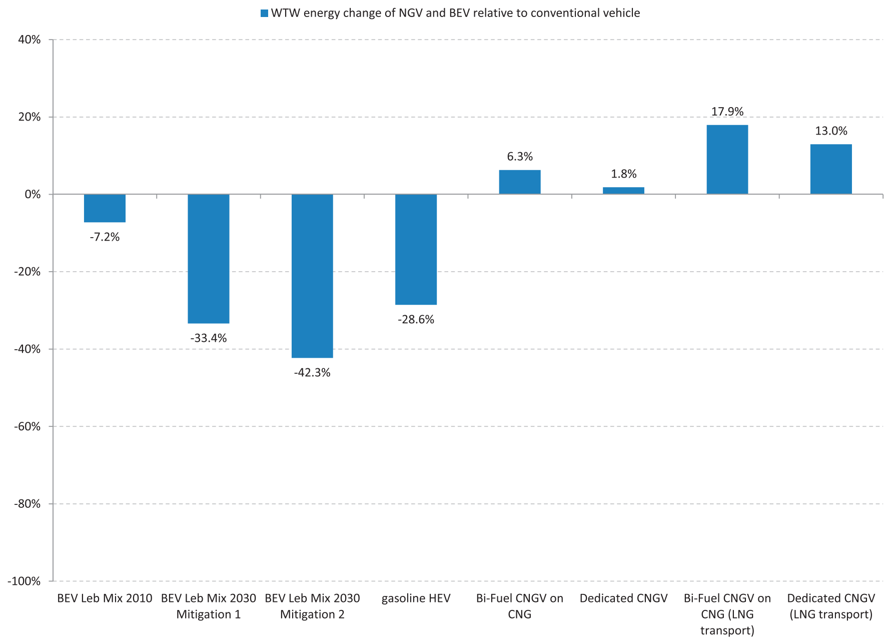


Fig. 25 - WTW energy changes of NGV, gasoline HEV and BEV relative to average consumption of the Lebanese cars fleet of 2007.

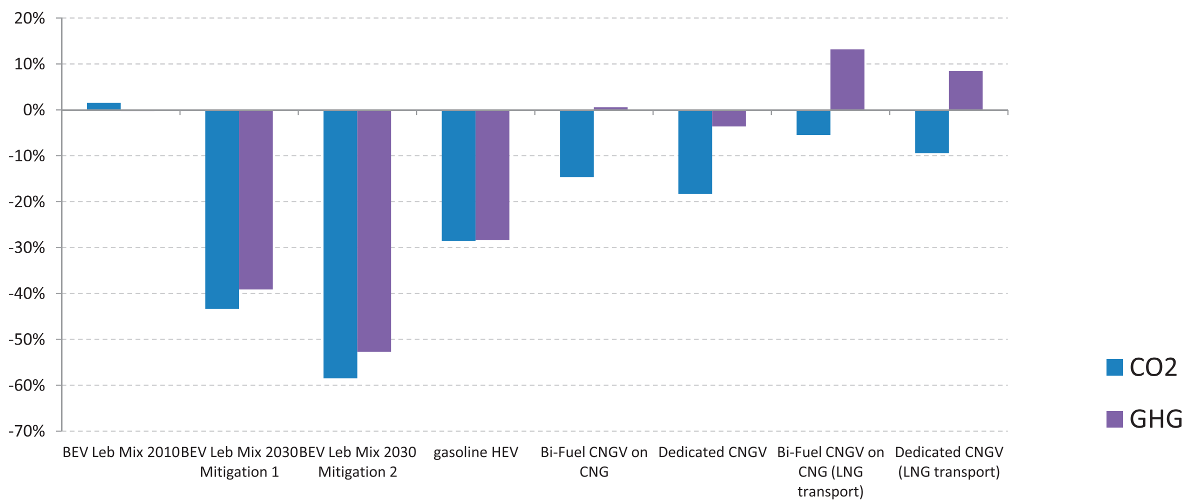


Fig. 26 - WTW GHG emissions change of NGV, gasoline HEV and BEV relative to the Lebanese cars fleet of 2007.

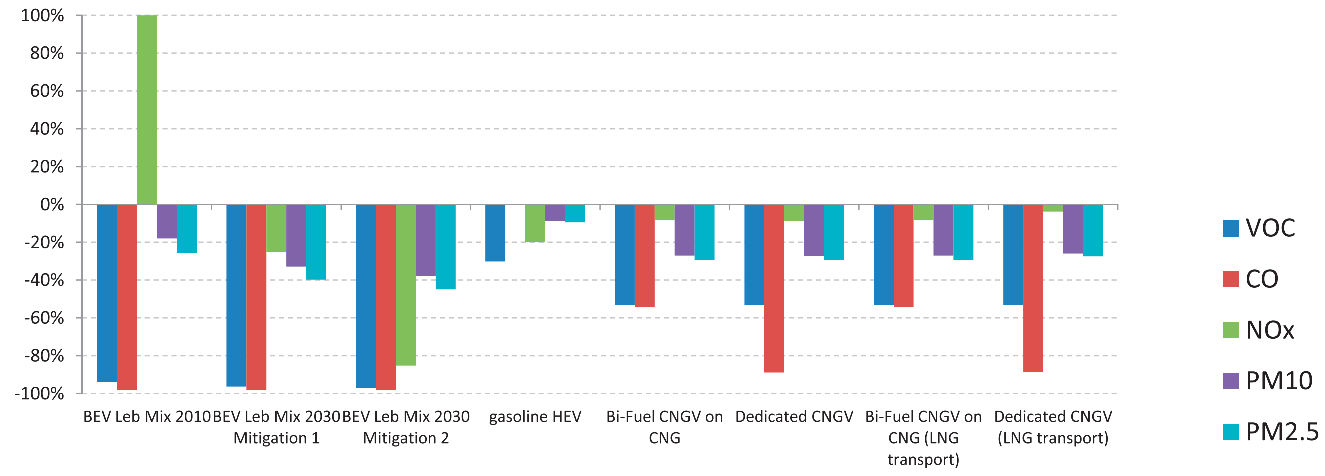


Fig. 27 - WTW pollutants change of NGV, gasoline HEV and BEV relative to the Lebanese cars fleet of 2007 under GBA driving conditions.

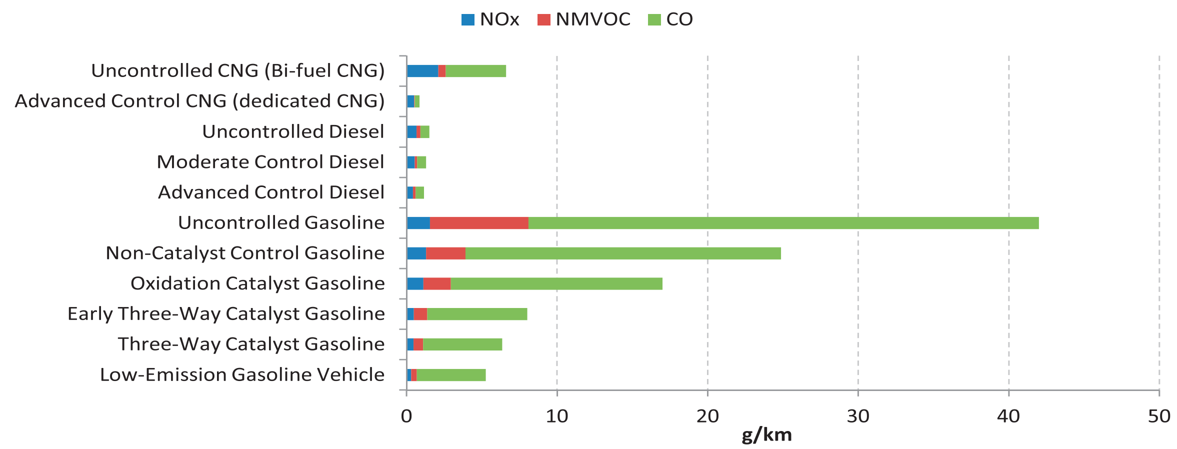


Fig. 28 - Vehicle operation emissions of CNG, diesel and gasoline technologies

Source: (IPCC, 1996).

5.2.8 Conclusions

This section brings all energy and environmental benefits of identified mitigation technologies into the same scale (Table 24), in order to compare in terms of passenger-kilometer the figures of the studied technologies.

The technologies are classified under the two studied mitigation strategies: (1) renewing the existing passenger cars fleet through a scrappage programme and (2) revitalizing the public transport systems. For passenger cars, a compact vehicle is considered for the different technologies, in order to fairly compare the energy and CO_2 emissions savings.

Note that results are obtained from end-of-life on-road measurements and simulation tools, where specific models are developed, validated and adapted to the existing conditions of road passenger transport in GBA. Therefore, obtained results are specified for the case of Lebanon, and reflect realistic driving consumption and emissions.

5.2.9 Cost analysis of mitigation technologies

Technology prioritization decisions in transport often involve tradeoffs between conflicting technology outcomes. For example, deploying the high efficient electrified vehicles may be reconsidered by stakeholders when investment costs for infrastructure implementation are included in the assessment. Hence, a global comprehensive analysis is considered in this TNA, by providing the environmental and energy benefits on one side, and the associated costs on the other side. This section provides the cost analysis of the different identified technologies in order to rationalize the prioritization decisions.

Table 24 - Energy consumption and CO_2 emissions benefits of the identified mitigation technologies.

Mitigation strategies	Renew the existing passenger cars fleet						Revitalize public transport systems	
	Fuel efficient vehicles	Hybrid electric vehicles	Plug-in hybrid vehicles		Battery electric vehicles	Natural gas vehicles	Bus technologies with dedicated lanes	
			Charge frequency				Bus occupancy	
			2 times /day	1 time /day			15 pass /veh	30 pass /veh
Fuel consumption (1) (L/100km.pass)	3.19	2.91	1.32	2.25	0.00	4.17	3.80	1.27
Total energy consumption (2) (kWh/100km.pass)	29.34	26.81	17.36	23.49	11.61	38.40	34.99	11.66
PTW CO_2 savings (%) (3)	48.10	52.00	78.49	63.26	100.00	18-25	40.86	80.29
WTW CO_2 savings (%) (4)	26.5	28.6	N/A	N/A	-1.5 (43.4-58.5% in 2030)	14.7-18.3	N/A	N/A

(1) Fuel consumption of comparable compact passenger cars, in liter gasoline equivalent. The vehicle occupancy rate considered for passenger cars is 1.82 pass/veh, observed under GBA driving conditions. Note that average fuel consumption of 2007 Lebanese car fleet is 6.13 L/100km.pass.
(2) Fuel and electricity consumption of comparable compact passenger cars, expressed in kWh.
(3) Pump-To-Wheel (Vehicle operation) CO_2 savings relative to the average CO_2 emissions of the 2007 Lebanese passenger cars fleet, estimated 260.4 g/km.
(4) Well-To-Wheel CO_2 savings relative to the average CO_2 emissions of the 2007 Lebanese passenger cars fleet.

Cost analysis methodology

Different transport related types of costs are included in the analysis, as indicated in Table 25 Though the list considered is not exhaustive, it provides a reasonable basis for analyzing major technologies' cost benefits.

Cost analysis of bus technologies with dedicated lanes

Cost benefits

Bus technologies present clear cost savings per passenger-kilometer comparing to passenger cars, as illustrated in Fig. 29 and Fig. 30. In average bus occupancy (15 pass/veh), Diesel and CNG buses present cost savings around 75-83%. These savings could reach 92% during rush hours (30 pass/veh). As for passenger cars, savings could be considered significant only when the car is shared by 4 passengers, as illustrated in Fig. 30.

Note that this assessment is done with different fuel prices, from Egypt, Greece, Turkey, France, Germany and USA, where NG, diesel and gasoline are used for transport, as indicated in Table 26 (NGVA, 2011).

Additional cost to implement bus technologies

According to the Transport Union for Public Transport (UITP), the initial extra capital costs compared to a 12-meter diesel bus at USD 257,000 are summarized in Table 27.

In addition to the cost of the bus technology, public transport systems operate efficiently when using dedicated lanes like in BRT systems. However, BRT requires high investment costs for its infrastructure. Depending on the required capacity, urban context and complexity of the project, BRT systems can be delivered for 1 to 15 million USD/km (IPCC, 2007), with most existing BRTs in developing countries in the lower part of this range (ITDP, 2007). These figures are substantially lower than those for rail-based systems, which cost approximately 50 million USD/km (IPCC, 2007).

Table 25 - Transport costs considered in the assessment

Cost	Description
Annual operating cost	Vehicle operating costs, including fuel price spent over one year with a driving range considered 10,000 km. These costs are computed from energy consumption simulation and end-of-life measurement results, using current gasoline and electricity tariffs in Lebanon.
Maintenance cost	Vehicle maintenance costs, including reparation fees. Accident damages are excluded.
Additional purchase cost	Additional costs requested to purchase the vehicle comparing to similar gasoline powered vehicle from same segment.
End-of-life ownership cost	The total ownership cost of the vehicle over 250,000 km, including operation, maintenance and additional purchase costs. Purchase and resale car price are excluded.
Infrastructure cost	The infrastructure cost required for bringing the technology to a commercially operable level.

Table 26 - Fuel prices of Diesel, gasoline and CNG

	Regular Gasoline (Euro/liter)	CNG price equivalent per liter gasoline	Diesel (Euro/liter)	CNG price equivalent per liter diesel	Month	Year
Egypt	0.12	0.05	0.15	0.06	December	2006
Greece	1.71	0.60	1.47	0.69	July	2011
Turkey	1.00	0.46	0.83	0.53	June	2010
France	1.52	0.57	1.34	0.65	July	2011
Germany	1.55	0.64	1.40	0.73	July	2011
U.S.A.	0.63	0.29	0.75	0.34	May	2008

Source: (NGVA, 2011).

Table 27 - Additional initial capital costs in USD.

	CNG	LPG	Diesel + CRT(2)	Diesel + SCRT(3)
Vehicle (USD) (1)	51,400	38,550	6,425 - 7,710	12,850
Filling station (USD)	385,500 - 771,000	282,700	-	-
Safety devices (USD)	38,550 - 1,285,000	1,285,000	-	-
Cleaning installations (USD)	-	-	32,100	32,100

(1) Converted from EURO at the 2012 yearly average exchange rate of 1.285.
(2) CRT: Continuously Regenerating Technology. It reduces HC and PM by over 90% and CO by over 70%.
(3) SCRT: Selective Catalytic Reduction Technology. It is a four-way emission control system that reduces CO, HC, and PM by over 90% and NO_x by 70%.

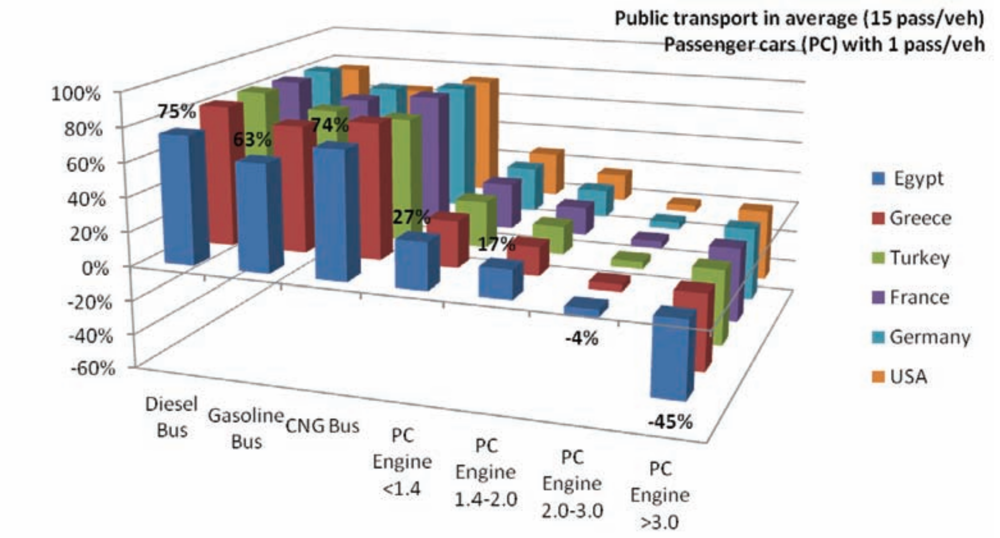


Fig. 29 - Cost savings of public transport buses in average use (15 pass/veh) and passenger cars (1 pass/Veh) relative to Lebanese car fleet average fuel cost with 1 pass/veh.

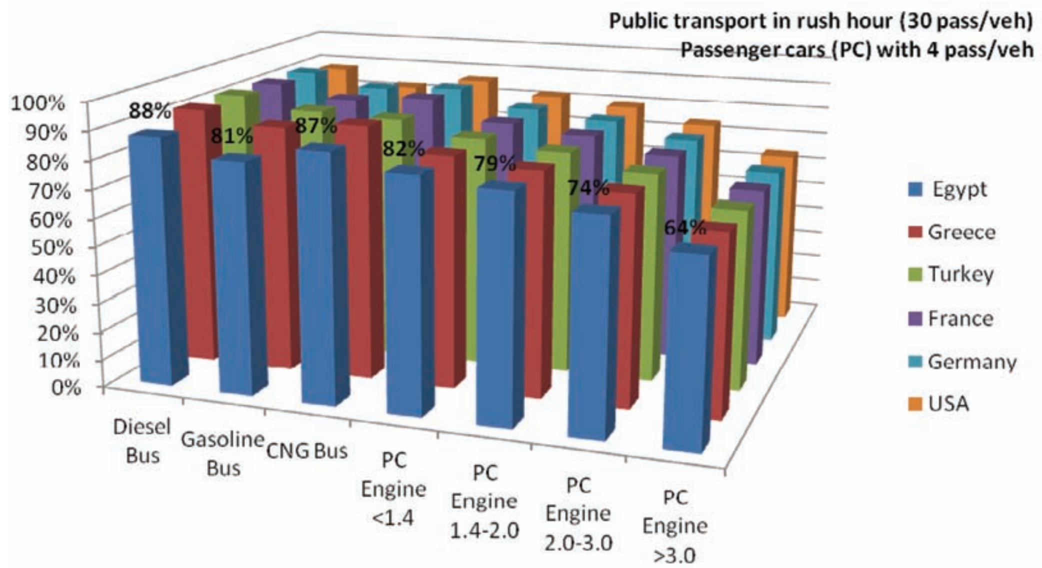


Fig. 30 - Cost savings of public transport buses in rush hours (30 pass/veh) and shared passenger cars (4 pass/veh) relative to Lebanese car fleet average fuel consumption with 1 pass/veh.

Cost analysis of mitigation passenger car technologies

In order to simplify the cost assessment done for the different passenger car technologies, Table 28 brings all results into a comparable scale. Different variables are considered for coming up with cost results coherent with the existing conditions in GBA: the energy consumption estimated under GBA driving conditions, an annual total mileage of 10,000 km and the current fuel and electricity tariffs in Lebanon, considered 1.2 USD/liter and 0.15 USD/kWh respectively.

The results are computed for a compact-size passenger car, with an average occupancy of 1.82 as estimated in GBA.

Combining environmental and energy saving results to the cost benefits, the following conclusions are drawn:

- For revitalizing the public transport systems, diesel and CNG bus technologies coupled to dedicated corridors present the highest development benefits, in terms of energy and environmental benefits, and cost savings. However, efficient pricing and optimized demand management strategy are essential to the well deployment and efficient use of these technologies.
- Under the strategy of renewing the passenger cars fleet, fuel efficient gasoline powered vehicles and self-sustaining hybrid vehicles present significant energy, emissions and costs savings, with an acceptable additional cost if tax and legislative reforms are applied. These technologies do not require any specific infrastructure investments.
- If additional savings are aimed for, plug-in hybrid, battery electric and natural gas vehicles would be the solution, however, at the expense of higher purchase costs and the need of a costly infrastructure for refueling the vehicles. Note that NGVs may benefit from the NG pipeline network to be implemented by the MoEW for providing the coastal power plants with NG.

Table 28 - Cost analysis summary Table

Mitigation strategies	Renew the existing passenger cars fleet						Revitalize public transport	
	Fuel efficient vehicles	Hybrid electric vehicles	Plug-in hybrid vehicles		Battery electric vehicles	Natural gas vehicles	Bus technologies	
			Charge frequency				Bus occupancy	
			2 times/ day	1 time/ day			15 pass/ veh	30 pass/ veh
Operating cost savings (1) (USD/10,000 km)	640	700	910	770	965	960	75-92% savings relative to passenger car.	
Maintenance cost savings (2) (%)	0		27-77			19	-	-
Additional purchase cost (after tax reforms) (USD)	150-600	1,000-4,000	5,700-7,400		>15,000 (3)	2,000	-	-
End-of-life ownership cost savings (4) (USD)	9,450	12,750	18,000	14,500	19,375	18,700	-	-
Infrastructure cost	0	0	• 18,000 USD/public recharging station. • 1,800 USD/private recharging station.			• 500,000 USD fueling station. • pipelines cost. • NG transport 4.5 USD/ GJ.100km.	1 to 15 million USD/km for dedicated corridors.	
Timeframe	Short-term		Medium/Long			Medium	Short/Medium	

(1) Operating cost savings relative to Lebanese car fleet of 2007. Gasoline price is estimated 1.2 USD/liter and electricity tariff 0.15 USD/kWh.
(2) The maintenance cost of conventional gasoline powered compact-segment vehicle is estimated 0.026 USD/km.
(3) Leasisng option 100 USD/month.
(4) End-of-life ownership cost savings relative to Lebanese car fleet of 2007. The passenger cars end-of-life assessment is considered 250,000 km. Purchase and resale car price are excluded.

5.2.10 Criteria and process of technology prioritization

The technology prioritization process for the transport sector is carried out using a Mutli-Criteria Analysis (MCA) decision-making exercise, where transport experts and stakeholders assessed the identified mitigation technologies based on to their importance in meeting national mitigation goals. This section presents the selection process and criteria used in the prioritization exercise.

Selection process

For each identified technology, factsheets were elaborated and disseminated to a wide spectrum of researchers and experts from national and international institutions for review. 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.

Based on this extensive dissemination process, an expert consultation workshop and individual consultations were conducted to ensure that the opinion and feedback of relevant institutions and experts are taken into consideration.

During the consultation workshop, the proposed weights were validated and the ranking was conducted through an open discussion among the experts and scores were attributed based on general consensus. Rankings were also completed during individual meetings.

Selection criteria

The criteria were selected based on two main objectives: minimizing the GHG and pollutant emissions for the transport sector and maximizing the environmental, social, and economic development benefits.

Accordingly, five main criteria for technologies selection were identified: (1) consistency with national policy and local context, (2) technology effectiveness, (3) technology cost-effectiveness, (4) environmental effectiveness and (5) social acceptability. Each of the criterion is attributed specific sub-criteria and assigned a weight based on its significance in meeting the two objectives, as indicated in Table 29.

The rating values attributed to each criterion were from 0 to 5, and determined by the following:

5: high relevance/ high impact
3: relevant/ moderate impact
1: less relevant/ less impact
0: not relevant/ no impact

Results of technology prioritization

Table 30 presents the final scores that were attributed to the proposed technologies of the transport sector. The main points raised during the working group session and the individual meetings revolved around:

- The need to couple the bus technologies with dedicated corridors and to optimize its operation and promote its use through proper policies and measures. Otherwise, bus public transport would bring negative impacts on the traffic, the environment and the economy, as is observed currently in GBA.
- The need to optimize the use of the existing infrastructure by adopting intelligent transport systems in demand management.
- Lebanon needs short timeframe solutions to improve its air quality rather than reduce its GHG emissions, as air pollution has daily direct impact on passengers' health, whereas Lebanon's contribution to world's GHG emissions is insignificant. As a result, it was decided to use a higher weight factor for the criterion of improving the air quality than that of reducing GHG emissions.
- Though electric mobility has proven itself as the future of transport, deployment of electrified vehicles that need to be plugged to the grid is difficult to achieve on the short and medium terms, as Lebanon is in deficit in terms of electricity generation.
- Though OEM Natural gas vehicles are safe to use, uncertified and self-retrofitted NGVs present significant safety concerns. Hence, in the lack of control policies for safety regulation, natural gas will only be considered for use in public transport buses or for electricity generation for electrified vehicles.

As a result, the MCA exercise enabled the selection of priority technologies for the transport sector in Lebanon. The top-ranked technologies are 1) Bus technologies using diesel and natural gas for revitalizing the public transport, 2) Hybrid electric vehicles and 3) Fuel efficient gasoline vehicles for renewing the passenger cars fleet.

Table 29 - Criteria and weights for the prioritization process.

Criteria	Weights	Comments
Consistency with national policy and local context:		
Relevant to existing national plans and needs	1	The technology supports the national needs for reducing GHG and pollutant emissions (particularly reducing traffic in GBA), and is aligned with national energy supply security plans.
High applicability potential	1	The technology does not have barriers with high risks hindering the deployment.
Technology effectiveness:		
Efficient technology	5	The technology ensures a low consumption of fossil fuel per passenger-kilometer.
Safe technology	2	The technology ensures safety to passengers as well to maintenance technicians. Case of accidents must be considered in the safety assessment of the technology.
Reliable technology	1	The technology is reliable and mature and can be implemented without worries.
Technology cost-effectiveness:		
Low infrastructure investment costs	4	The technology does not require high investment costs for the infrastructure, indispensable for its operation. Examples of infrastructure are land use for bus corridors, recharging stations for plug-in and electric vehicles, pipelines and compressed gas stations for natural gas vehicles, etc.
Operating and maintenance cost savings	2	The technology presents significant annual operating and maintenance cost savings comparing to conventional gasoline powered vehicles.
Affordable technology	3	The purchase cost of the technology is affordable for passengers, if accompanied with taxes and legislative reforms.
Environmental effectiveness:		
GHG emissions reduction	5	The technology reduces significantly the GHG emissions during vehicle operation. Note that well-to-wheel emissions reductions must be considered for electric and plug-in hybrid vehicles.
Improvement of air quality	5	The technology reduces significantly the pollutant emissions during vehicle operation. Note that well-to-wheel emissions reductions must be considered for electric and plug-in hybrid vehicles.
Reduction of hazardous waste	2	The technology does not generate hazardous waste.
Social benefits:		
Socio-economic benefits	1	The technology presents good impact for socio-economic development and creates job opportunities.
Short timeframe for applicability	1	The technology does not require too much time for bringing it to a commercially operable status.

Table 30 - Technology prioritization results

	Criteria	Fuel efficient vehicles	Hybrid vehicles	Plug-in hybrid vehicles	Electric vehicles	Natural gas vehicles	Bus technologies
Consistency with national plans	Relevant to existing national plans	3.7	3.7	3.0	3.0	3.7	5.0
	High applicability potential	4.0	4.0	1.7	1.7	3.7	4.0
Technology effectiveness	Efficient technology	2.7	3.3	4.3	4.3	2.7	5.0
	Safe technology	4.0	3.0	3.0	3.0	3.3	5.0
	Reliable technology	4.7	4.0	3.0	2.7	4.0	5.0
Technology cost-effectiveness	Low infrastructure investment costs	4.3	4.3	1.7	1.7	3.0	3.7
	Operating cost savings	3.0	3.3	4.0	4.0	4.0	5.0
	Affordable technology	4.3	3.7	2.7	1.7	4.0	5.0
Environmental effectiveness	GHG emissions reduction	3.0	3.3	4.3	4.3	2.7	4.7
	Improvement of air quality	3.0	3.7	4.0	4.7	3.7	4.3
	Reduction of hazardous waste	3.0	2.7	2.3	2.3	3.0	4.7
Social benefits	Socio-economic benefits	2.3	2.7	3.0	3.0	3.3	5.0
	Short timeframe for applicability	4.0	4.0	2.0	2.0	3.0	4.3
	Total /100	69.3	71.3	63.0	63.0	66.3	91.5

5.3 Barrier Analysis and Enabling Framework

5.3.1 Preliminary targets for transport technology transfer and diffusion

Reviewing the existing conditions of the transport sector and the needed mitigation actions, and in order to revitalize the public transport systems and renew existing passenger cars fleet, the preliminary targets are:

- Promote and modernise the bus mass transit system, operable on dedicated lanes in GBA.
- Create a market of hybrid electric vehicles.
- Promote fuel efficient gasoline-powered vehicles.

Beside the preliminary targets, indirect objectives are tackled and do not lack of importance:

- Contribute to a sustainable mobility sector: cleaner environment, efficient, affordable, safe and diversified transport means.
- Enhance Lebanese transport sector brand image.
- Reduce passenger per kilometre transport costs.
- Minimize on the long term the government financial and legislative burdens on the government.

The approach followed in order to set a preliminary programme design for the deployment of the prioritized transport technologies is illustrated and narrated in Fig. 31 and 32.

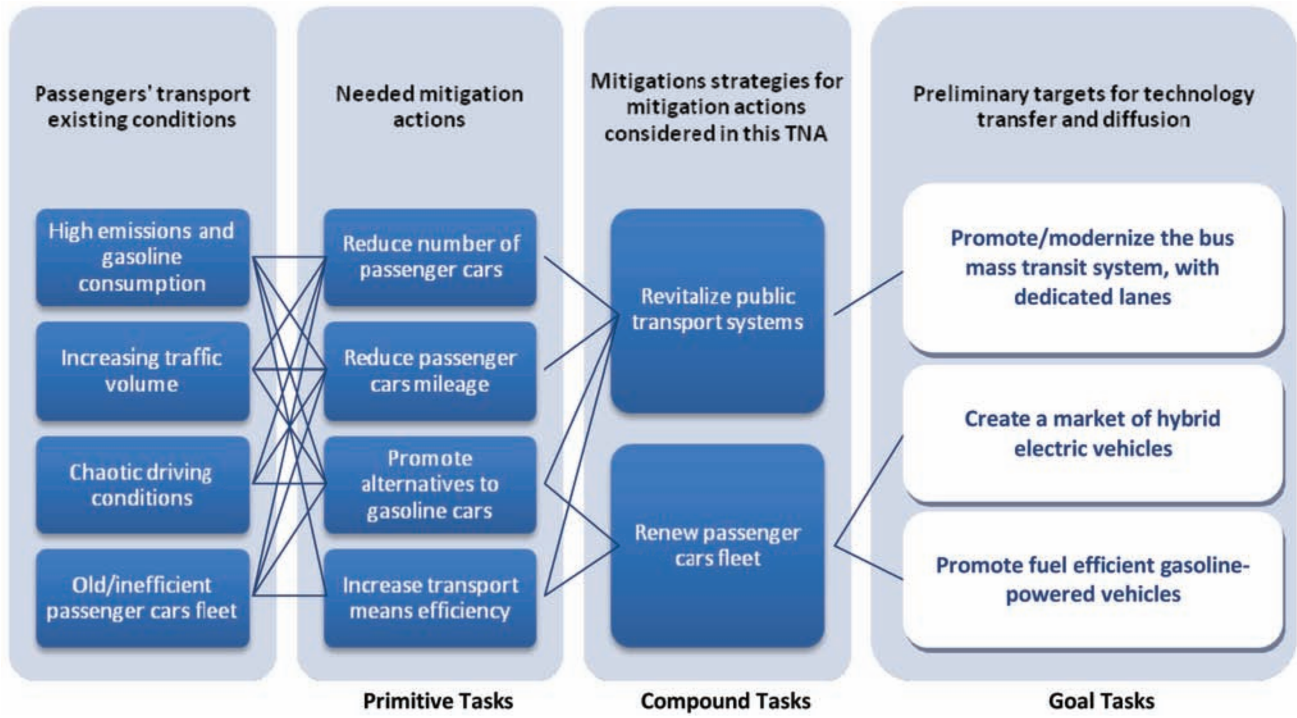


Fig. 31 - Hierarchical process for setting up preliminary targets for transport technologies transfer and diffusion.

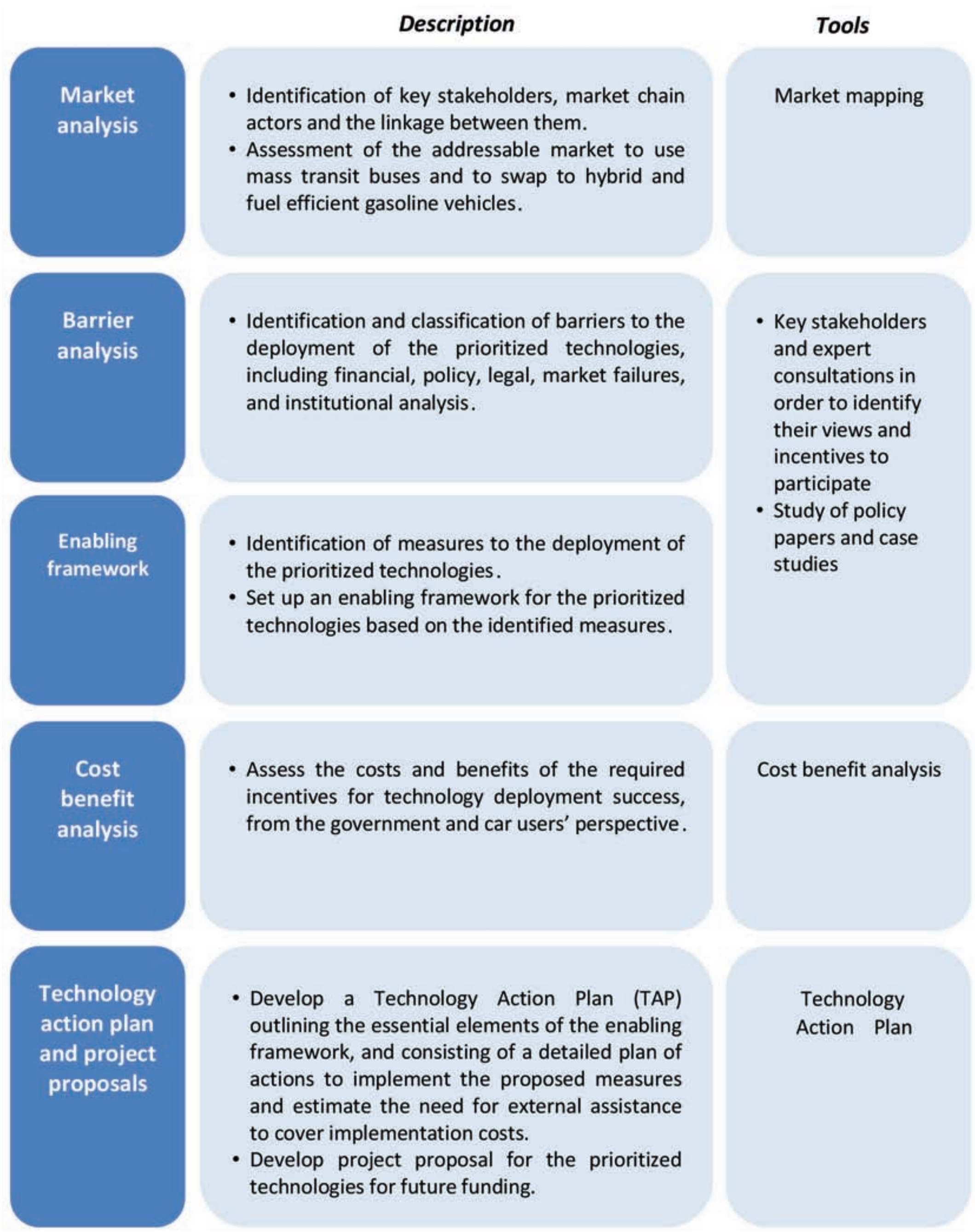


Fig. 32 Approach for developing preliminary programme deployment of the prioritized transport technologies.

5.3.2 Market analysis for deployment of transit bus technologies and passenger car scrappage programme

The first step in the technology deployment approach is carrying out the market chain analysis. It serves two purposes: first, it is a framework for identifying the key stakeholders enabling the deployment process, the market chain actors and the linkage between them; second, it is a practical tool for assessing the addressable market interested in using mass transit buses and/or swapping to hybrid and fuel efficient vehicles. Market maps for mass transit buses, hybrid electric and fuel efficient gasoline vehicles are presented in annex IV. The identified stakeholders for both programmes: the mass transit system and the scrappage scheme are summarized in Table 31. They are categorized along supply, addressable market and programme enabling entities. Therefore, most of these stakeholders have been included in the consultation meetings held during the barrier analysis and enabling framework process.

Table 31 - Stakeholders and market chain actors of mass transit system and passenger cars scrappage programme.

Supply	Enabling stakeholders	Addressable market
Bus dealers. Hybrid car dealers. Fuel efficient gasoline car dealers. Association of pre-owned car importers.	Government entities: Ministry of Environment. Ministry of Finance. Ministry of Public Works and transport. Ministry of Interior and Municipalities. Central Bank of Lebanon.	Private passenger car owners. Taxi owners and taxi drivers union. Commercial car owners. Land transport union.
	Non government entities: Commercial banks. International donors.	

5.3.3 Methodology for barrier analysis

Barrier analysis can be understood as mapping out the roots to the real constraints hindering the deployment of the technologies, in order to determine the proper measures. The methodology for the barrier analysis followed in this report is outlined in Fig. 33. Each step was conducted and validated during individual consultation meetings with stakeholders identified in the market mapping technique (refer to Table 31).

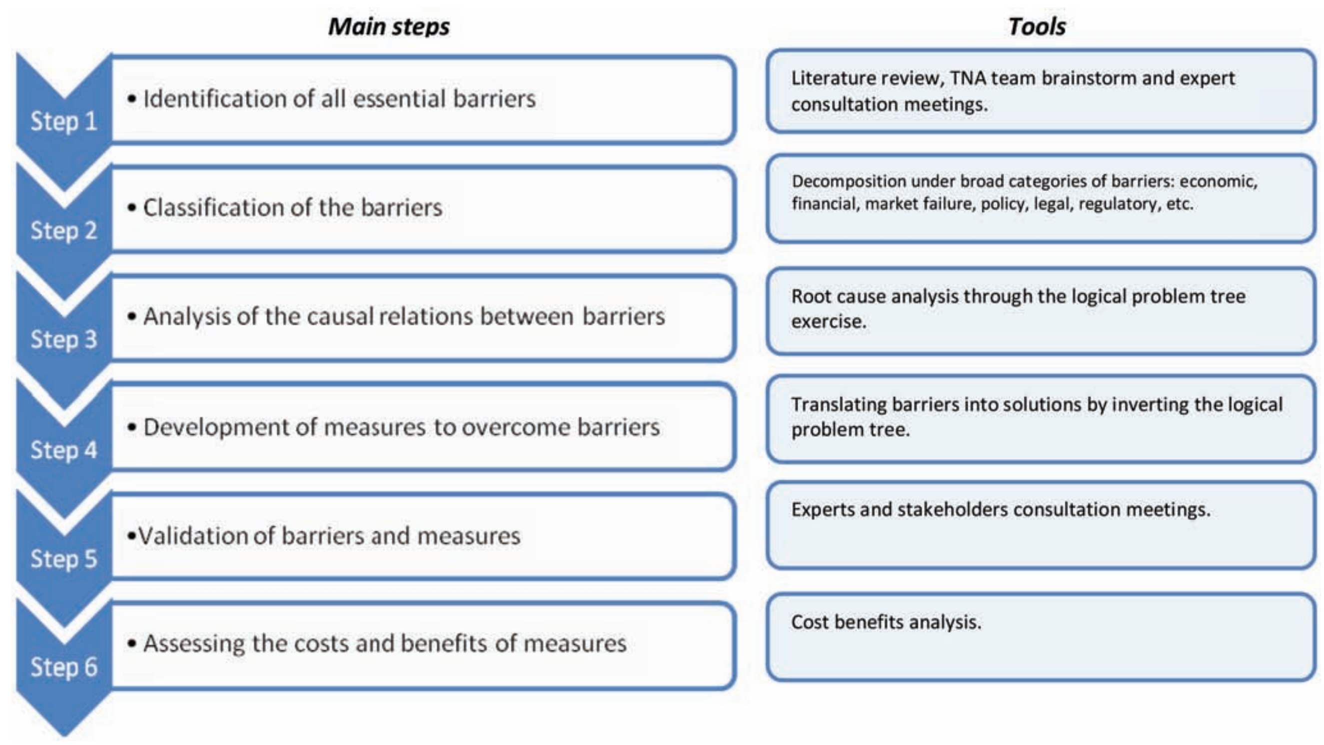


Fig. 33 - Main steps in identifying and analyzing barriers and in developing measures to overcome them.

5.4 Analysis of Technology: Deployment of transit bus technologies on dedicated lanes

5.4.1 General description of transit bus technologies

The prioritized mass transit technologies are diesel buses. The use of natural gas in buses is still at the early pre-design phase in the MoEW due to uncertainties and lack of data on the natural gas supply chain and distribution infrastructure. .

Diesel buses are still the most used bus technology worldwide, and the study presented in the TNA under GBA driving conditions showed that diesel bus public transport is a real mean to short-term solution to the environmental pollution issues in GBA, particularly when they are coupled with dedicated lanes and a well designed transport demand management system. They contribute to the different aspects of sustainable developments in GBA mainly (1) improvement of air quality, (2) reduction of GHG emissions, (3) congestion reduction, (4) increase in energy supply security due to reduction of imported oil, (5) social equality and poverty eradication by providing affordable transport with lower operating costs than passenger cars per passenger-kilometer, (6) economic prosperity by reducing travel times and congestion.

5.4.2 Identification of barriers

The barrier analysis work was carried out through a root-cause analysis presented in annex IV, summarized by a logical problem tree.

Main conclusions from the analysis are as follow:

- The starter problem of not having collective transport is the current poor market infrastructure for mass transit bus systems.
- The main barriers are:
    - The poor demand due to the mismanagement of the existing old and unmaintained fleet, the poor bus network and the long travel time.
    - The underdeveloped supply due to limited capacity of relevant institutions and insufficient number of specialized experts, particularly at the MoPWT.
    - The well-established alternatives to mass transit due to the lack of regulatory framework, from which the government is reaping benefits through tax revenues levied on fuel import and on car purchase and road usage.
- The root cause to all barriers is the absence of transport policy at the national level, providing a coherent transport demand management strategy. This lack of national policy is mainly due to having a government clash of interests and therefore limited willingness to invest.

The main economic and financial barriers are the high implementation costs of a mass transit bus systems operating on dedicated lanes, along with the inappropriate financial incentives allocated to passenger car users through loan banking facilities and easy access to pre-owned imported cars. Decomposition of barriers is summarized in Table 32.

The main non financial barriers consist of the lack of institutional capacity for planning and operation management, the absence of regulatory framework to favor mass transit buses. Decomposition of barriers is outlined in Table 33.

Table 32 - Decomposition of financial barriers to deployment of mass transit bus systems.

Economic and financial barriers		
High purchase cost of bus technologies	Inadequate government policies on purchase cost.	• High customs and excise fees (Custom and excise fees are applied similar to passenger cars). • 10% VAT on car value and duty. • For public transportation cars, car registration fees are 2% of the vehicle's estimated value.
High implementation cost	Transit bus systems need to be operated on dedicated lanes, which reduce parking areas.	• Additional costs must be considered for lanes reservation and building parking towers.
Inappropriate financial incentives and disincentives	Favorable treatment for conventional pre-owned gasoline vehicles.	• Banking loan facilities to buy pre-owned vehicles. • Large scale of pre-owned car import. • Inappropriate road-usage fees on pre-owned and brand new cars.
	Non-consideration of negative externalities in pricing transportation means using conventional gasoline vehicles.	• High urban pollution and GHG emissions due to excessive use of gasoline in old and inefficient passenger cars fleet. • Long travel time wasted due to chaotic traffic conditions in GBA.
	Tax on maintenance and repair imported spare parts.	• Custom and excise fees. • 10% VAT.
Fiscal burden on the public treasury	The current arrangement for provision of Public Transport service is fiscally unsustainable.	• The Railway and Public Transport Authority (RPTA), which maintains minimal service, requires a subsidy of USD 8.7 million per year, over twice the amount it earns from fare revenues to remain viable (in 2007). • The government subsidizes the social security obligations of the 33,000 red-plate holders estimated to be about USD 32.4 million per year (in 2007).

Table 33 - Decomposition of non-financial barriers to deployment of mass transit bus systems.

Market imperfection		
Poor market infrastructure for transit bus systems	Poor passengers demand for transit bus systems.	• Poor bus network with low frequencies (Current bus systems do not serve all boroughs, even within GBA). • Long travel time since no reserved lanes are allocated to bus. • Old and unmaintained bus fleet.
	Under-developed supply channels of transit bus system (Lack of a coherent, reliable and efficient mass transit system).	• Insufficient number of transit buses (currently no buses owned by the government are running). • No bus-stop stations. • The actual mass transit system lacks coherent organization, therefore, it does not comply with the mobility requirements and needs. • There is improper distribution of the existing public transport supply over the market. The main cities (Beirut and Tripoli) are overserved and witness severe competition among operators while other Lebanese regions suffer from a shortage of mass transit service providers. • No capability to compete with private operators of buses and minibuses which are not subject to stringent regulations, under the current institutional capacity of relevant authorities.
	Mismanaged public transport sector.	• Irregularities in bus operation, with no real-time information on the bus operation status. • Low passengers acceptance due to cleanliness and safety issues. • Poor information on existing bus tracks and network.
Market control by incumbents	Well-established alternatives to public transit systems.	• Easy access to own and use private passenger cars. • Oversupply of red plates in the marketplace: the quotas on the number of shared taxis and minibuses have not been set in relation to market demands. • Uncontrolled and unorganized shared and private taxis sector (50,000 are on the market, 17,000 are illegal, operate mostly in GBA). • Private bus operators are more competitive than public operator.
Policy, legal and regulatory		
Insufficient legal and regulatory framework	Legislation favor incumbent transport means.	• No/insufficient regulations to specify the operation maneuvers of private bus operators and taxi owners.
	Lack of implementation of legislation governing buses emissions.	• No regulation or legislation on fuel efficiency and emission standards of imported pre-owned cars (such as decree 6603/1995 relating to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and exhaust quality).
Clash of interests	Deployment of transit bus systems go against the perceived interest of the government.	Deploying transit bus might deprive the government from some revenues: • Tax revenues from customs on car purchase. • Revenues from VAT. • Revenues from registration. • Revenues from road-usage fees. • Tax revenues levied on consumed gasoline.
No enforcement to deploy transit bus systems	Missing/insufficient executive and regulatory bodies.	• Insufficient number of employees in relevant authorities to mass transit systems (particularly MoPWT).
	Insufficient willingness to enforce laws and regulations.	
Institutional and organizational capacity		
Limited institutional capacity	Limited capacity to promote and enhance market of transit bus systems.	• Limited number of employees at MoPWT, DGLMT and RPTA
	Limited number of service and maintenance specialists.	• Insufficient number of qualified bus drivers and technicians for maintenance and damage repair
	Need for specialized bodies and experts in relevant ministries and institutions at transportation planning level and operational level.	
	Fragmentation of responsibility among concerned government agencies; gap in the transport system management function with overlapping jurisdiction.	Several institutional actors deal with the field of Passenger Transportation. Each one is in a way in charge of the organization of the transport system and its functions and decisions influence the whole public transport system. These actors are: • Directorate General of Land and Maritime Transport (DGLMT) • Directorate General of Roads and Buildings which is within the MoPWT and responsible for the construction, rehabilitation and maintenance of public roads and government buildings. • Ministry of Interior and Municipalities which is in charge of vehicle registration and inspection, driver's licensing and traffic code implementation. • RPTA which is in charge of public transport operations. • Municipalities which are in charge of roads within municipal jurisdiction, and associated regulation of transport and traffic.
	Lack of technical expertise among Traffic Management Organization (TMO) staff, inhibiting it from carrying out the traffic management mandates it was conceived for.	
Human skills		
Insufficient personnel for preparing projects	Insufficient number of specialized experts in relevant ministries at planning and operational levels.	
Social, cultural and behavioral		
Consumer preferences and social biases	Lack of confidence in public transport.	• Mismanaged sector.
	Passengers prefer the easy way of using their private passenger cars.	• Passenger cars present the ultimate mean for freedom of mobility since there are no parking or access restrictions in GBA.
Information and awareness		
Lack of information	No dissemination of information on ecological and economical benefits of transit bus systems.	• No extensive efforts are needed on this point since the current traffic and economic situation in GBA serve as driving force to push travelers toward mass transit means.

5.4.3 Identification of measures

The range of measures for the deployment of a bus mass transit system in GBA, operating on dedicated lanes are presented in Table 34 and Table 35. Financial measures consists mainly of facilitating the government investments in mass transit buses. On the other side, financial disincentives cannot be imposed on other modes of transport in order to penalize them (except the road-usage fees applied to passenger cars); however, additional efforts should be made to improve the quality of service of bus mass transit systems, in order to provide a quality of service that approximates that which car drivers have been used to. As a result, dedicated lanes, wide coverage to all boroughs, real-time information, uninterrupted operation, are inevitable services.

Financial measures cannot guarantee alone the success of deployment of mass transit system. They should go along with non financial measures, summarized in Table 35. They consist mainly on deploying effective measures for improving the operation management and the infrastructure, in addition to setting up a regulatory framework that clearly manages the operation maneuvers of public bus operators, private bus operators and taxi owners.

Table 34 - Financial measures to deploy a bus mass transit system on dedicated lanes in GBA.

Economic and financial measures		
Appropriate financial incentives	Favorable treatment for mass transit buses rather than conventional pre-owned gasoline vehicles.	• Exempt mass transit buses from custom and excise fees. • Exempt from the registration fees (2% of the estimated car price).Exempt spare parts from custom and excise fees, particularly catalytic converters and filters. • Allocate concessionary fares to older people, students and disabled persons. • Use smart card ticketing schemes allowing travelling on all mass transit buses in GBA with one flexible ticket, available on daily, weekly, monthly, or yearly basis (Long term subscriptions bring additional savings to travelers).
	Encourage taxi and shared taxi owners to work in the bus mass transit system.	• Give special incentives to taxi drivers to get involved in the bus mass transit system in order to limit the number of illegal taxis (17,000 taxis) and reduce the extensive number of taxis (33,000 taxis).

Table 35 - Non financial measures to deployment of bus mass transit system on dedicated lanes in GBA.

Market development		
Develop market infrastructure	Stimulate passengers demand to use mass transit buses.	• Design of a complete bus network (bus tracks and bus stop locations) covering all boroughs within GBA
	Deploy effective infrastructure measures like an optimized land use planning.	• Reserve lanes within GBA for bus operation (reserved lanes are expected to substitute the parking spaces on both sides of the main avenues; therefore, parking spots must be constructed and managed by municipalities)
	Deploy effective operation measures like optimizing the operation management of the bus mass transit system (The objective is to provide a quality of service that approximates that which car drivers have been used to, in order to maintain a high level of mobility access in GBA with a drop in overall car usage).	• Conserve a clear and regular bus operation • Implement a real-time information system, tracking the bus operation and displaying the waiting time (information to be displayed on screens in bus stations, on mobile smartphones through special applications and on dedicated websites) • Deploy personalized travel planning tools in order to optimize and predict the travel time • Implement intelligent transport technologies like the transit signal priority in order to reduce the bus stop times on red lights • Set up stringent maintenance and cleanliness programme.
	Develop the supply channels of bus mass transit system.	• Purchase sufficient number of transit buses with the proper powertrain technology, in order to cover the designed network and avoid irregularities in operation • Construct bus stations taking into consideration the physical access to buses and stations (for example: improvements to pavements, access ramps for people with limited accessibility, timetables which can be read by those with visual impairment) • Construct relevant maintenance and repair workshops.
Manage the transport demand rather than being controlled by incumbents	Deploy a combination of access, personal travel planning and parking spots to lock the benefits from the aimed operational and infrastructural measures	
Technological development	Encourage and rely on R&D institutions in order to adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems.	• Follow up on environmental and economical benefits, and to test advancement in new technologies • Favor R&D to create local spare parts manufacturer.

Policy, legal and regulatory		
Set up a regulatory framework for mass transit sector	Legislation favor mass transit transport means in general and public bus transit in particular.	• Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners (such regulations must be preceded by setting up a national policy for the global mass transit sector, including the role of each of the private and public operators and the taxi owners).
	Enforce the deployment of bus transit systems.	• Create/enhance executive and regulatory bodies in charge of ensuring the design, deployment and follow up of the regulatory framework. • Restructure, empower and enhance the role of the traffic management organization (TMO).
	Implement legislation governing buses emissions.	• Update and implement decree 6603/1995 relating to standards for operating diesel trucks and buses, monitoring and permissible levels of exhaust fumes and exhaust quality • Enforce the bus inspection programme requirements and mandating the presence of catalytic converters.
	Enforce legislative reforms in urban planning laws, expropriation laws (if needed in some areas), and traffic laws.	• Redefine the use of urban road infrastructure, taking into consideration the total/partial exclusive use of lanes in mass transit buses. • Encourage municipalities to build parking spots to optimize the urban road space and allow reservation of lanes for mass transit buses. • Adopt a transit signal priority on red lights in order to reduce the bus travel time.
Institutional and organizational capacity		
Develop institutional capacity	Enhance bus transit services.	• Recruit and train bus drivers on eco-driving attitude and safety principles. • Recruit and train specialized maintenance technicians. • Recruit and train management and control staff in charge of managing and optimizing the planning and bus operation.
	Clarify and centralize responsibility among concerned government agencies in order to tackle the gap in the transport system management function.	
	Restructure, empower and enhance the role of the Traffic Management Organization (TMO).	• Develop technical expertise among TMO staff, in order to carry out the traffic management mandates it was conceived for.

Social awareness		
Dissemination of information	Aware travelers on ecological and economical benefits of transit bus systems.	• Provide information on CO_2 and fuel savings comparing to passenger cars, through the proper info display tools: mobile applications, dedicated website, media campaigns, etc.

5.4.4 Action Plan for deployment of transit bus technologies on dedicated lanes

Target for technology transfer and diffusion

The objective of the TNA for deploying mass transit buses is to highlight the benefits of bus transit system on dedicated lanes in GBA in terms of fuel savings and emissions reduction. The assessment is carried out per bus unit, and results show considerable savings. Therefore, the focus is to identify the proper strategy to revitalize the public transport and the most efficient bus technologies under the current driving conditions in GBA. Specifying the number of buses and design of the mass transit road networks need an engineering assessment study and was left for further steps with relevant authorities.

However, according to studies carried out by the MoPWT on public transport revitalization relying on bus transit, it is estimated that 507 buses will be needed in GBA, 85 in Tripoli, and 45 to serve intercity; a total of 637 buses countrywide. The total non-recurring investment in vehicles, infrastructure, terminals, depots, etc., is estimated at USD 400 million. Such revitalization target could be implemented on a 5 year basis. It is recommended that urban buses be operated on natural gas for a better air quality; however, this plan is mainly affected by the security of supply of natural gas to Lebanon, and a comprehensive feasibility study needs to be carried out to assess this option. The Technology Action Plan for transit bus technologies operating on diesel and on dedicated lanes is presented in Table 36.

Table 36 - Technology Action Plan for transit bus technologies on dedicated lanes

Measures	Priority	Objectives	Responsibilities	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Design a complete bus network covering all boroughs within GBA and reserve lanes for bus operation	1	Shift travel demand to efficient transport means: bus transit system.	Municipalities OCFTC DGRB CDR	Short term	Bus network on reserved lanes in GBA.	500,000 (design study of the network).
Ensure sufficient number of transit buses with the proper powertrain technology	1	Cover the designed network with sufficient number of buses and avoid irregularities in operation	MoPWT	Short term	Purchase of the required buses.	0
Exempt mass transit buses (and their spare parts) from custom and excise fees, and from registration fees	1	Decrease the cost incurred for the government on the import of the mass transit buses and give appropriate financial incentives for mass transit buses.	MoF	Short term	Law on fee exemption enacted by the government.	N/A
Create an employee package for taxi drivers (including social benefits, insurance, retirement plans, etc.)	1	- Encourage taxi and shared taxi owners to work in the bus mass transit system - Limit the number of illegal taxis (17,000 taxis) and reduce the extensive number of taxis (33,000 taxis)	MoPWT OCFTC MoF	Short/ Medium term	Package for bus drivers.	1,000 (legal services to create a package).
Establish smart card ticketing schemes with appropriate reduced tariffs	2	-Stimulate passengers demand to use mass transit buses. - Shift travel demand to efficient transport means: bus transit system.	OCFTC	Medium term	Smart card ticketing schemes.	0
Optimize the operation management of the bus mass transit system: conserve a clear and regular bus operation, implement a real-time information system, deploy personalized travel planning tools, implement transit signal priority, set up stringent maintenance and cleanliness programme , construct relevant maintenance and repair workshops	2	- Provide a quality of service that approximates that which car drivers have been used to with passenger cars.	MoPWT DGLM OCFTC	Short/ Medium term	Operation management strategy.	0
Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners	3	Manage the transport demand rather than being controlled by incumbents (private and public operators and the taxi owners)	MoPWT	Short term	Legislation on specifying the operation maneuvers between the various mass transit operators.	0
Draft new amended laws for increasing parking space and reserving lanes for buses	4		MoPWT	Short/ Medium term	Parking spots and reserved lanes for mass transit buses in congested urban areas.	0

Measures	Priority	Objectives	Responsibilities	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Develop technical expertise among TMO staff and high level management	5	- Carry out the traffic management mandates it was conceived for. - Enhance the role of the Traffic Management Organization (TMO).	MoPWT	Medium term	Well-trained TMO staff.	8,000 (technical training of 15 employees).
Provide information on CO_2, fuel and cost savings comparing to passenger cars	6	- Increase awareness of travelers on ecological and economical benefits of transit bus systems. - Shift travel demand to efficient transport means: bus transit system.	MoPWT	Short/ Medium term	info display tools on CO_2 and fuel savings: mobile. applications, dedicated website, media campaigns, etc.	50,000 (full awareness campaign).

5.5 Analysis of Technology: deployment of hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme

5.5.1 General description of hybrid electric vehicles and fuel efficient gasoline-powered vehicles

Fuel efficient gasoline powered vehicles

Fuel efficient vehicles are conventional gasoline powered vehicles with low consumption, equipped with advanced technologies, reduced vehicle weight, downsized engine, idle stop/start systems and continuous variable transmissions.

Considerable consumption and CO_2 emissions savings are observed with fuel efficient vehicles from 10% to 50% comparing to the world average new cars fleet of 2005, and from 35% to 64% comparing to the Lebanese average consumption of the passenger cars fleet in 2007 under GBA driving conditions. Therefore, all these vehicle segments must be promoted through proper incentives and adequate tax policies, to substitute the current Lebanese trend of buying large inefficient cars.

Hybrid electric vehicles

Hybrid electric vehicles (HEV) combine an electric motor and battery pack to the internal combustion engine (ICE) found in conventional vehicles. They are characterised by low consumption, high driving range, reduced emissions and downsized engine. Hybrid vehicles present 40% to 53% fuel and CO_2 savings compared to small to midsize cars.

5.5.2 Identification of barriers

Barriers for deployment of fuel efficient gasoline cars are few and a fuel efficient car market is already established. However, these cars need additional measures are needed to favor their deployment over the imported pre-owned vehicles that are flooding the market.

As for hybrid cars, the market is still inexistent due to the following main barriers:

- The low demand for hybrid vehicles due to the high purchase cost of these cars, the lack of consumer or market incentives and the wrong perception of consumers regarding hybrid cars' performance.
- The high demand for pre-owned non efficient gasoline vehicles due to the low cost of these cars, the banking loan facilities, and the current inappropriate road-usage fees.
- The root cause to all barriers is similar to that for deploying mass transit buses: the inadequate current transport policy and the lack of national policy providing a coherent transport demand management strategy. Once again, this lack of national policy is mainly due to having a government clash of interests and therefore limited willingness to invest.

The main economic and financial barrier is the inappropriate financial incentives and disincentives, through a favorable treatment to conventional pre-owned gasoline vehicles, faced by lack of any incentive for fuel efficient and hybrid technologies.

Decomposition of barriers for hybrid and fuel efficient vehicles is summarized respectively in Table 37.

The main root cause of non-financial barrier is the loss of revenues for the government from taxes related to the import of gasoline and gasoline vehicles. In fact, the government collects revenues from taxes levied on imported gasoline and car purchase, in addition to road-usage fees proportional to engine displacement. Moreover, private companies import the gasoline for transportation; therefore, the government does not have any interest in reducing the imported quantity, unless the assessment of the impact of the external costs resulting from the excessive dependence on gasoline (health concerns, emissions and pollution impact, etc.) is internalized. Decomposition of barriers is outlined in Table 38.

Table 37- Decomposition of financial barriers to deployment of hybrid and fuel efficient vehicles.

Economic and financial barriers		
High purchase cost particularly of hybrid vehicles	Inadequate government policies on purchase cost (MoF, 2011)	• High customs and excise fees. • Inadequate registration fees. • Inadequate road-usage fees. • 10% VAT on car's estimated value plus duty.
Financially not viable to some dwellers.	Low affordability amongst part of rural and peri-rural dwellers	• Low income (CAS, 2011).
Inappropriate financial incentives and disincentives to both hybrid and fuel efficient vehicles	Favorable treatment to conventional pre-owned gasoline vehicles	• Banking facilities to buy pre-owned vehicles • Large scale of pre-owned car import dating up to 8 years old. • Inappropriate road-usage fees on pre-owned and brand new cars.
	No market incentives to deploy hybrid and fuel efficient vehicles	• High customs and excise fees. • 10% VAT on car's estimated value plus duty.
	No consumer incentives to buy hybrid and fuel efficient vehicles	• Inadequate registration fees. • Inadequate road-usage fees at registration. • High insurance fees. • Must pay loan interest.
	Non-consideration for externalities in pricing transportation means using conventional gasoline vehicles	• High urban pollution and GHG emissions due to excessive use of gasoline in old and inefficient passenger cars fleet. • Long travel time wasted due to chaotic traffic conditions in GBA.

Table 38 - Decomposition of non financial barriers to deployment of hybrid and fuel efficient vehicles.

Market failure/imperfection		
No hybrid vehicles market	Poor demand for hybrid.	• High purchase and ownership costs. • No market incentives. • No consumer incentives. • Low consumer acceptance (resistance to change).
Underdeveloped competition	Insufficient number of hybrid vehicle suppliers	• HEV suppliers have no incentives or will to invest before any law is ratified exempting these cars from excise and custom taxes (Bejjani, 2012; Younis, 2012).
Lack of reference projects in Lebanon	The recent extensive use of sub-compact fuel efficient cars by private companies has led to promoting them, due to the positive feedback on the tangible fuel consumption savings. No such experience is available for hybrid vehicles	
Policy, legal and regulatory		
Insufficient legal and regulatory framework	Legislation favor conventional gasoline vehicles	• Lack of stringent fuel-efficiency and carbon standards on imported pre-owned and new gasoline vehicles. • Lack of implementation of legislation governing vehicle emissions (such as Decree 6603/1995). • Lack/corrupted safety control bodies on pre-owned imported cars when entering the country.
	Lack of coherent tax policies	• Higher road-usage fees on new cars which have low emission levels v/s lower road-usage fees on pre-owned old imported vehicles with unknown/high emission levels (MoF, 2011) (For example, a new 10 horsepower efficient car pays USD 216 road-usage fees, and a 50 horsepower car made before 1997 pays USD 153, 30% less).
	Hybrid and fuel efficient cars deployment goes against the perceived interest of the government	• Deploying HEV and fuel efficient cars might deprive the government from some revenues: • Tax revenues from customs on car purchase. • Revenues from VAT, consumed gasoline, registration and from road-usage fees.
Network failures		
Weak connectivity between actors favoring HEV and fuel efficient cars deployment	Insufficient coordination between relevant ministries and HEV suppliers. No cooperation between relevant ministries and R&D institutions.	
Incumbent networks of pre-owned car importers are favored	No regulation or legislation on fuel efficiency and emission standards of imported pre-owned cars.	
Lack of involvement of stakeholders in decision-making regarding transport policies	Stakeholders' consultation culture missing.	

Institutional and organizational capacity		
Lack of professional institutions	• Need for specialized bodies in relevant ministries at transportation planning level and operational level. • Lack of/inefficient regulatory body in the transport sector. • Lack of institutions to support technical standards for transportation.	
Limited institutional capacity	No R&D culture in transportation.	• R&D facilities are missing. • Lack of appreciation of R&D role in mitigating transport technologies.
Human skills		
Lack of service and maintenance specialists	Low availability of qualified technicians for HEV maintenance and damage repair except at car dealers.	
Inadequate personnel for preparing projects	Limited number of specialized experts in relevant ministries.	
Social, cultural and behavioral		
Tradition and habits	Resistance to change due to unfamiliarization and wrong perception of new technologies.	
Lack of confidence in HEV	Unknown product due to inadequate information on HEV performance.	Wrong perception on hybrid vehicles' performance.
Information and awareness		
Inadequate information	No dissemination of information to consumers on HEV performance, environmental and economical benefits, etc.	
Technical		
Inadequate standards, codes and certification	Lack of initiatives to set standards on vehicle emissions and fuel efficiency.	
	Standards not obligatory.	
	Lack of facilities for testing vehicles and certification.	
Data and information		
Lack of mobility monitoring data	Limited monitoring data to support transport studies aiming at the development of sustainable transportation strategies.	• Lack of Mobility Monitoring Indicators (MMI) framework, which serve as the basic step in setting a national sustainable mobility strategy • The Central Administration of Statistics (CAS) publishes very basic information on transport sector status. • Transport studies carried out by ministries and relevant authorities are not shared, neither the results nor even the information on the content (as a result, work is duplicated without reaching to a national transport strategy set up).

5.5.3 Identification of measures

Creating conditions for deploying green transport alternatives in general and hybrid and fuel efficient vehicles in particular requires government-mandated regulatory measures together with incentives that motivate a shift in behavior. Based on the analysis of current barriers facing that deployment, the following measures are suggested so that conditions favorable to efficient transport can be cultivated.

The range of financial measures presented in Tables 39 and 40 are intended to enable the creation of a hybrid vehicle market and to favor sales of fuel efficient vehicles, to encourage both sides of the market chain: the car suppliers to invest, and the consumer to swap old cars with hybrid or a fuel efficient car. Concurrently, disincentives should be introduced to limit the market of non-efficient and pre-owned imported vehicles. Therefore, a balance must be created through proper allocation of purchase taxes and/or road-usage fees, based on a stringent fuel-efficiency and emission standards on pre-owned vehicles, instead of allowing fees based on engine horsepower and the model year.

An example is the **French Bonus-Malus programme** applied since 2007 to new vehicle purchase. The registration or purchase tax is a one-off tax levied on vehicles related to the CO_2 rate of emission, according to a differentiated energy class system currently consisting of seven emission classes. Vehicle emitting more than 150 g/km are subject to malus and those lower than 110 g/km receives a bonus subsidy from the government (ADEME, 2011). Moreover an annual Malus of USD 205 (160 Euros) is owed by owners of vehicles emitting more than 245 g/km. Bonus-Malus scheme and programme outcomes are summarized in Fig. 34 and Fig. 35, showing the success of the programme has succeeded in favoring the sale of fuel efficient cars, reaching 56% in 2009 for the bonus classes.

Financial measures must go along with non financial actions mainly in issuing the requested legislations and setting the regulatory framework for implementing the incentives and making the relevant tax reform. Moreover, information dissemination to consumers during car purchase on consumption, emissions and money savings is of high importance in order to cope with the resistance to change of consumers and the wrong perception on hybrid car performance.

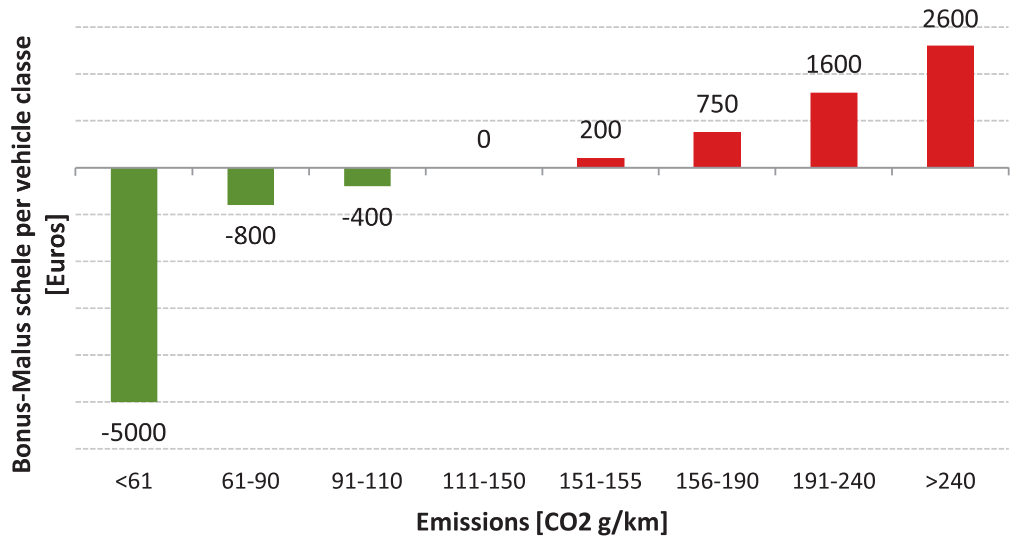


Fig. 34 - Bonus-Malus on car sales per emissions class (a negative value is a bonus).

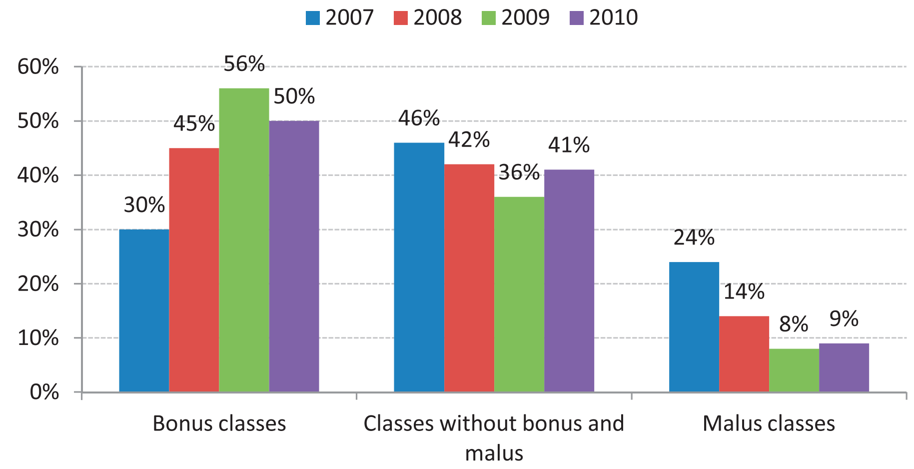


Fig. 35 - Structure of car sales according to the bonus-malus scheme.

Table 39 - Financial measures for the creation of hybrid vehicle market and favoring sale of fuel efficient vehicles.

Economic and financial measures		
Government incentives to reduce vehicle purchase and ownership costs	Market incentives	• Exemption from customs and excise fees on vehicles to favor hybrid and fuel efficient car suppliers invest. • Exemption from custom and excise fees on non conventional hybrid spare parts (battery, electric motor, etc.) in order to favor spare parts suppliers invest.
	Consumer incentives	• Exemption from registration fees. • Exemption from road-usage fee at registration. • Payment of minimum salvage value (ex. USD 2,500) as down payment for car loan. • Extension of loan period to 8 years particularly for hybrid car purchase. • Reduce loan interest and/or full subsidy of loan interests for heavy mileage drivers like taxi owners.
	Technicians incentives	• Help domestic maintenance and repair technicians to buy equipments through banking facilities (kafalat programme).
Government disincentives to import of non efficient pre-owned vehicles	Set up coherent tax policies disadvantaging the demand for high fuel consuming pre-owned vehicles	• Reduce gradually maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100,000 km, rather than 8 years as the current figure. • Road-usage fees must be reconsidered according to fuel efficiency and/or emissions rather than engine displacement as the current figure: - Increase gradually road-usage fees on old high consuming vehicles, already owned by consumers. - Increase road-usage and registration fees on imported pre-owned high consuming vehicles. - Reduce road-usage and registration fees on new and pre-owned low consuming vehicles. - Increase road-usage fees on the second owned car, for private use.
	Set up stringent fuel-efficiency and emissions standards on pre-owned imported vehicles	• Fuel-efficiency and emissions standards are intended to help setting adequate tax policies *(Bonus-Malus: polluters pay more taxes)*, in order to favor low consuming new and pre-owned vehicle rather than high consuming pre-owned vehicles.

Table 40 - Non-financial measures for the creation of hybrid vehicle market and favoring sale of fuel efficient vehicles.

Market development		
Implement a vehicle retirement programme with incentives	Create a car termination plant	• Create a plant that deals with the car termination process after the swap in the scrappage programme (interested customers in swap shall not have a grant salvage value for their old car or any incentive unless they got the certificate of car termination from the MoE or other special entity in charge). Car termination process is one of the success key of the scrappage programme; therefore, old car termination options should be clearly stated and formulated.
Policy, legal and regulatory		
Set up legal and regulatory framework to create HEV market and promote fuel efficient vehicles	Issuance of law exempting these cars from customs, registration and road-usage fees at registration in order to amend vehicle taxation system into a more balanced environmentally oriented scheme	• Exemption of new HEV from customs and excise fees, and from registration and road-usage fees at registration. • Exemption/reduction of new fuel efficient vehicles from custom and excise fees. • Payment of minimum salvage value (ex. USD 2,500) as down payment for hybrid vehicle loan. • Exemption of salvage old cars from unpaid road-usage fees in order to encourage their owners to swap their old cars (as in the law, these owners cannot sell their cars if they do not pay all due road-usage fees). • Full subsidy of loan interests over loan period for taxi drivers, students and disabled persons swapping for hybrid cars.
	Implement legislation governing vehicle emissions	• Update and implement decree like that of 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality. • Enforce/update the vehicle inspection programme requirements taking into consideration the special requirements for hybrid cars' inspection, in addition to mandating the presence of catalytic converters on conventional gasoline vehicles.
Set up new coherent tax policies	Issuance of law modifying the current tax figure in order to cope with the high demand for high fuel consuming pre-owned vehicles	• Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees.
Institutional and organizational capacity		
Create professional institutions	Create institutions to support technical standards for transportation	• Set up a mechanical inspection unit at the port of Beirut in charge of checking up the emissions and safety standards of imported pre-owned cars before entering the country.
Promote technological development	Promote R&D culture in transportation in order to adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems in GBA	• Encourage local industry to develop and manufacture spare parts • Give incentive to R&D institutions which play an essential role in mitigating transport technologies • Encourage universities to create engineering mobility programmes.
Social awareness		
Awareness campaign to promote hybrid and fuel efficient cars	Dissemination of information to consumers on these cars' performance, environmental and economical benefits	• Enforce new car dealers to include factsheets on all vehicles, clearly displaying information on vehicle average fuel consumption and annual fuel costs, in addition to average CO_2 emissions. • Enforce marketing campaign (billboards, TV, etc.) to include the mentioned above consumption and emissions labeling of the car. • Enforce all government vehicles to switch to HEV when buying new cars, in order to take the lead as a reference project.
	Dissemination of information to particular consumers which have high annual mileage like taxi drivers and commercial vehicle users	• Present additional financial incentives like the full subsidy of loan interests over the loan period.
Data and information		
Set up a mobility monitoring organism (with an easy and free access to data, particularly for R&D institutions)	Create Mobility Monitoring Indicators (MMI) framework to support transport studies aiming at the development of sustainable transportation strategies	• Delegate the CAS with additional experienced personnel and authority to provide on yearly basis the complete MMI set. • Enforce cooperation and communication on transport studies between relevant authorities resource savings.

5.5.4. Action Plan for deployment of hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme

Target for technology transfer and diffusion

The aim from promoting and deploying hybrid and fuel efficient vehicles is not introducing additional passenger cars to the fleet (1.5 million cars are officially registered in 2010) but replacing non efficient vehicles. Therefore, the target consists of developing and implementing a complementary, integrated car scrappage programme aiming at reducing emissions from the existing fleet, where old, illegal, highly emitting, non fuel efficient vehicles would be bought by the Government and scrapped. In return, owners of scrapped cars are allocated an incentive to buy a new hybrid or fuel efficient car. Incentives can have various forms, such as custom and excise exemption, exemption from registration and road usage fees, payment of minimum salvage value (ex. USD 2,500) as down payment for new car loan, reduce loan interest and/or full subsidy of loan interests for heavy mileage drivers like taxi owners.

Such programme pursues a range of social and economic goals in addition to reducing emissions, such as preventing vehicle abandonment, lowering consumer spending on gasoline, and stimulating new vehicle sales. As a result, the vehicle turnover rate increases by incentivizing vehicle retirement.

The implementation of a car scrappage programme in Lebanon is a top priority measure that needs to be undertaken in parallel to implementing a bus mass transit system on dedicated lanes. However, car scrappage can have various forms of incentive-based applications. For heavy mileage drivers like taxi owners, where swapping to hybrid or fuel efficient vehicles have a high impact on enhancing air quality and reducing emissions, maximum incentives should be allocated. The estimated size of the taxi drivers interested by a car swap under scrappage programme is around 12,000 over 8 years, with driver age lower than 55 and car model year older than 2007. However, for private passenger car owners, estimated size depends largely on the incentives to be allocated: a well-defined programme could target a car fleet renewal between 8% and 10% by 2020.

Strict control needs to be exerted simultaneously in order to enforce the ban on old cars and therefore prevent the illegal import of such old cars that need scrapping. In parallel, strict emission standards need to be defined and enforced, in addition to amending the vehicle taxation system and registration fees into a more balanced environmentally oriented scheme. A comprehensive feasibility study needs to be carried out to assess and well-define such programme.

The technology Action plan for the deployment of hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme is presented in Table 41.

Table 41 - Technology Action plan for hybrid and fuel efficient gasoline-powered vehicles through a scrappage programme

Measures	Priority	Objectives	Responsible parties	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)
Exemption from customs and excise fees, exemption from registration fees, exemption from road-usage fee at registration	1	- Create appropriate financial incentives for hybrid and fuel efficient cars. purchase - Reduce car purchase and ownership costs.	MoF	Short term	Law on tax exemption by government.	0
Payment of minimum salvage value (ex. USD 2,500) as down payment for car loan, extension of loan period to 8 years, reduce loan interest	1		MoF BDL. Commercial Banks	Short term	Car loan package and facilities for hybrid and fuel efficient cars.	2,500 per car
Reduce gradually maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100,000 km, rather than 8 years as the current figure	1	- Create disincentives for import of non efficient pre-owned cars - Limit the import of pre-owned non fuel efficient vehicles.	MoM	Short/ Medium term	Law on import of pre-owned cars.	0
Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees, and where taxes like the road usage fees are reconsidered according to fuel efficiency and/ or emissions rather than engine displacement as the current figure	2	Set up new coherent tax policies to cope with the high demand for high fuel consuming pre-owned vehicles.	MoF	Short term	Bonus-Malus tax scheme.	10,000 (for the preparation of the bonus-malus draft policy)
Create a car scrappage programme based on swapping current passenger cars with hybrid and fuel efficient cars	2	Renew the passenger car fleet Enhance the efficiency of the passenger car fleet.	MoF New cars dealers	Short term	Car scrappage program.	30,000
Create a car termination plant that deals with the car termination process after the swap in the scrappage programme	3	Implement a vehicle retirement programme to remove old cars from the fleet.	MoPWT MoIM MoE	Short/ Medium term	Car termination plant.	-
Update decree 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality to cover all types of vehicles	4	Improve air quality as transport sector is the main air polluter.	MoE	Short/ Medium term	Updated law 6603/1995.	0
Update the vehicle inspection programme requirements taking into consideration special requirements for hybrid cars' inspection, in addition to mandating the presence of catalytic converters on conventional gasoline vehicles	4	Improve the vehicle inspection programme.	MoE MoIM	Short/ Medium term	Updated vehicle inspection programme.	50 per trained person
Set up a mechanical inspection unit at the port of Beirut in charge of checking up the emissions and safety standards of imported pre-owned cars before entering the country	5	- Create institutions to support technical standards for transportation - Limit the import of deficient and crashed pre-owned cars.	MoPWT MoE	Short/ Medium term	Mechanical inspection unit at the port of Beirut.	-
Establish awareness campaign	6	Promote hybrid and fuel efficient cars.	MoPWT MoE	Short/ Medium term	Awareness campaign.	50,000 (full awareness campaign)
Create Mobility Monitoring Indicators (MMI) framework	7	Develop sustainable transportation strategies.	MoPWT MoE CAS	Short/ Medium term	Mobility monitoring indicator framework delegated to CAS.	0

5.6 Enabling framework for overcoming the barriers in transport sector

Fully eradicating the problems of the Lebanese transport sector in GBA is neither affordable, nor economically feasible. However, much can be done to reduce and to lessen the burden of their negative impacts on travelers and the public treasury. Hence, effectively managing this sector requires both a holistic and integrated strategy that goes beyond the visible incidence of these problems and extends to setting a national transport policy, managing all transport services as a whole.

This project has served to highlight the barriers and measures of mass transit buses, hybrid vehicles and fuel efficient gasoline vehicles: technologies highly prioritized by transport experts and stakeholders. While there are many possible measures that can be deployed, there is no single perfect solution. The following Tables propose an enabling framework for a set of measures, presented at two levels. The first level addresses the common barriers of the prioritized technologies, and the second level is technology-specific.

Table 42 provides a summary of the common measures for deploying prioritized technologies.

Table 42 - Common measures for deploying the prioritized technologies.

Economic and financial measures	Policy, legal and regulatory	Institutional and organizational capacity	Social awareness	Data and information
Amend vehicle taxation system and registration fees into a more balanced environmentally oriented scheme: • Exempt mass transit buses and hybrid vehicles from custom and excise fees, registration fees • Exempt spare. parts from custom and excise fees, particularly catalytic converters and filters and electric components for hybrids.	Issuance of laws exempting vehicles from customs, and registration fees.	Create institutions to support technical standards for transportation: • Set up a mechanical inspection unit at the port of Beirut in charge of checking up the emissions and safety standards of imported passenger cars and buses before entering the country.	Aware travelers on ecological and economical benefits of transit bus systems and hybrid and fuel efficient vehicles: • Provide information on CO_2 and fuel savings comparing to passenger cars, through the proper info display tools: mobile applications, dedicated website, media campaigns, etc.	Create Mobility Monitoring Indicators (MMI) framework to support transport studies aiming at the development of sustainable transportation strategies: • Delegate the CAS with additional experimented personnel and authority to provide on yearly basis the complete MMI set. • Enforce cooperation and communication on transport studies between relevant authorities for time, money and efforts savings.
	Implement legislation governing vehicles emissions: • Update and implement decree like that of 6603/1995 relating to standards on permissible levels of exhaust fumes and exhaust quality. • Enforce/update the vehicle inspection programme requirements.	Promote R&D culture in transportation in order to adopt knowledge-intensive high-tech management approaches for solving complex urban transport problems in GBA: • Encourage local industry to develop and manufacture spare parts. • Give incentive to R&D institutions which play an essential role in mitigating transport technologies. • Encourage universities to create engineering mobility programmes.		

Table 43 - Specific measures for deploying mass transit bus system in GBA on dedicated lanes.

Economic and financial measures	Market development	Policy, legal and regulatory	Institutional and organizational capacity
Favorable treatment for mass transit buses rather than conventional pre-owned gasoline vehicles: - Allocate concessionary fares to older people, students and disabled persons. - Use smart card ticketing schemes allowing travelling on all mass transit buses in GBA with one flexible ticket, available on daily, weekly, monthly, or yearly basis (Long term subscriptions bring additional savings to travelers).	Stimulate passengers demand to use mass transit buses: - Design of a complete bus network (bus tracks and bus stop locations) covering all boroughs within GBA.	Legislation favor mass transit transport means in general and public bus transit in particular: - Set clear regulations specifying the operation maneuvers of private bus operations and taxi owners (such regulations must be preceded by setting up a national policy for the global mass transit sector, including the role of each of the private and public operators and the taxi owners).	Develop institutional capacity to enhance bus transit services: - Recruit and train bus drivers on eco-driving attitude and safety principles. - Recruit and train specialized maintenance technicians. - Recruit and train management and control staff in charge of managing and optimizing the planning and bus operation.
Encourage taxi and shared taxi owners to work in the bus mass transit system: - Give special incentives to taxi drivers to get involved in the bus mass transit system in order to limit the number of illegal taxis (17 000 taxis) and reduce the extensive number of taxis (33 000 taxis).	Deploy effective infrastructure measures like an optimized land use planning: - Reserve lanes within GBA for bus operation (reserved lanes are expected to substitute the parking spaces on both sides of the main avenues; therefore, parking spots must be constructed and managed by municipalities).	Enforce the deployment of bus transit systems: - Create/enhance executive and regulatory bodies in charge of ensuring the design, deployment and follow up of the regulatory framework (set above). - Restructure, empower and enhance the role of the traffic management organization (TMO).	Clarify and centralize responsibility among concerned government agencies in order to tackle the gap in the transport system management function.
	Deploy a combination of access, personal travel planning and parking spots to lock the benefits from the aimed operational and infrastructural measures (set above in this Table).		

Economic and financial measures	Market development	Policy, legal and regulatory	Institutional and organizational capacity
	Deploy effective operation measures like optimizing the operation management of the bus mass transit system: - Conserve a clear and regular bus operation. - Implement a real-time information system, tracking the bus operation and displaying the waiting time (information to be displayed on screens in bus stations, on mobile smartphones through special applications and on dedicated websites). - Deploy personalized travel planning tools in order to optimize and predict the travel time. - Implement intelligent transport technologies like the transit signal priority in order to reduce the bus stop times on red lights. - Set up stringent maintenance and cleanliness program.		
	Develop the supply channels of bus mass transit system: - Purchase sufficient number of transit buses with the proper powertrain technology, in order to cover the designed network and avoid irregularities in operation. - Construct bus stations taking into consideration the physical access to buses and stations (for example: improvements to pavements, access ramps for people with limited accessibility, timetables which can be read by those with visual impairment). - Construct relevant maintenance and repair workshop.	Enforce legislative reforms in urban planning laws, expropriation laws (if needed in some areas), and traffic laws: - Redefine the use of urban road infrastructure, taking into consideration the total/partial exclusive use of lanes in mass transit buses only. - Encourage municipalities to build parking spots to optimize the urban road space and allow reservation of lanes for mass transit buses. - Adopt a transit signal priority on red lights in order to reduce the bus travel time.	Restructure, empower and enhance the role of the Traffic Management Organization (TMO): - Develop technical expertise among TMO staff, in order to carry out the traffic management mandates it was conceived for.

Table 44 - Specific measures to create a market of hybrid and fuel efficient vehicles for implementing a scrappage programme.

Economic and financial measures	Market development	Policy, legal and regulatory	Social awareness
Government incentives to consumer: - Exemption from road-usage fee at registration. - Payment of minimum salvage value (ex. 2500 USD) as down payment for car loan. - Extension of loan period to 8 years particularly for hybrid car purchase. - Reduce loan interest and/or full subsidy of loan interests for heavy mileage drivers like taxi owners.	Create a car termination plant: - Create a plant that deals with the car termination process after the swap in the scrappage programme (interested customers in swap shall not have a grant salvage value for their old car or any incentive unless they got the certificate of car termination from the MoE or other special entity in charge). (car termination process is one of the success key of the scrappage program; therefore, old car termination options should be clearly stated and formulated).	Issuance of law modifying the current tax figure in order to cope with the high demand for high fuel consuming pre-owned vehicles: - Adopt a Bonus-Malus tax policy where polluters pay more annual road-usage fees.	Dissemination of information to consumers on these cars' performance, environmental and economical benefits: - Enforce new car dealers to post up factsheets on all vehicles, clearly displaying information on vehicle average fuel consumption and annual fuel costs, in addition to average CO_2 emissions. - Enforce all marketing campaign (billboards, TV, etc.) to post up the mentioned above consumption and emissions labeling of the car. - Enforce all government vehicles to switch to HEV when buying new cars, in order to take the lead as a reference project.
Government incentives to technicians: - Help domestic maintenance and repair technicians to buy equipments through banking facilities (kafalat programme).			Dissemination of information to particular consumers which have high annual mileage like taxi drivers and commercial vehicle users: - Present additional financial incentives like the full subsidy of loan interests over the loan period.
Set up stringent fuel-efficiency and emissions standards on pre-owned imported vehicles: - Fuel-efficiency and emissions standards are intended to help setting adequate tax policies (Bonus-Malus: polluters pay more taxes), in order to favor low consuming new and pre-owned vehicle rather than high consuming pre-owned vehicles.			

Economic and financial measures	Market development	Policy, legal and regulatory	Social awareness
Government disincentives to import of non efficient pre-owned vehicles: Set up coherent tax policies disadvantaging the demand for high fuel consuming pre-owned vehicles: - Reduce gradually maximum age of imported pre-owned vehicles to 3 years with a mileage lower than 100 000 km, rather than 8 years as the current figure. - Road-usage fees must be reconsidered according to fuel efficiency and/or emissions rather than engine displacement as the current figure: Increase gradually road-usage fees on old high consuming vehicles, already owned by consumers Increase road-usage and registration fees on imported pre-owned high consuming vehicles Reduce road-usage and registration fees on new and pre-owned low consuming vehicles. - Increase road-usage fees on the second owned car, for private use.			

5.7 Cost benefit analysis for identified measures in transport sector

Specific transportation costs evaluated

Cost Benefit Analisys is carried out in this study in order to evaluate the economic impacts of the prioritized technologies on the government and the car users. The economic evaluation considered comes under the objective of maximizing the cost reduction of daily passengers' trips. It involves quantifying the cost of market resources like the ownership and operation costs, and non-market resources like the travel time, the crash impact and environmental quality. The specific transportation costs evaluated are summarized in Table 45.

Table 45 - Specific transportation costs assessed in the CBA.

Specific cost	Description	Cost category[(1)]	Market/Non market
Vehicle ownership	Cost for owning a vehicle, including the vehicle purchase cost (minus its salvage value by the end of the vehicle life estimated 10 years), insurance fees, custom and excise fees, registration fees, road-usage fees and financing charges.	Internal-fixed	Market
Vehicle operation	Vehicle operation costs including the cost of consumed fuel, maintenance and tires costs.	Internal-variable	Market
Travel time	The cost of the time used during the travel.	Internal-variable	Non-market
Congestion	The external costs a vehicle imposes on other travelers.	External	Non-market
Parking	Parking fees borne directly by the car users or the government.	Internal-fixed	Market
Internal crash	Damage costs of vehicle accidents borne directly by travelers.	Internal-variable	Non-market
External crash	Damage costs a traveler imposes on others during vehicle accidents.	External	Non-market
Air pollution	Costs of air pollution emissions from vehicle exhaust.	External	Non-market
GHG emissions	Cost of reducing GHG emissions or removing GHGs from the atmosphere through carbon dioxide sequestration	External	Non-market
Operation subsidies	Financial subsidies for implementing the required measures.	External	Market
Fuel tax revenues	Revenues to the government from tax on consumed fuel of passenger cars.	External (from the government perspective) Internal-variable (from car user perspective)	Market

(1) Cost categories are: internal/external, fixed/variable. Internal costs are directly borne by the car user; external costs are borne by others. Variable costs are related to the external variable factors like the fuel consumption or the mileage; fixed costs are not affected by these external variable factors.

Transport modes and travel conditions evaluated

Table 46 summarizes the transport technologies evaluated in this CBA that was prioritized in an early stage of the TNA. The specific cost estimates of Table 45 are computed for each of the considered technologies under three travel conditions (urban-peak, urban off-peak and rural). These estimates are based on extensive research of the real Lebanese driving conditions in GBA through simulation and on-road measurements (Mansour et al., 2011; Mansour and Zgheib, 2012), in addition to assessing the Lebanese vehicle market (Mansour et al., 2011; MoF, 2011; MoE/UNDP/GEF, 2011; Team, 2010).

Methodology for computing the net benefits

Transportation is undoubtedly one of the most complicated economic sectors. It exhibits a number of specific features that renders a common economic wisdom in considering only the relevant peculiarities in the assessment of the sectors' costs and benefits (refer to Table 45). Transportation costs and benefits tend to have a mirror-image relationship: benefits are considered as a reduction in costs, and costs are considered a reduction in benefits. Accordingly, benefits of the identified measures are computed as a reduction in transport costs of the prioritized technologies comparing to BAU. Two BAU technologies are considered, the transport costs of a typical average Lebanese car and those of a typical non-fuel efficient gasoline car. For example, the mass transit bus system benefits are calculated based on the reduction of its total costs (internal and external) per passenger-kilometer compared to the total costs obtained with BAU technologies. As a result, this CBA starts in next section by quantifying the internal and external costs of each of the studied technologies.

Table 46 - Transport technologies evaluated.

Technology[(1)]	Description
Average gasoline car	Mid-size passenger car emulating the average consumption of the Lebanese car fleet. Purchase cost: USD 30,000. Fuel consumption (urban peak/ urban off-peak/ rural): 15.8/ 11.2/ 9.1 l/100km.
Non fuel efficient gasoline car	Large passenger car or SUV emulating the non fuel efficient vehicles observed in the Lebanese fleet. Purchase cost: USD 50,000. Fuel consumption (urban peak/ urban off-peak/ rural): 23.6/ 16.6/ 13.5 l/100km.
Sub-compact fuel efficient car	Small passenger car from the sub-compact segment. Purchase cost: USD 13,000. Fuel consumption (urban peak/ urban off-peak/ rural): 9.5/ 6.7/ 5.4 l/100km.
Compact fuel efficient car	Mid-size passenger car from the compact segment with fuel efficient powertrain. Purchase cost: USD 25,000. Fuel consumption (urban peak/ urban off-peak/ rural): 11.4/ 8.0/ 6.5 l/100km.
Micro hybrid electric vehicle	Sub-compact hybrid passenger car equipped only with stop/start hybrid functionality. Purchase cost: USD 15,000[(2)]. Fuel consumption (urban peak/ urban off-peak/ rural): 6.4/ 5.8/ 4.7 l/100km.
Full hybrid electric vehicle	Compact hybrid passenger car with maximum hybrid functionalities: stop/start, brake energy recovery, electric boost, electric drive mode. Purchase cost: USD 35,000[(2)]. Fuel consumption (urban peak/ urban off-peak/ rural): 5.4/ 5.3/ 4.9 l/100km.
Diesel bus	12-meter diesel bus operating on dedicated lanes in GBA. Purchase cost: USD 300,000 (borne by the government). Fuel consumption (urban peak/ urban off-peak/ rural): 33.4/ 33.4/ 27.2 l/100km.

(1) The estimated average annual mileage for all passenger cars is 15 000 km. The vehicle life is considered 10 years for passenger cars and 20 years for buses.
(2) Considered purchase cost of hybrid vehicles is exempted from custom/excise fees and registration fees.

Cost Benefit Analysis

This section describes and estimates the specific transport costs presented in Table 45 for the following technologies: (1) mass transit bus technologies, (2) hybrid vehicles and (3) fuel efficient gasoline-powered vehicles. These monetized cost estimates are provided for urban peak, urban off-peak and rural driving conditions in GBA, then average savings are computed on the base that urban peak constitute 51.1% of the total travel time, 31.2% for urban off-peak and 17.7% under rural. This travel distribution is determined from an extensive GPS survey of GBA driving conditions (Mansour and Zgheib, 2012). They represent GBA average costs, except where noted otherwise due to lack of data.

Methodology and estimates of specific transport costs under GBA driving conditions

- *Vehicle ownership and operating costs*

The direct user expenses to own and use transport technologies are computed in this section under the vehicle ownership costs and the vehicle operating costs. These costs permit to determine savings that result from alternative and fuel-efficient transport means with respect to the BAU, considered in this study the average gasoline passenger car. Table 47 and Table 49 summarize the vehicle operating and ownership costs of the considered technologies in USD/veh.km and in USD/pass.km, assuming that the vehicle occupancy in GBA estimated at 1.2 pass/veh for passenger cars and 25 pass/veh for buses, under urban peak driving conditions. Similar exercise for operating costs is applied for GBA off-peak and rural driving conditions, summarized in Table 48.

Table 47 - Vehicle operating costs of the studied transport technologies under GBA peak driving conditions.

	Average car	Non fuel-efficient car	Sub-compact fuel efficient car	Compact fuel efficient car	HEV Stop/ Start	HEV Full Hybrid	Diesel bus
Fuel consumption(1) (USD/veh.km)	0.1900	0.2826	0.1135	0.1362	0.0965	0.0648	0.2896
Maintenance(2) (USD/veh.km)	0.0275	0.0311	0.0262	0.0262	0.0262	0.0112(3)	0.2858(4)
Tires(5) (USD/veh. km)	0.0060	0.0124	0.0060	0.0060	0.0060	0.0060	0.0400(6)
Operating costs (USD/veh.km)	0.2234	0.3261	0.1457	0.1683	0.1286	0.0819	0.6154
Operating costs(7) (USD/pass.km)	0.186	0.272	0.121	0.140	0.107	0.068	0.025

(1) computed from the vehicle fuel consumption under GBA driving conditions (l/100km) (Annex V, Table 1), the annual mileage (estimated at 15000 km) and the fuel cost (1.2 USD/liter of gasoline and 0.867 USD/liter of diesel).
(2) estimated from the American Automobile Association in 2010 as no local data is available (AAA, 2010).
(3) estimated from end-of-life accelerated on-road vehicle testing, on 6 full-hybrid electric vehicles (USDOE, 2011).
(4) estimated from the Environmental and Energy Study Institute (EESI, 2009).
(5) average tire costs in the Lebanese market are 120 USD/tire for compact passenger cars and 250 USD/tire for large passenger cars and SUV. The total mileage considered before changing tires is 50 000 km.
(6) estimated from maintenance results over 12-month period on New York city transit buses (Barnitt, 2006).
(7) vehicle occupancy in GBA is estimated 1.2 pass/veh for passenger cars 25 pass/veh for buses under urban peak driving conditions.

Table 48 - Vehicle operating costs of the studied transport technologies under GBA off-peak and rural driving conditions.

	Average car	Non fuel-efficient car	Sub-compact fuel efficient car	Compact fuel efficient car	HEV Stop/ Start	HEV Full Hybrid	Diesel bus
Operating costs under GBA off-peak(1) (USD/pass.km)	0.139	0.202	0.093	0.107	0.087	0.067	0.025
Operating costs under rural(2) (USD/pass.km)	0.119	0.171	0.081	0.092	0.080	0.063	0.022

(1) Vehicle occupancy off-peak driving conditions is estimated 1.2 pass/veh for passenger cars and 10 pass/veh for buses.
(2) Vehicle occupancy under rural driving conditions is estimated 1.2 pass/veh for passenger cars and 15 pass/veh for buses.

Table 49 - Vehicle ownership costs of the studied transport technologies.

	Average car	Non fuel-efficient car	Sub-compact fuel efficient car	Compact fuel efficient car	HEV Stop/ Start	HEV Full Hybrid
Vehicle purchase(1) (USD)	30000	50000	13000	25000	15000	35000
Salvage value(2) (USD)	7600	12660	3290	6330	3800	8860
Insurance(3) (USD/year)	510	800	263.5	437.5	292.5	582.5
Custom/Excise(4) (USD)	10666.7	20666.7	2283.3	8166.7	3166.7	13166.7
Registration(5) (USD)	1200	2000	520	1000	600	1400
Registration (USD)	1200	2000	520	1000	600	1400
Road-usage fees(6) (USD)	810	2286.7	810	810	810	810
Financing charges(7) (USD/year)	597.5	995.8	258.9	497.9	298.7	697.1
Ownership costs (USD/year)	3549	5959	1626	2983	1852	4114
Ownership costs (USD/veh.km)	0.2366	0.3972	0.1084	0.1989	0.1235	0.2743
Ownership costs (USD/pass.km)	0.1972	0.3310	0.0903	0.1657	0.1029	0.2286

(1) Estimated from Lebanese market survey and personal communication with BUMC (Toyota dealer) (Bejjani, 2012)
(2) Vehicle depreciation is estimated 20% for the first year and 12% for the following years. Vehicle life is estimated 10 years.
(3) Insurance fees are computed according to the following formula: 14.5% of the vehicle purchase cost during the loan period (5 years), in addition to 150 USD/year after loan period for the last 5 years. The total insurance sum is divided over the 10 years of the vehicle life.
(4) Refer to (MoF, 2011) for details of the custom and excise fees.
(5) Car registration fees are 4% of the vehicle's estimated value, considered in this study similar to the vehicle purchase cost (MoF, 2011).
(6) Road-usage fees are locally known by "road-usage fees". New cars are exempted from this fee for the first 3 years (Informs, 2012). Refer to (MoF, 2011) for details on the road-usage fees. All vehicles are considered in the 11-20 horsepower category, except the non fuel efficient car 31-40 horsepower. The estimated values are computed over the vehicle life (10 years).
(7) Financing charges are the bank loan interest over the 5 years car loan.

Therefore, the total vehicle costs (which stand for the ownership and the operation costs) per vehicle-kilometers and per passenger-kilometers are illustrated in Fig. 36. Note that these costs are borne by the user and not the government. Moreover, the subsidy measures intended for hybrid and fuel efficient car buyers has not been included in this section (refer to section operation subsidies by Lebanese government).

- *Travel time*

The cost of travel time refers to the cost of time spent on transport, including waiting as well as actual travel. It is the product of time spent traveling (measured in hr/veh.km) multiplied by unit costs (measured in USD/hr). The traveling time is estimated from the vehicle average speed (Annex V, Table 2), and the unit cost is estimated at 5 USD/hr, for an average wage rate of 800 USD/month (CAS, 2011).

Travel time costs vary significantly, depending on various factors. For example, time spent in discomfort has higher unit costs than time spent in comfortable conditions. Hence, for this evaluation, travel is divided into four categories, with different cost values, as summarized in the Table 50 (Litman, 2011a).

Travel time cost results are summarized in Table 51, under urban peak driving conditions. Two different scenarios are considered for the bus transit system: (1) bus transit operating on dedicated lanes in GBA and (2) bus transit not operating on dedicated lanes. Results for off-peak and rural driving conditions are summarized in Table 52.

Fig. 36 - Total vehicle costs of the studied transport technologies under GBA peak driving conditions.

Table 50 - Travel time cost categories used in the CBA.

Category	Description	Cost value	Portion of travel time
Paid	Travel by employees when being paid, including business people traveling to meetings, and workers traveling between job sites.	150% wage rates	5% commercial travel
Personal, high cost	Personal travel during which travelers experience significant discomfort or frustration, such as driving in congestion or pedestrians and transit passengers in uncomfortable conditions.	50% wage rates for drivers, 35% of wages for passengers	20% Typical for urban-peak commute that occurs under congested or unpleasant conditions
Personal, medium cost	Personal travel during which travelers experience no discomfort.	25% wage rates for adults	50% Typical of errand trips under uncongested conditions
Zero-cost travel time	Travel that users enjoy and so would pay nothing to reduce their travel time.	No cost	25% Typical for recreational travel and some personal travel

Table 51 - Travel time cost under GBA peak driving conditions in US¢/pass.km.

	Passenger cars	Bus system not operating on reserved lanes	Bus system operating on reserved lanes
Paid	2.1	2.6	1.9
Personal, high cost	2.8	3.4	2.5
Personal, medium cost	3.6	4.3	3.1
Zero-cost travel time	0	0	0
Travel time cost (US¢/pass.km)	8.5	10.2	7.5

Table 52 - Travel time cost under GBA off-peak and rural driving conditions in US¢/pass.km.

	Passenger cars	Bus system not operating on reserved lanes	Bus system operating on reserved lanes
Travel time cost under GBA peak driving conditions (US¢/pass.km)	3.8	4.6	4.3
Travel time cost under rural driving conditions (US¢/pass.km)	2.9	3.5	2.9

- *Congestion*

Congestion costs consist of both internal and external costs that result from the interference among vehicles during traffic, particularly as traffic volumes approach the maximum road's capacity. These costs are the incremental delay during traffic, the additional fuel consumption, the vehicle components wear, the pollution emissions and the cost of the passengers' discomfort (Hau, 1992).

To prevent double counting, internal congestion costs that are borne by the drivers are not considered in this section since they have been accounted for under the travel time cost, the emissions cost, the crash cost and the vehicle operating cost. Therefore, Table 53 presents the external congestion costs a vehicle imposes on other travelers.

- *Crash costs*

The crash costs assessed in this study is the monetized value of damages caused by vehicle accidents. They include the damages to the individual traveling by a particular vehicle (internal costs), and the damages imposed by an individual on other travelers (external costs).

Due to lack of data availability on crash costs in Lebanon, data are borrowed from the literature. The internal crash costs are estimated at 5.2, 5.8 and 0.25 US¢/pass.km for average car, compact car and diesel bus respectively; and the external crash cost at 3.4, 3.3 and 16.5 US¢/veh.km respectively (Litman, 2011c).

- *Air pollution*

Air pollution costs refer to motor vehicle air pollutant damages, including human health, ecological and esthetic degradation. The scope of pollutant emissions analysis in this study is narrowed to considering only emissions from vehicle exhaust pipes. Therefore, air pollution cost estimates are based on reflecting only exhaust emissions during vehicle operation (CO, NO_x, PM, VOC, SO_2). It excludes upstream emissions that occur during fuel production and distribution, and the pollution associated with vehicle manufacturing, as these costs are not borne by the Lebanese government.

Literature provides extremely divergent estimates of air pollution costs (Delucchi, 2004; Litman, 2002; Holland et al., 2002; Wang et al., 1995). Average estimates are considered in this analysis, and air pollution estimates are summarized in Table 54, in US¢/pass.km (Litman, 2011d).

- *GHG emissions*

The greenhouse gas emission values are based on the mitigation cost estimates, which is the cost of reducing GHG emissions from the atmosphere through carbon dioxide sequestration, and therefore reducing future climate change damages. Several studies suggest that GHG mitigation costs will remain 20-50 USD/tonne of CO_2 equivalent for some time, although this may increase to achieve larger emission reductions (Litman, 2012). A value of 35 USD/tonne is used in this analysis as the default value.

To calculate the per kilometer cost of GHG emissions, the Tank-to-Wheel GHG emissions from the analyzed transportation technologies (in g/km) are multiplied by the considered GHG mitigation cost. Results are summarized in Table 55.

- *Operation subsidies by Lebanese government*

Reviewing the identified measures to deploy hybrid and fuel-efficient gasoline vehicles, market and consumer incentives are inevitable. The incentives mainly intend to reduce the vehicle purchase and ownership costs, through:

- exemption from customs and excise fees on vehicle and spare parts to favor suppliers invest
- exemption from registration fees and from road-usage fee at registration
- payment of minimum salvage value as down payment for the car loan
- banking facilities through loan extension up to 8 years
- reduce loan interest and/or full subsidy of loan interests over loan period

Table 56 summarizes the government subsidy assuming an average annual mileage of 15,000 km per vehicle and an average occupancy of 1.2 passengers per vehicle.

- *Fuel excise*

The government collects indirect revenues from car usage through a tax levied on imported liters of gasoline. Excise on gasoline is not an added value tax, it a specific tax levied as function of volume. It is estimated around 400 LBP/liter of gasoline (0.267 USD/liter). Table 57 highlights the gasoline excise revenues of the government on the evaluated transport technologies.

Table 53 - Congestion costs considered in the analysis in US¢/pass.km.

	Passenger car	Diesel bus operating on dedicated lanes	Diesel bus not operating on dedicated lanes
Urban peak	6.73	0.1	0.67
Urban off-peak	1.04	0.25	0.25
Rural	0	0	0

Table 54 - Air pollution costs in US¢/pass.km, including exhaust emissions only.

	Urban Peak	Urban Off-peak	Rural
Gasoline average car	3.23	2.71	1.35
Sub-compact gasoline fuel efficient car	2.39	2.01	1.00
Compact gasoline fuel efficient car	2.66	2.23	1.11
Stop/start hybrid electric vehicle	2.51	2.11	1.05
Full hybrid electric vehicle	1.20	1.01	0.50
Diesel bus not operating on dedicated lanes	0.46	1.00	0.05
Diesel bus operating on dedicated lanes	0.40	1.00	0.05

Table 55 - GHG emission costs in US¢/pass.km.

	urban peak	urban off-peak	rural
Gasoline non efficient car	1.60	1.13	0.91
Gasoline average car	1.07	0.76	0.61
Sub-compact fuel efficient car	0.64	0.45	0.37
Compact fuel efficient car	0.77	0.54	0.44
Stop/Start hybrid electric vehicle	0.43	0.39	0.32
Full hybrid electric vehicle	0.36	0.36	0.33
Diesel bus	0.12	0.30	0.20

Table 56 - Government subsidy for full hybrid HEV, stop/start HEV and fuel efficient gasoline vehicles (US¢/pass.km).

	Sub-compact fuel efficient gasoline car	Compact fuel-efficient gasoline vehicles	Stop/start hybrid electric vehicle	Full hybrid electric vehicle
Customs/Excises[(1)]	1.27	4.53	1.76	7.31
Registration[(2)]	0	0	0.33	0.78
Road-usage fees[(3)]	0	0	0	0
Salvage/Return on salvage[(4)]	0	0	0	0
Subsidy of loan interest[(5)]	0	0	0	0
Total subsidy	1.27	4.53	2.09	8.09

[(1)] Refer to (MoF, 2011) for details of the custom and excise fees. The vehicle costs are estimated at USD 13,000, 25,000, 15,000 and 35,000 for the sub-compact, compact, stop/start and full hybrid vehicles respectively.
[(2)] Car registration fees are 4% of the vehicle's estimated value, considered in this study similar to the vehicle purchase cost (MoF, 2011).
[(3)] Road-usage fees are locally known by "road-usage fees". New cars are exempted from this fee for the first 3 years (Informs, 2012).
[(4)] This value is the difference between the salvage value of the swapped old car, borne by the government, and the return on salvage value. An efficient car termination programme of swapped cars should bring this value to zero.
[(5)] The government full subsidy of loan interest over loan period is not considered in this analysis. Taxi drivers, students and disabled persons are only eligible for this incentive.

Table 57 - Gasoline excise on the evaluated transport technologies in US¢/veh.km.

	Average gasoline car	Non fuel efficient gasoline car	Sub-compact fuel efficient car	Compact fuel efficient car	Stop/start hybrid electric vehicle	Full hybrid electric vehicle
Urban peak	4.2	6.3	2.5	3.0	1.7	1.4
Urban off-peak	3.0	4.4	1.8	2.1	1.7	1.4
Rural	2.4	3.6	1.5	1.7	1.3	1.3

Cost benefit analysis results

The objective of the CBA is to identify the cost value of the prioritized measures and technologies in order to support setting a beneficial transport policy, favoring lower-cost transport technologies over higher-cost transport technologies. Thus, it is of great interest to presents the costs and benefits results from two perspectives: the passenger car users' perspective and the government's perspective.

- *Costs and benefits from the passenger car users' perspective*

Considerable savings are observed, particularly when car users swap from non efficient cars to buses or fuel efficient cars (Fig. 37 and Fig. 38). Such swap becomes feasible if the car purchase loan is spread to over an 8-year loan period, as illustrated in the net cash flow of car users (Fig. 40 and Fig. 41). The net cash flow calculation is based on both revenues and mandatory charges. Therefore, the benefits depend on the income activity of the car user (Fig. 39).

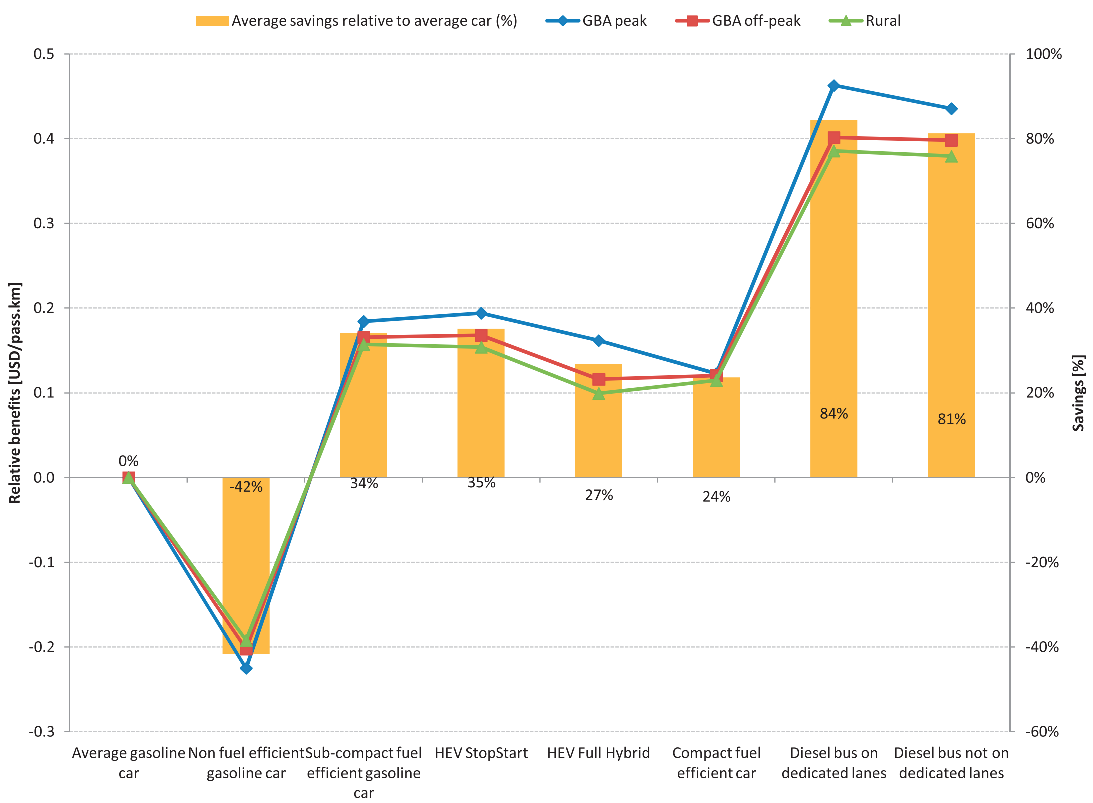


Fig. 37 - Car users benefits of transport technologies relative to average car under GBA driving conditions.

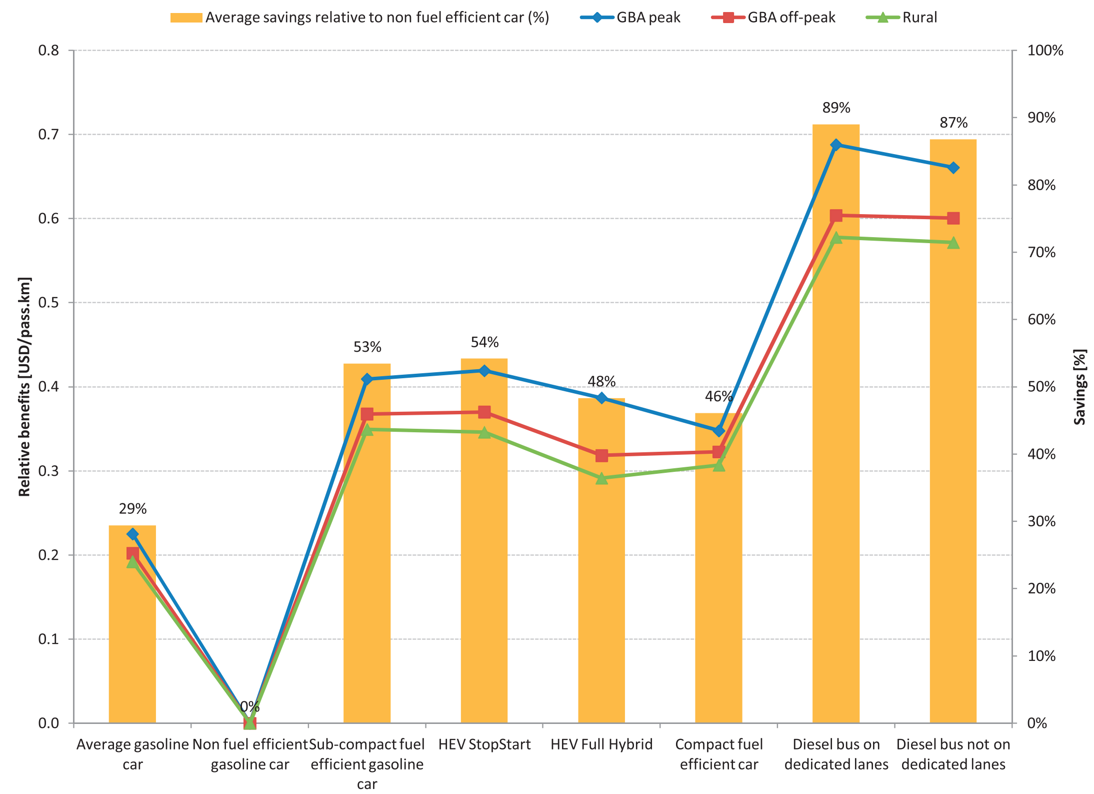


Fig. 38 - Car users benefits of transport technologies relative to non fuel efficient car under GBA driving conditions.

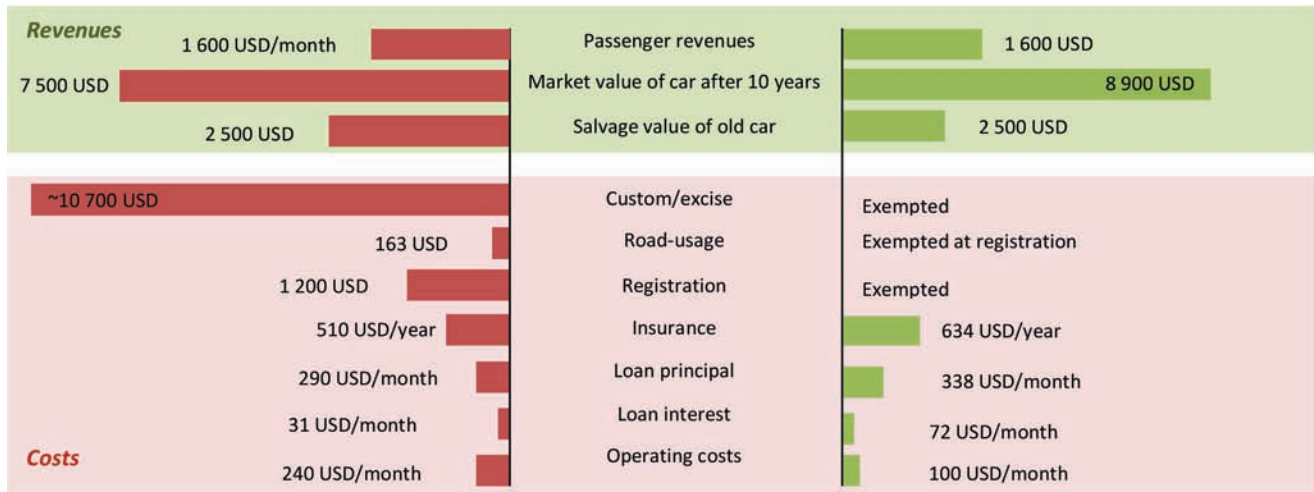


Fig. 39 - Revenues and costs of an average car versus a full hybrid car.

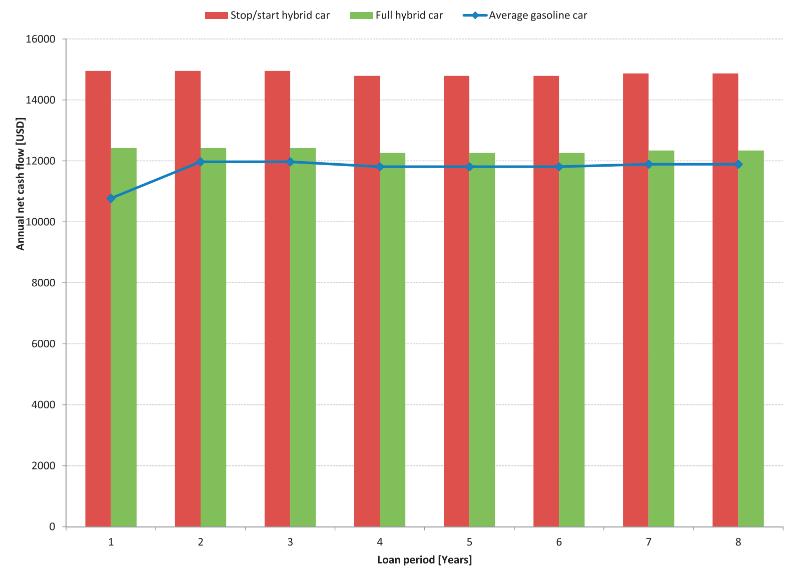


Fig. 40 - Annual net cash flow for a stop/start and full hybrid car user over an 8-year loan period.

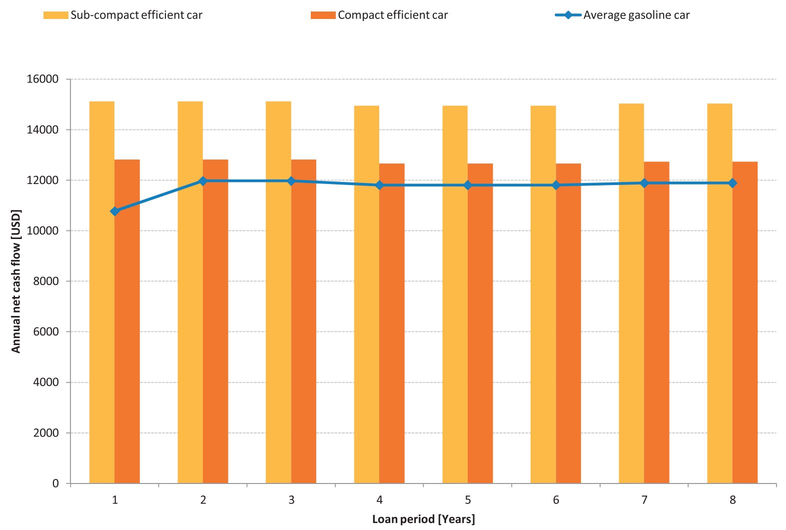


Fig. 41 - Annual net cash flow for a sub-compact and compact fuel efficient car user over an 8-year loan period.

At this stage, it is interesting to identify the specific key parameters that maximize the car users' benefits. For passenger cars, full hybrid cars serve as a good example. It costs nearly 0.4 USD/pass.km: 27% and 48% more beneficial than the average and the non fuel efficient cars respectively. The largest benefit examined come from the vehicle operation cost reduction due to the higher efficiency of the hybrid powertrain, as illustrated in Fig. 42 and Fig. 43. As a result, including energy efficiency as decision-making criteria for buying a car is a key parameter for achieving considerable benefits. Thus, energy efficiency indicators must imperatively be communicated to car buyers, through appropriate standards and regulations imposed by the government.

Similar analysis shows that the diesel bus operating on dedicated lanes in GBA brings additional benefits to travelers, 84% and 89% more beneficial than the average and the non fuel efficient cars respectively. Benefits come mainly from reducing the vehicle ownership cost, the vehicle operation cost in addition to reducing the crash and parking costs, and no operation subsidy has to be borne by the government, as illustrated in Fig. 43.

Therefore, maximizing the transport benefits from the car users' perspective implies selectively eliminating the worst energy efficient vehicle technologies in the fleet and stimulating replacement by the best performing vehicles (including mass transit buses) with the highest energy efficiency per passenger-kilometer.

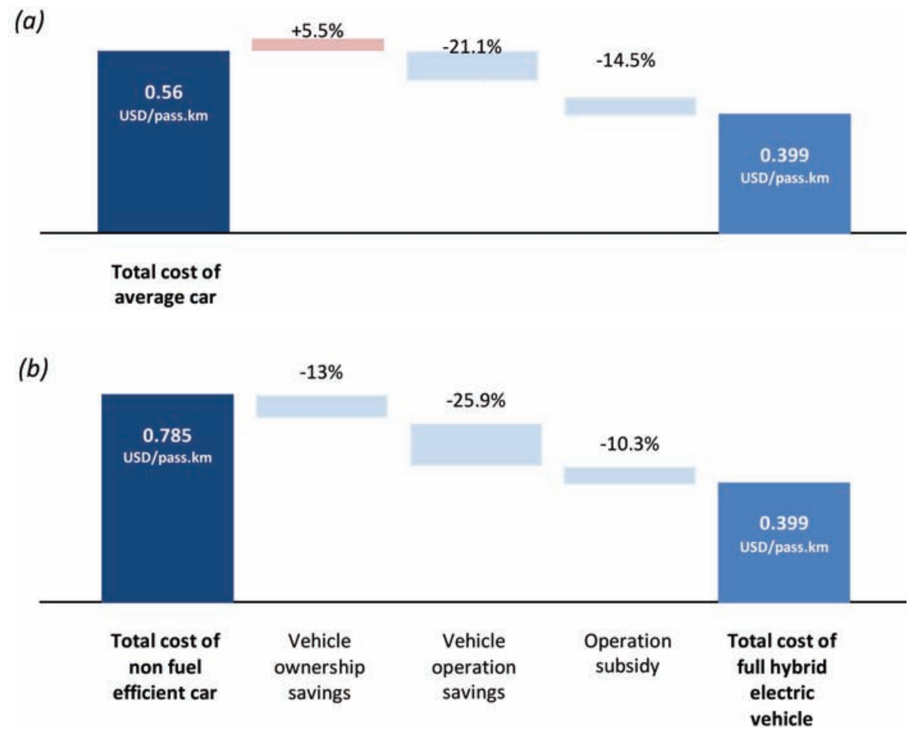


Fig. 42 - Cost savings breakdown of hybrid electric vehicle users under GBA peak driving conditions: (a) relative to average car, (b) relative to non fuel efficient car.

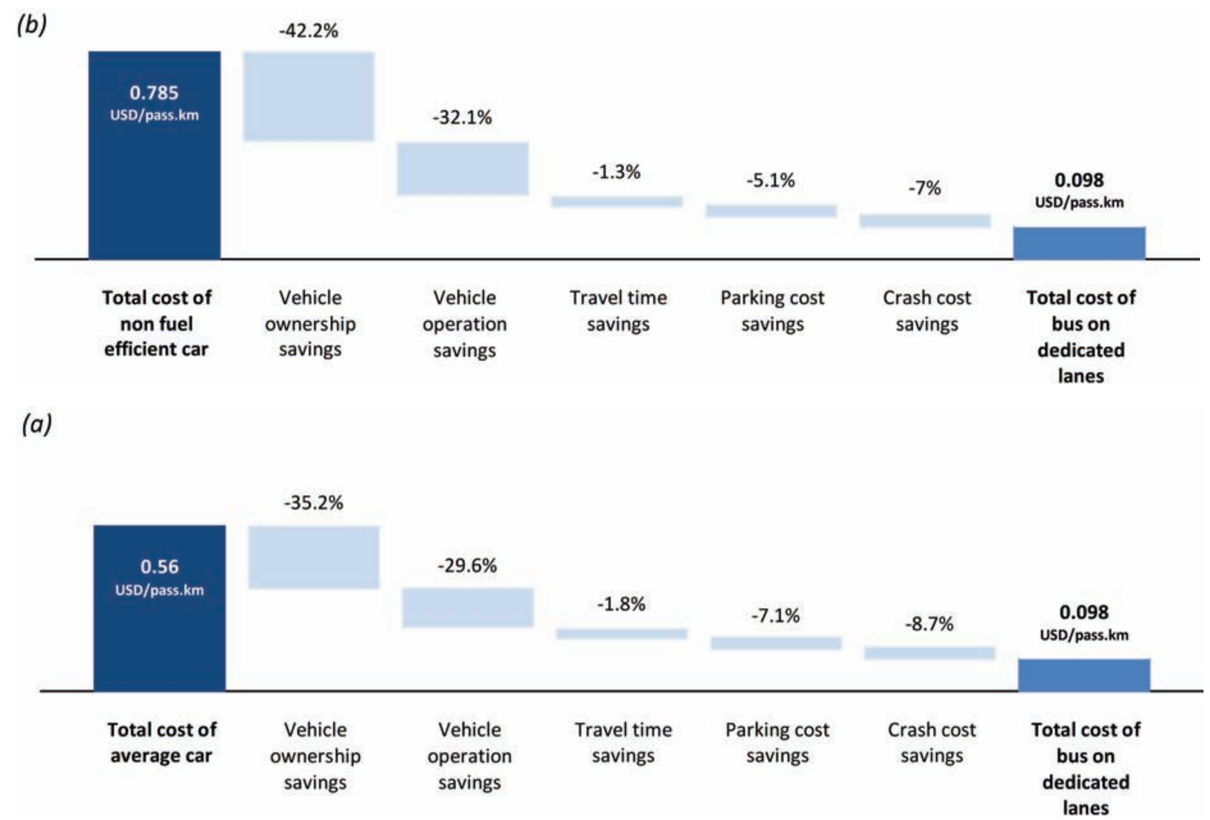


Fig. 43 - Cost savings breakdown of bus users on dedicated lanes, under GBA peak driving conditions: (a) relative to average car, (b) relative to non fuel efficient car.

- *Costs and benefits from the government's perspective*

Several scrappage and fleet renewal schemes have been implemented worldwide in order to improve air quality, reduce dependence on imported fuels, reduce CO_2 emissions and support the automotive industry (ECMT, 1999; ITF, 2011). Among the well designed fleet renewal schemes: the United States CARS programme, the German Umweltprämie and in France the Prime à la Casse programme in 2009. All the 3 programmes did not succeed in recovering the total government costs. Only 80% of the US government costs were recovered through societal benefits like fuel savings, pollutant and CO_2 emissions savings, traffic casualties and serious injuries avoided. The German and French programmes were even poorer with 25% and 46% of cost recovery respectively (ITF, 2011). Therefore, objectives of scrappage and fleet renewal programmes are not designed to bring benefits to the government rather than for economic stimulus and environmental and health protection. Fleet renewal programmes are designed for their economic stimulus, environmental and health protection rather than cash benefits to the government.

Similar figures are observed in this CBA exercise from the Lebanese government perspective. Scrappage scheme by swapping average cars with hybrid and fuel efficient cars would allow the government to recover between 44% and 90% of the government costs (Fig. 44). Only bus systems would bring benefits. However, it is worth mentioning that the current trend of massive market submerge with non fuel efficient cars also do not allow cost recovery for the government: 33% of losses are observed comparing to an average car. Therefore, a well designed scrappage programme would be beneficial if mainly targeting on eliminating non fuel efficient cars, as illustrated in Fig. 45.

Note that, observed results derive from the current figures of tax levied on fuel imports in Lebanon, from road-usage fees, from custom duties excise tax, and VAT from cars at import. However, a well designed and effective scrappage programme should be implemented in parallel with a tax reform, at least at the road-usage fees, where high-polluters should be penalized and low-polluters recompensated. With such reform, the government will be able to optimize more efficiently its revenues from the scrappage programme.

- *Upper purchase cost limit of the hybrid electric and fuel efficient cars*

Since not all hybrid and fuel efficient cars allow total recovery of the government costs, as illustrated in Fig. 45, there is an upper purchase cost limit of these cars for having 100% recovery. The maximum purchase cost is estimated at USD 23,000, as illustrated in Fig. 46. Therefore, all fuel efficient and hybrid electric vehicles with lower purchase cost should be subsidized without any loss to be borne by the government.

Table 58 summarizes the government foregone revenues and the car users' benefits over the vehicle life (estimated 10 years), under the scrappage programme. The societal and economical benefits to car users' are 2.5 to 5 times the foregone revenues borne by the government during the programme. Therefore, such programme implies an important economical stimulus to car users.

- *Peak shift savings*

An additional interesting issue to consider in the CBA is improving the level of service of GBA roads, and therefore, switching from urban peak to off-peak driving. From both the government and the car users' perspectives, maximizing benefits is obtained from shifting transport demand to bus mass transit operating on dedicated lanes, as illustrated in Fig. 47 and Fig. 48. As a consequence, the new thinking approach in establishing a sustainable transport policy in GBA is (1) to shift transport demand massively to mass transit systems, (2) to swap non efficient technologies with efficient technologies through well designed scrappage scheme, and (3) to switch from peak to off-peak driving conditions by avoiding unnecessary trips and shifting demand to mass transit.

The CBA has considered the different technologies under the mitigation strategies proposed in the TNA. Internal and external costs have been computed from both perspectives: passenger car users and the government, under the current Lebanese driving conditions.

Considerable savings are observed from car users' perspective in both cases: swapping to fuel efficient vehicles or shifting to bus transit system. The benefits examined come from reducing the vehicle operation cost reduction due to the higher efficiency of the buses and the hybrid car technologies investigated.

Fig. 44 - Government benefits of transport technologies relative to average car under GBA driving conditions.

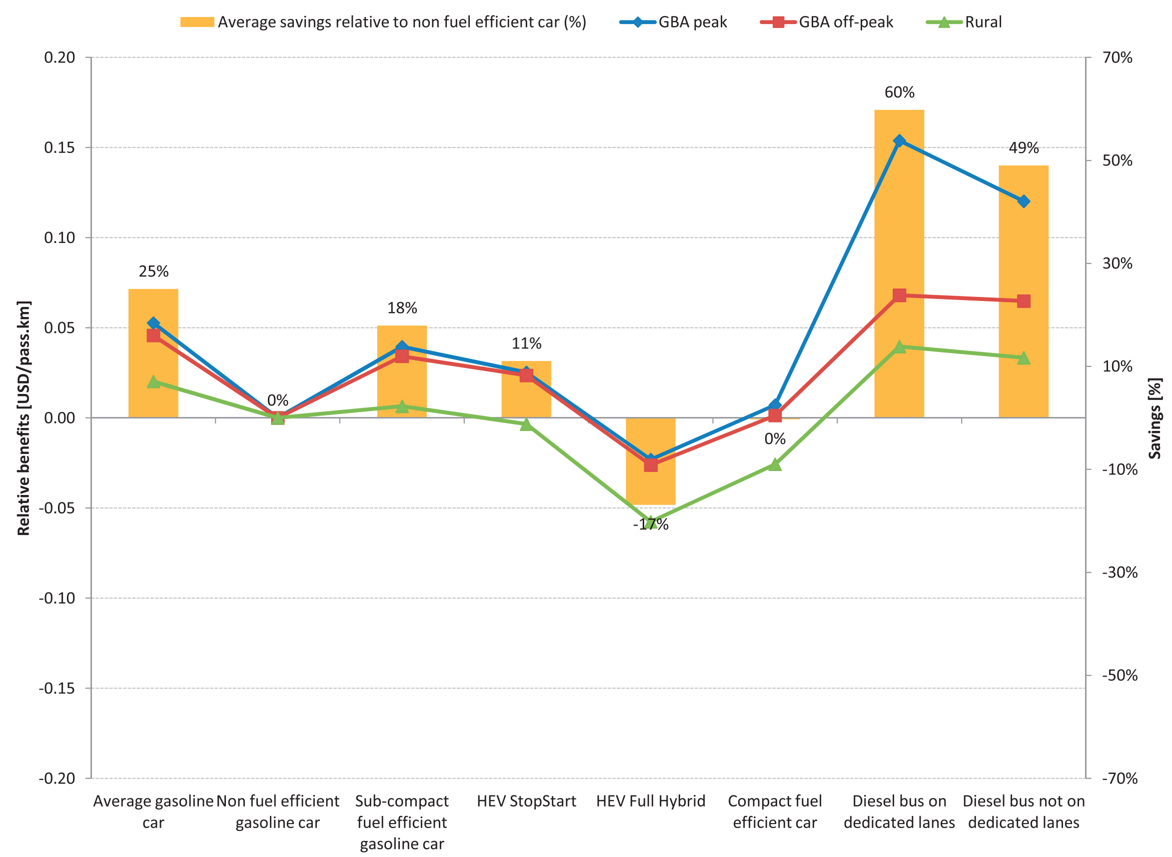


Fig. 45 - Government benefits of transport technologies relative to non fuel efficient car under GBA driving conditions.

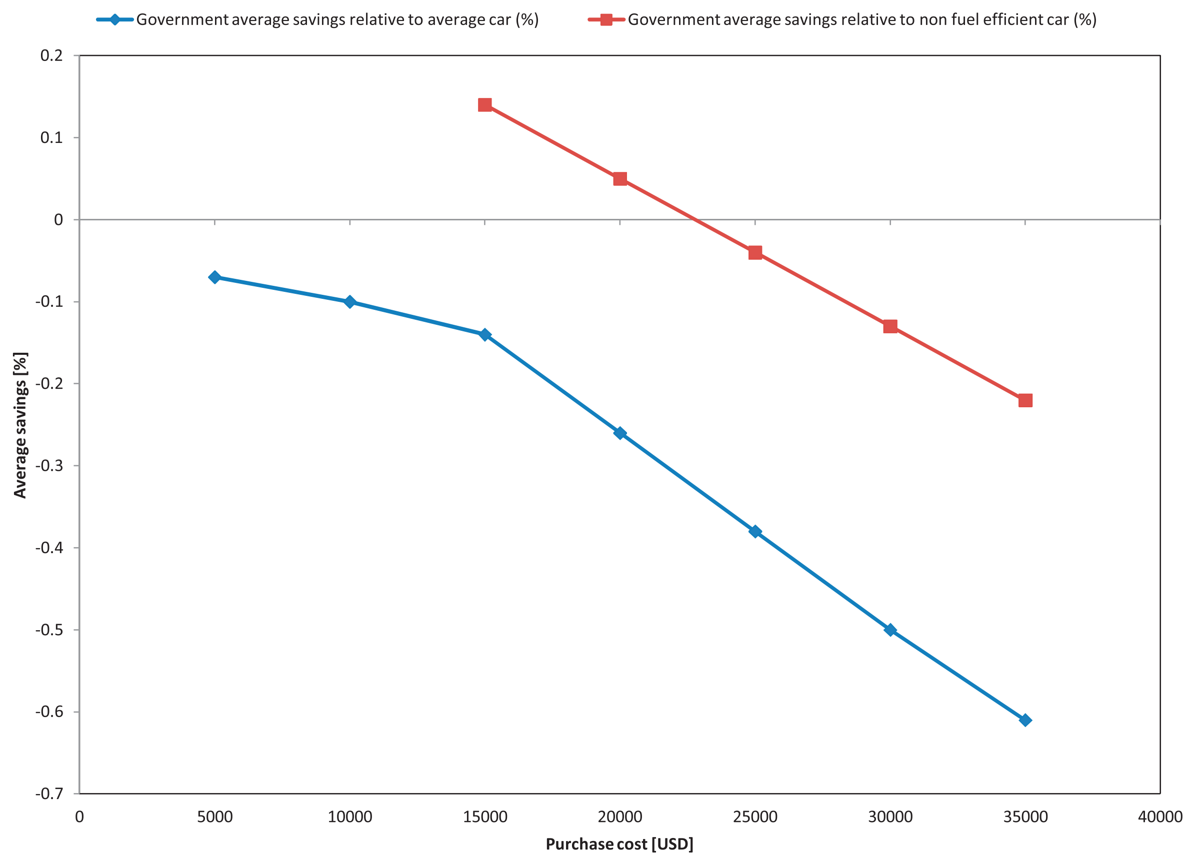


Fig. 46 - Upper purchase cost limit of hybrid and fuel efficient cars.

Table 58 - Government foregone revenues and car users' benefits over 10 years for the upper purchase cost limit of hybrid and compact fuel efficient cars.

	Hybrid electric vehicle at USD 23,000	Compact fuel efficient car at USD 23,000
Government foregone revenues relative to average car(1)	Car tax exemption at purchase: USD 8,000 Foregone gasoline excise fees due to fuel savings: USD 4,175 Total: USD 12,175	Car tax exemption at purchase: USD 7,100 Foregone gasoline excise fees due to fuel savings: USD 1,800 Total: USD 8,900
Car users' benefits relative to average car(2)	USD 31,770 /veh	USD 22,140 /veh

Government foregone revenues relative to non fuel efficient car(1)	Car tax exemption at purchase: USD 8,000 Foregone gasoline excise fees due to fuel savings: USD 7,275 Total: USD 15,275	Car tax exemption at purchase: USD 7,100 Foregone gasoline excise fees due to fuel savings: USD 4,900 Total: USD 12,000
Car users' benefits relative to non fuel efficient cars(2)	USD 70,000 /veh	USD 60,350 /veh

(1) The government forgone revenues are the operation subsidies in addition to the forgone gasoline excise fees due to fuel savings.
(2) The car users' benefits considered include car ownership savings, operating cost savings, travel time reduction, parking and crash savings and the operation subsidies received from the government.

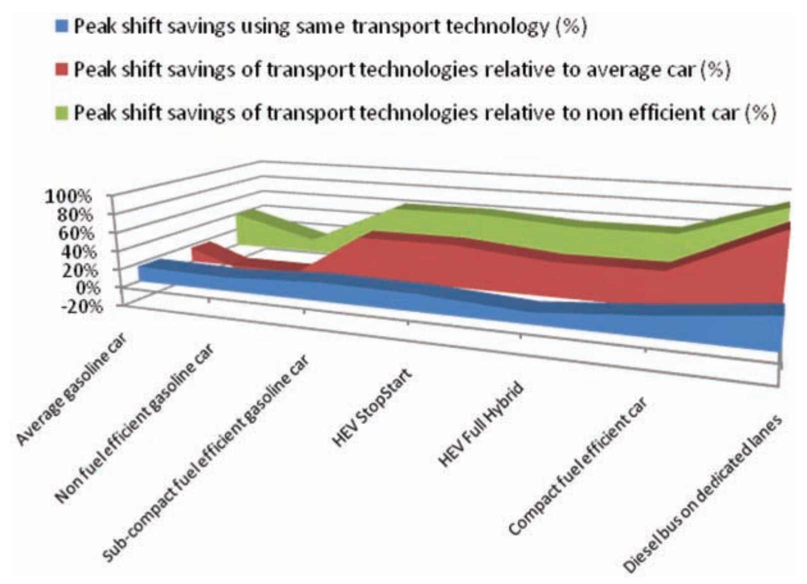


Fig. 47 - Peak shift savings from the car users' perspective.

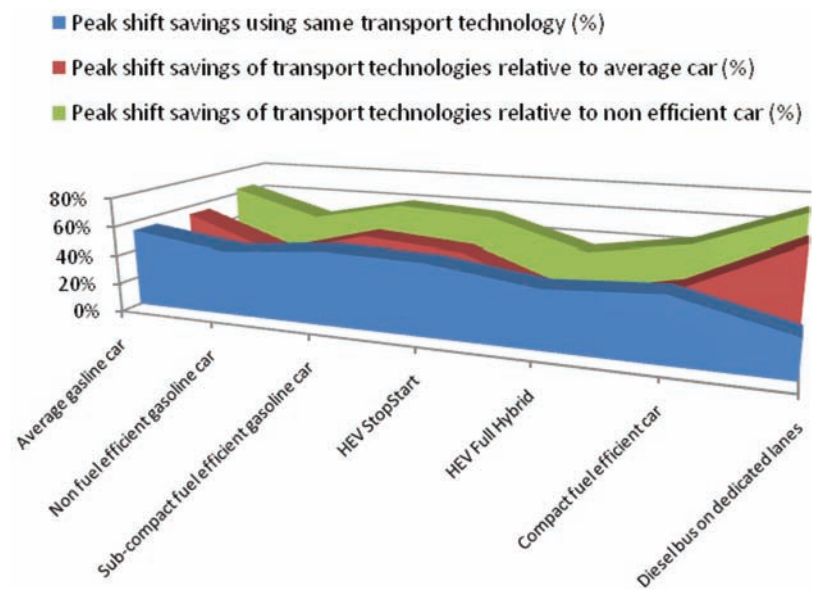


Fig. 48 - Peak shift savings from the government perspective.

Similar benefit figures are observed in this CBA exercise from the Lebanese government perspective, particularly adopting bus transit system on dedicated lanes in GBA. Scrappage scheme as defined in this CBA would allow the government to partially recover its investment costs. However, the current trend of massive market submergence with non fuel efficient cars also implies considerable cost (losses) on the government.

As a result, according to this CBA, the development of transport sector within the transition to a sustainable mobility and a green economy would be well served for both the Lebanese government and the car users by the adoption of the following specific actions:

- Shifting travel demand in GBA to the most efficient mode: bus transit on dedicated lanes, as benefits are considerable for both the car users and the government.
- Eliminating the least energy efficient vehicle technologies in the fleet and stimulating replacement by the best performing vehicles, through implementing a well designed scrappage programme.
- Adopting in parallel to the scrappage programme a tax reform scheme, at least at the road-usage fees, where high-polluters are penalized and low-polluters recompensed. With such reform, the government will be able to optimize more efficiently its revenues from the scrappage programme.

The Agriculture Sector

6.1 Sector overview

The geographical situation of Lebanon and its topography offers the possibility of diversifying agriculture production. Five agro-climatic zones characterize the country: On the coastal strip, tropical crops, citrus and horticulture crops are grown. On the lower altitudes, olive, grape and other Mediterranean crops are predominating. Temperate fruit orchards cover the middle altitudes, while field crops, grapes and fruit orchards are biggest in central and western Bekaa. Northern Bekaa with large marginal lands has few irrigated crops and rainfed cereals or fruit trees. The total cultivated area is 277,169ha out of which 58,600 ha of olive trees, 77,100ha of other fruit trees, 69,600ha of cereals and 41,700ha of vegetable crops (MoA, 2007). Half of the agriculture surface is irrigated and only 2% of it is protected under greenhouses and tunnels. Irrigated crops are mainly vegetables and fruit trees, whereas rainfed cropping characterizes mostly olive tree, tobacco, cereals and legumes. The major agriculture areas of the country are located in the Bekaa (38% of the arable land) and North Lebanon (28%). Lebanese exports accounted to some USD 140 million in 2007 and mostly comprise fruit and vegetable crops. However, Lebanon relies on food imports to satisfy the local demand. Imported fresh food products reached USD 583 million for the same year (MoA, 2007). Therefore, the food security balance is chronically negative in the country, and the agriculture sector only contributes 5.5% of the GDP (Presidency of the Council of Ministers, 2006).

The Second National Communication report to the UNFCCC (MoE/UNDP/GEF, 2011) for Lebanon highlighted the crops that are of a national economical and social importance and vulnerable to climate change. These include potato, tomato, apple, cherry, grapevine, banana and wheat. The impact of climate change on agriculture production and quality has been extensively studied under diverse scenarios for the mentioned crops. The report shows that negative impact is likely to occur in the near future leading to an accelerated trend of food insecurity. The vulnerability of these crops was evaluated and it was found very fluctuating under the different scenarios and between the different regions. Some of the crops will not meet their chilling requirement which will negatively affect their yields (potato, fruit trees), while others will be affected by increasing heat and drought waves (cherry, tomato, wheat, grape). The decrease in precipitations and the available water for irrigation will have a direct impact on irrigated agriculture areas and crops (banana, apple, potato, tomato). Moreover, increased temperature and humidity will augment pest outbreaks in some crops (olive, potato, tomato and apple). National adaptation measures have been proposed either to directly face up to climate change impacts or to increase the resilience of the farmers and the crops to such variability. Agriculture is confronted to produce more marketable products under unpredictable climate conditions. Adaptation to climate change is crucial not only to support the livelihood of rural populations and to sustain the viability of the agriculture sector, but also to maintain a tolerable level of food security.

The Agriculture Strategy the Ministry of Agriculture for the period 2010-2014 stressed out the problem of “desertification and land degradation, due to climate change”. The strategy cites the “limited of national legislative framework for the agriculture sector in Lebanon”, and puts among its priority axis the elaboration of necessary laws, decrees and decisions. The Agriculture Strategy has a target of promoting sustainable agriculture under its different agriculture systems.

6.1.1 Scope of work

The objective of this project is to propose technologies for adaptation to climate change for vulnerable crops (potato, tomato, apple, cherry, banana, olive, grape and wheat) and production systems (i.e. open field or protected crops, irrigated or rainfed crops). These crops are major exportable products, with a high national production value, and are considered as essential components of food security. The deployment of these technologies will bring a positive impact on agriculture in general, and enhance the sustainability of the system by improving agriculture practices, reducing chemical inputs, sustaining natural resources, reducing cost of production and preserving or increasing farmers’ income. In other words, the suggested technologies should enable to: i) increase yields and preserve food security, ii) sustain production under different climatic scenarios, iii) make the production systems more efficient, and iv) reduce GHG emissions from agriculture production system (ICTSD, 2010).

6.2 Possible adaptation technology options in the Agriculture sector and their adaptation benefits

Among the list of globally available technologies related to the adaptation of the agriculture sector to climate change, a number of technologies have been selected to cover all the agriculture sub-sectors, except animal husbandry. Since small ruminants vulnerability to climate change relies on natural rangelands ecosystems, an ecosystem-based management approach would be preferred over other adaptation technology.

The proposed technologies in most cases are a combination of hard technologies (i.e. equipments, seedlings) and soft technologies (i.e. software, communication, management), as presented below.

6.2.1 Conservation Agriculture (CA)

Conservation agriculture is one of the most sited technologies that harness adaptation to mitigation measures (FAO, 2007; CGIAR, 2010). Its principle is minimal tillage with conservation of crop residues to conserve both water and organic matter. Avoiding plowing not only saves energy, but mostly reduces carbon dioxide emissions from the soil. Studies have shown that conservation agriculture involves minimal machinery for land preparation and is suitable from most crops. It doesn’t necessarily improve yield under all agro-climatic zones, however, its benefits are mostly significant in arid and semi-arid zones (i.e. northern Bekaa), which are in fact the most vulnerable. Crops grown under conservation agriculture have shown to be more resilient to drought conditions, leading to minimal inter-annual yield variation. The direct benefit for farmers includes the increase in income due to savings in the cost of production, which varies between USD 350/ha to USD 650/ha according to the crop type, when compared to conventional agriculture (ACSAD/GIZ, 2010).

6.2.2 Risk Coping Production Systems (RCPS)

The Risk Coping Production Systems technology is a set of different field practices involving landscape management and diversification of production: terracing, windbreak plantation, intercropping, agro-forestry, crop rotation and crop and livestock association production system (FAO, 2007). Many of these features rely traditional knowledge, and increase crop and farmer’s resilience through minimizing climate adverse impacts on the crops. Terraces enhance water and soil conservation on mountain slopes while windbreaks protect the crops from dry winds in the coastal and inland plains (WOCAT, 2007). Some of these features are adapted or better fit to field crops (i.e. crop rotation, crop and livestock association) and require large exploitation areas in order to be cost-effective. The diversification of the production system minimizes possible damages related to pest outbreaks, market congestion and climate adverse. Yield and income are not directly affected, but their stability is better guaranteed. The adaptation benefit will be indirectly related to the reduction of inputs (fertilizers, water, pesticides and herbicides) and to the reduction of damages related to climate extremes (heavy rain, drought). Crop rotation of wheat/vetch over a period of 2 years for cereals for example, has shown an increase of income reaching USD 200/ha if compared to conventional monoculture of wheat (ACSAD/GIZ, 2010).

6.2.3 Selection of Adapted Varieties and Rootstocks (SAVR)

Plant breeding and biotechnology are the two pillars for producing plant varieties that help the sector cope with climate change (CGIAR, 2010; FAO, 2007). Adapted varieties could be tolerant or resistant to different climate/soil aspects such as drought, salinity, low chilling requirement, snow, frost, cold, heat and short or long vegetative season. Even if Genetically Modified Organisms and Property Rights are major barriers towards the development and deployment of these technologies, Lebanon relies on the import of conventionally selected varieties and rootstocks. Several non-patented varieties are also multiplied locally and disseminated to farmers. However, the selection of the varieties for plantation is mostly market oriented, rather than based on adaptation to climate. The plantation of suitable selected varieties and rootstocks could have a positive result on yields (20% at least) with early bearing of fruits in fruit trees (2-4 years gain) and consequently a better income for farmers, when compared to conventional fruit orchards with old varieties grafted on non-selected rootstocks.

6.2.4 Integrated Pest Management (IPM)

Integrated Pest Management or Ecological Pest Management (MoE/UNDP/GEF, 2011; FAO, 2007) is a concept that relies mainly on timely field observations rather than timely based spraying. Consequently, farmers tend to adapt their operations according to the occurrence of pest outbreaks. Since outbreaks are uncertain and related to climate variability, then resilience of farmers to climate change is increased. IPM helps reducing pesticide use, and consequently greenhouse gas emissions. In addition, the cost of production is diminished and the impact on human health and the environment is reduced. If yield improvement is not always obtained, improved quality of production is more certain. An increase of income is expected due to a decrease of the cost of production (15-30% according to the crop and area) and a higher added value of the final product.

6.2.5 Integrated Production and Protection for greenhouses (IPP)

An Integrated Production and Protection system for greenhouses is also a technology that has started to be promoted to modernize the greenhouses (FAO, 2004). Even if this technology targets a minor agriculture sub-sector, it is important to keep production under greenhouses sustainable. Off season production is not only of a higher added value, but contributes also to food security, especially that greenhouses are considered the most cost-effective agriculture systems around urban areas. IPP combines hard technologies like adapted greenhouse structure, insect proof net, thermal plastic film and fertilization system, with soft technologies or practice, like integrated pest management, and the selection of adapted varieties and rootstocks. Most studies report an improvement in both yield and production quality under IPP when compared to conventional production under traditional greenhouses (Hanafi, 2008).

6.2.6 Early Warning System - Information and Communication Technologies (EWS-ICT)

Amongst the most recognized technologies for adaptation to climate change is Early Warning System, which relies mostly on weather stations, satellite and aerial images for weather forecast (MoE/UNDP/GEF, 2011; UNFCCC, 2006). This hardware is topped up with a set of software technologies which are essential to implement risk analysis of different features related to climate (i.e. frost, snowfall, flood, moisture, cold and heat waves, wind, drought and pest outbreaks). The effectiveness of the system is centered on the dissemination of the warning to vulnerable target groups. EWS cannot be effective without embedding developed Information and Communication Technologies. These technologies work mainly on increasing the readiness of different beneficiary groups to different uncertainties and can also be used as tools for other technologies like IPM and Index Insurance, or technologies related to water monitoring (Ospina and Heeks, 2011).

6.2.7 Index Insurance (II)

Index insurance is a new soft technology that is gaining popularity worlwide under the adaptation measures worldwide. However, the technology can only be use once weather stations equipped with the necessary ICT are established and the institutional and organizational requirements are arranged. Index insurance is based on one climatic index that has the highest negative impact on agriculture revenues in a defined area, or for a defined crop. These could be frost, drought, hot wind, hail, flood, snow, and heat or cold waves. Index insurance relies on weather station data, and avoids field assessment. However, no indexing has been set yet. Financial mechanisms for funding and administrative issues related to indemnity distribution to affected farmers are to be determined to ensure effectiveness and viability of the system. When properly deployed, Index Insurance would be an opportunity for investment, and also a tool to increase the resilience of farmers to climate change (MoE/UNDP/GEF, 2011). The SNC mentions that climate variability will lead to an increase by 20% in fruit set failure in cherry for example leading to a reduction of farmers' income compared to current climate. Index insurance is meant to cover the damages for farmers and enable them to sustain their livelihood.

6.2.8 Criteria and process of technology prioritization

Process of technology prioritization

The technology prioritization process was elaborated following the UNDP handbook guidelines (2010) and based on the Multi-Criteria Analysis 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.

Based on this extensive dissemination process, expert consultation meetings were held where a pool of experts validated the MCA criteria and relative weights. Accordingly a scoring exercise was conducted resulting in technologies ranking based on the following equation:

$$\frac{\text{Tech.score-min.score}}{\text{Max.score-min.score}} \times \frac{\text{Weight of criterion}}{\text{Total weights}}$$

Selection Criteria

An identified set of criteria allowed the comparison between these technologies based on the three pillars of sustainable development: economical viability, environmental reliability and social acceptability or readiness. Technologies should be cost-effective, environmentally sustainable and socially acceptable (UNFCCC, 2006).

The selection criteria were identified as follows: capital and operational cost, importance of economical impact, improvement of resilience to climate, technology capability and suitability for the country, human and information requirement and social suitability for Lebanon. Each criterion answers more than one question. For example, the importance of economical impact embeds not only the generated income at farm level, but also the contribution to the GDP at national level. The later is related to the number of beneficiaries or targeted area as well as the degree of impact of the technology on the different crops. These criteria include as well the increase in yields, efficiency of the production system, preservation of food security (economical impact), the capability of the technology to sustain production under different climatic scenarios and its capacity to reduce GHG emissions from agriculture production systems (criteria related to environmental reliability).

For the prioritization exercise, absolute scale with misleading figures and numbers were avoided and ranking on relative basis over a top score of 5 has been used based on the MCA approach.

Weights have been attributed to each criterion, as they do not have the same importance or impact, and since choices are not influenced in an equal way by each criterion. For example, the capital and operational cost define the easy access to the technology and its economical viability, which are crucial requirements for the decision making process and which are more significant than human or information requirement. The criteria related to financial issues are the driving force in the selection, and consequently are double weighted. Oppositely, criteria related to human and social aspects are relatively less important in the selection, since these factors are subject to change and improvement when the financial resources are found, and consequently these criteria were not weighted. Consequently, economical viability criteria were higher weighed, followed by those related to environmental reliability and finally the criteria associated to social readiness. The criteria description, their scale and weight are described below in Table 60.

Table 59 - Suggested criteria of selection for the agriculture sector

Economic Viability	Capital and Operational cost.
	Importance of economical impact.
Environmental reliability	Improvement of resilience to climate.
	Technology capability and suitability.
Social Readiness	Human and information requirement.
	Social suitability for Lebanon.

Table 60 - Brief description of the criteria of selection with the respective scales and weights.

Criterion	Description	Scale	Weight
Capital and operational cost	The initial cost to establish the technology as well as the annual maintenance and operational costs. Some figures per surface or volume units are provided for some technologies. It highlights the easiness of access of farmers to the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	Highest (2)
Importance of economical impact	It integrates the following indicators: • Increase of income/profit at farm level. • Number of beneficiaries/covered area. • Economical importance of targeted crops. • It highlights the equity among regions and importance to food security and national policy.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Highest (2)
Improvement of resilience to climate	The technology's ability on improving crop resilience under current and future climate scenarios. If several types of impact due to different climate adverse (drought, frost, chilling requirement, insect outbreak, etc.) are minimized, the degree of improvement is higher.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Technology capability and suitability	It assesses how much the technology is widely applicable within the different bioclimatic zones. If it is applicable for different crops, or cropping systems, and suitable for different geographical contexts, it is higher scored. It highlights the degree of viability of the technology.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Social suitability for Lebanon (readiness)	Social acceptance at all levels: farmers and social suitability, organizational requirements and institutional arrangements at decision-makers level.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Human and information requirement (readiness)	Human requirements and their qualification, coupled with the capacity building and technology/information transfer needed to deploy the technology. It highlights the time requirement to establish and disseminate the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	Standard (1)

Results of the technology prioritization

Table 61 presents the final scores that were attributed to the proposed technologies of the agriculture sector. The main points raised during the discussion were related to the complementarity of the technologies, the extent of geographical coverage, the applicability and use by farmers and the importance of capital and operational costs in the decision making process.

As a result, the MCA exercise enabled the selection of priority technologies for Lebanon in an objective way and based on consensus. The top-ranked technologies as shown in Table 62 were: 1) Selection of Adapted Varieties and Rootstocks, 2) Conservation Agriculture and 3) Risk Coping Production Systems over more costly and less applicable technologies. Although most of the participants showed interest in the EWS-ICT and II, it was unanimously agreed that under the current circumstances, there cannot be considered priority technologies. The urgent need to establish a solidarity fund or another mechanism to increase the human resources, training and capacity building for EWS_ICT and IPP was highlighted by all experts.

Table 61 - Results of MCA exercise for the agriculture sector

Criteria	Weight	Conservation Agriculture		Risk Coping Production Systems		Integrated Pest Management		Selection of adapted varieties / rootstocks		Integrated Production and Protection for greenhouses		Early Warning System - Information and Communication Technologies		Index Insurance	
		Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score
Capital and operational cost	2	5	0.222	3	0.111	4	0.167	3	0.111	1	0.000	2	0.056	2	0.056
Importance of Economical impact	2	4	0.167	3	0.111	5	0.222	5	0.222	1	0.000	5	0.222	3	0.111
Improvement of resilience to climate	1.5	4	0.125	4	0.125	3	0.083	4	0.125	5	0.167	5	0.167	4	0.125
Technology capability and suitability	1.5	4	0.125	5	0.167	4	0.125	5	0.167	5	0.167	3	0.083	3	0.083
Social suitability for Lebanon (readiness)	1	3	0.074	4	0.111	3	0.074	4	0.111	2	0.037	4	0.111	2	0.037
Human and information requirement (readiness)	1	5	0.111	4	0.083	2	0.028	5	0.111	3	0.056	3	0.056	3	0.056
Total		25	0.824	23	0.708	21	0.699	26	0.847	17	0.426	22	0.694	17	0.468

Table 62: Multi-Criteria Analysis results for the technologies of the agriculture sector.

Rank	Technology	MCA score
1	Selection of Adapted Varieties and Rootstocks.	0.847
2	Conservation Agriculture.	0.824
3	Risk Coping Production Systems.	0.708
4	Integrated Pest Management.	0.699
5	Early Warning Systems/Information and Communication Technologies.	0.694
6	Index Insurance.	0.468
7	Integrated Production and Protection (greenhouses).	0.426

6.3 Barrier Analysis and Enabling Framework

6.3.1 Preliminary targets for technology transfer and diffusion for agriculture

The three prioritized technologies for the agriculture sector as identified by stakeholders are: i) Selection of Adapted Varieties and Rootstocks (SAVR), ii) Conservation Agriculture (CA) and iii) Risk-Coping Production Systems (RCPS).

RCPS includes several features as presented in Fig. 49. However, in this report, only adapting plantation systems (density of plantation, orientation, distances between rows and plants, etc.) and adapted training systems and pruning in fruit orchards and vineyards

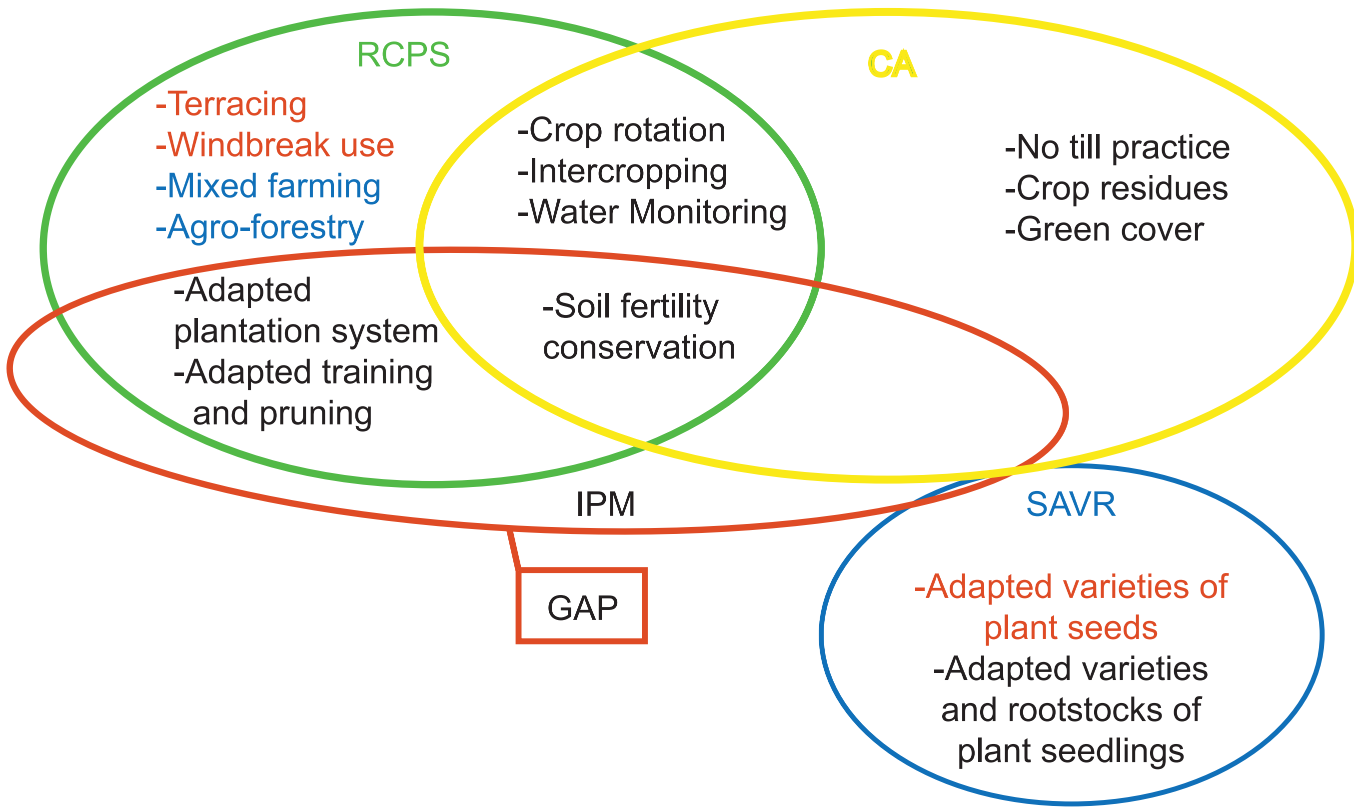


Fig. 49 - Prioritized technologies inter-linkage

Source: Author's own design

will be tackled since crop rotation, intercropping and green cover maintenance are already covered under CA.

Adapting plantation systems and adapted training systems and pruning in addition to many other practices applied at farm level, could be included in what is known as "Good Agriculture Practices" (GAP), currently promoted through MoA's policy. Good Agricultural Practices are "practices that address environmental, economic and social sustainability for on-farm processes, and result in safe and quality food and non-food agricultural products" (FAO COAG, 2003). Fig. 49 indicates the common areas where each of the technologies cross over with GAP cross. However, Integrated Pest Management (IPM), which is generally recognized as one of the main adaptation tools to climate change and which was ranked 4th in technology prioritization, is a core component of GAP. Therefore, the barrier analysis for the RCPS will include analysis for IPM and will be classified as Good Agricultural Practices, embedding adapted plantation system, adapted training and pruning and IPM as shown in the red circle in Fig. 49. This allows avoiding duplication with the two other technologies.

6.3.2 Classification of technologies

Technologies are divided into: i) consumer goods, ii) capital goods, and iii) non-market goods, as shown in Fig. 50.

The Selection of Adapted Varieties and Rootstocks is a typical consumer good, with a wide market and a large number of stakeholders. On the other hand, Conservation Agriculture is a non-market good, with an objective oriented mostly to change farmer's behavior and practices within the exploitation. As for Risk-Coping Production Systems, depending on the nature of the measures, it can be a consumer good where minimal material is required from the market (i.e. selective pesticides, insect-proof nets, mulch, etc.), a capital good when investments are required in goods enabling the production of the end-market product (i.e. terraces, trellis), or non-market goods such as in Good Agriculture Practices, where field operations are adapted to cope with climate change.

CONSUMER GOODS	CAPITAL GOODS	OTHER NON-MARKET GOODS
• Selection of Adapted Varieties and Rootstocks. • Risk-Coping Production Systems.	• Risk-Coping Production Systems.	• Conservation Agriculture. • Risk-Coping Production.

Fig. 50 -Technology classification according to type of goods for agriculture sector

Source: The author's own design

6.3.3 Methodology of identification of barriers and action plans

The barrier analysis for the agriculture sector mainly relied on literature review and individual consultations with experts in the field, followed by a consultation meeting with representatives from public institutions, experts and technicians from research institutes, NGOs, service providers and farmers.

Following a Logical Problem Analysis (LPA), problem trees were drawn for each technology, showing inter-linkages between causes (key barriers) and effects and validated by the stakeholders. Accordingly, a list of specific measures were collectively proposed to overcome the selected barriers.

Identified measures have been developed in action plans and a Cost Benefit Analysis (CBA) was conducted for each technology. Assumptions and figures were validated by the concerned stakeholders and experts in the field. The Net Present Value (NPV) was estimated as follow:

$$NPV = \frac{(\text{Benefits} - \text{Costs})}{(1 + \%\ \text{of annual interest})^n}$$

A fixed discount rate (loan interest rate) of 6% was used based on the average of the lending rate of Kafalat program.

A more in-depth CBA will be required at later stages to better estimate the real cost and benefits of adaptation of the agriculture sector.

Finally, action plans specific to each technology were proposed to reach the targets of increasing resilience of the agriculture sector to climate change. These Technology Action Plans (TAP) are designed in a matrix that answers basic questions on the measures or activities to be conducted, their priority, their importance and responsible entities. The matrix includes as well the time frame of these activities, the indicators for their monitoring and evaluation, estimated budget to conduct them and finally the potential donors.

Note that many aspects are common to all technology action plans. In many cases, the same activities are to be conducted by the same actors for different beneficiaries under different technology action plans. Result-based indicators for monitoring and evaluation are proposed in most cases. Donors are common to all action plans as well. For this purpose, mainstreaming of efforts and coordination are highly required to achieve a maximum efficiency and effectiveness of the proposed action plans.

The process of barrier analysis and overcoming them is resumed in Fig. 51.

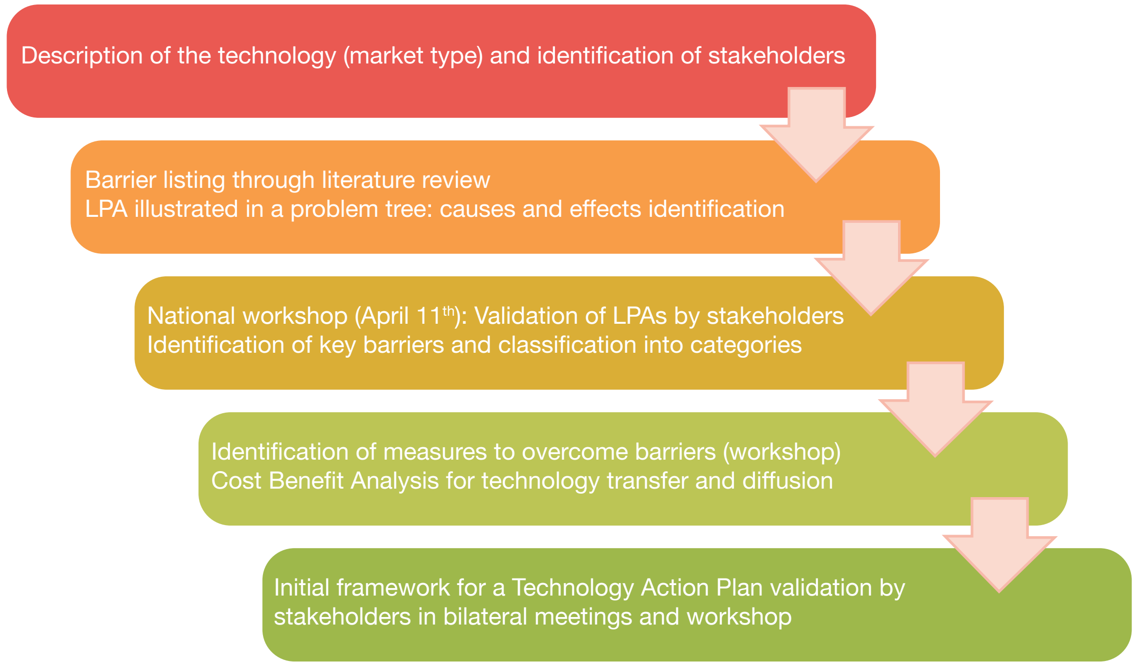


Fig. 51 - Process of Barrier Analysis and Technology Transfer and Diffusion

Source: The author's own design

6.4 Analysis of Technology: Conservation Agriculture (CA)

6.4.1 General description of Conservation Agriculture

Conservation agriculture is a "technology" based on changing agriculture practices within the exploitation by conserving soil and water through no-till and the use of agriculture residues in addition to rotating crop and green cover plantation to preserve soil fertility and break down weeds and pests lifecycle. It is a non-market good, as it doesn't involve investments in capital or market goods. Existing seeder equipments for annual and grain crops can be adapted for seeding.

Conservation agriculture is slowly moving from a trial stage towards a diffusion stage since no regulations exist to enhance the deployment of this technology in Lebanon. The government, through the Bureau of Cereals has been historically subsidizing wheat production, to sustain the cultivation of this "strategic" crop. A similar approach has been adopted for tobacco plantations (through annual governmental decisions) and sugar beet. However, this has proven not to be sustainable and cost-effective and the subsidies for the sugar beet were cut off. A more "practice-oriented" approach is required to promote the diffusion of CA, especially amongst cereals and legume growers, although no decisions are taken towards this issue at governmental level. An initiative from GIZ Lebanon and the MoA aimed at elaborating an initial frame for the transfer and diffusion of CA in Lebanon. In addition ACSAD/GIZ have been promoting this type of agriculture for the last four years and efforts with research institutes including AUB and LARI have aimed at promoting CA in northern Bekaa and Akkar.

6.4.2 Identification of Barriers for Conservation Agriculture

Conservation Agriculture covers around 1500ha all over the country. However, several key barriers hinder the proper diffusion of CA including:

- Limited information and the inherited behavior affecting farmer's perception of no-till. Farmers have been tilling their lands for centuries, and it would be difficult to change this attitude, especially that their information about benefits of CA is still precarious.
- Few skilled extension technicians: Technicians are not necessarily aware of the concept of CA and the agricultural extension services established by MoA are not providing farmers with the adequate amount and quality of relevant information.
- Limited demonstration plots: Farmers are difficult to convince unless they visualize the advantages of CA, and rare demonstration plots have been established as case studies to generate concrete results.
- Re-use of agriculture residues: Cereal growers rent their land for grazing after harvesting their crops to maximize their profit, which leaves the soil without crop residues to be used under CA.
- Inappropriate Land Tenure system: since CA embeds crop rotations and requires few years to show significant results, a yearly-basis rental period is not appropriate.
- Insufficient revenues: This is very typical for rainfed agriculture, especially for cereal growers who tend to rent their land post harvest for grazing, which makes CA perceived as a risky practice.
- Low yields in rainfed agriculture (especially cereal and legume growers): subsidies are only paid for wheat production, and are not based on the type of agriculture production system.
- Limited research and development programmes: There is limited R&D initiatives namely in areas where CA could be deployed (olive groves, cereal and legume plantation in semi-arid zones, fruit orchards).
- Budget constraints: no budget is allocated for research and development or to subsidize CA.
- Deficiency in institutional and financial arrangements: No decrees and laws for resource mobilization for subsidies or R&D are existent or to change subsidy policy from crop-oriented to practice oriented.

Fig. 52 illustrates the problem tree with causes and effects of the rejection of CA.

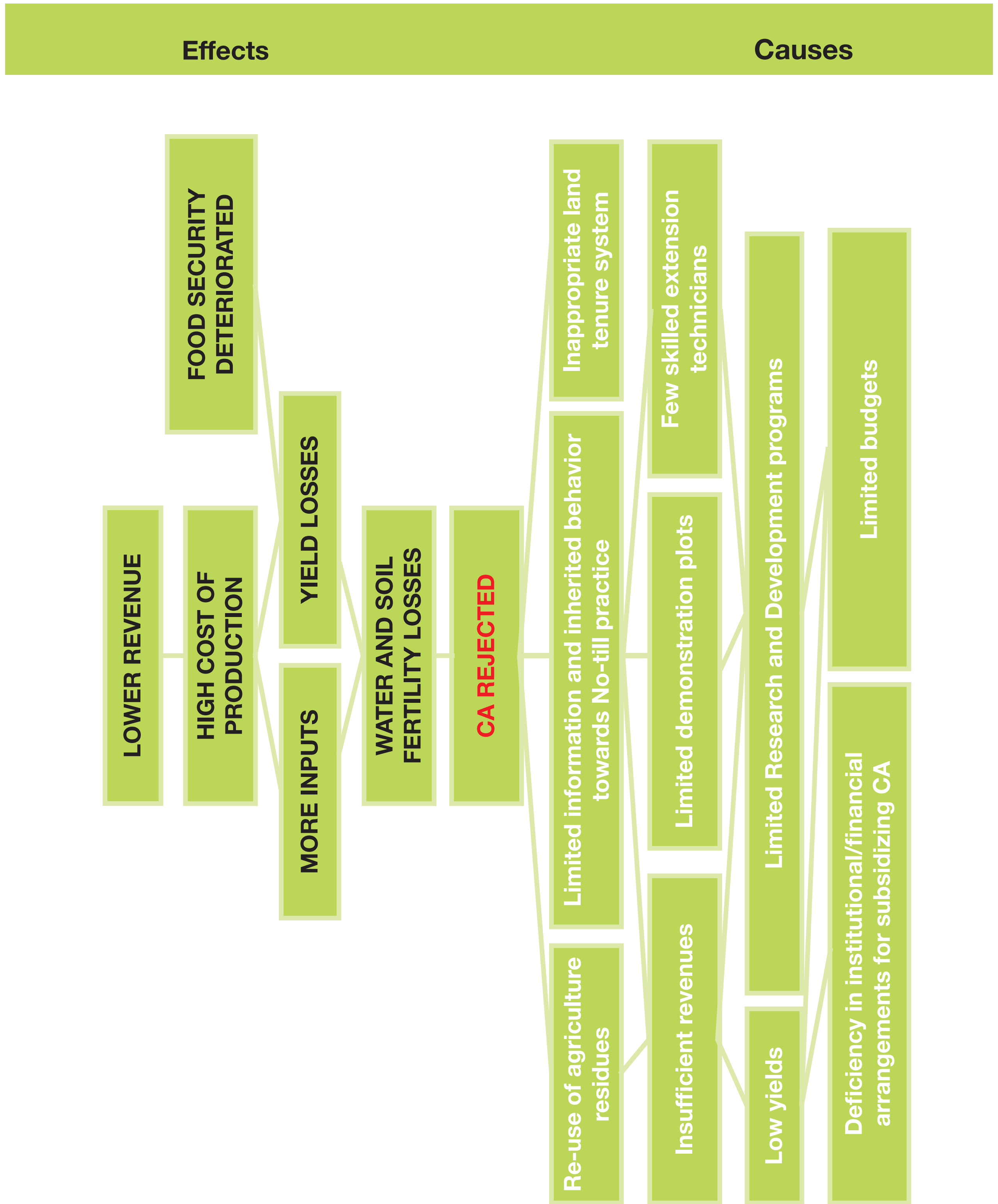


Fig. 52 - Problem tree for Conservation Agriculture.

Source: Author's own design

6.4.3 Identification of measures for Conservation Agriculture

The causes of non-adoption of Conservation Agriculture and their respective measures are presented in Table 63.

Table 63 - List of barriers for CA and respective measures to overcome them

Category	Barriers	Measures	Stakeholders
Human skills	Lack of skilled extension service.	Training of trainers for extension service and NGO technicians.	MoA, NGOs
Institutional and organizational capacity	Lack of research and development programmes.	Increasing research and development programmes on CA into different research stations of the country (LARI) and on farm level, on different crops under diverse climatic and soil conditions.	LARI, AUB
Policy, legal and regulatory	- Inappropriate Land tenure system: need long term renting (killing barrier). - Deficiency in institutional arrangements for subsidies.	Changing crop-oriented subsidies (i.e. to wheat and tobacco) to practice-oriented subsidies.	MoEc, MoF, Parliament
Information and awareness	- Limited information at farmers and decision maker's level. - Limited number of demonstration plots.	Organizing awareness campaign and field visits to demonstration plots.	MoA, LARI, NGOs, farmers
Economic and financial	- Budget restrictions for R&D. - Absence of appropriate subsidies. - Cereal growers' low income. - Export of agricultural residues.	Allocating the necessary budget for research and development and for subsidies.	MoF, MoA, LARI, AUB
Social, cultural and behavioral	Inherited behavior affecting farmer's perception of no-till and the export of agriculture residues.	- Arranging field visits to demonstration plots -Conducting seminars for farmers to show the comparative advantage of no-till.	MoA, LARI, NGOs, farmers

6.4.4 Cost benefit analysis for CA

Conservation Agriculture requires mostly research and development programmes all over the bioclimatic zones of the country, in order to transfer and diffuse scientific proven practices for farmers growing different crops under diverse conditions. Institutional and financial arrangements are required as well to allocate subsidies whenever needed.

Costs related to CA are estimated as follow, and validated by stakeholders and literature on potato and olive productions for integrated production protocols (MoA, CNRS, CIHEAM, IC, 2008):

- Research and development: USD 240,000 (4 years).
- Institutional/financial arrangements: USD 10,000.
- Training of trainers: USD 5,000.
- Training for farmers: USD 15,000.
- Subsidies: USD 50/ha for cereals and legumes.

The projected annual budget for subsidies is shown Fig. 53. The total cost for the deployment of all measures, including subsidies will be hence USD 3.47 million. If the actual subsidizes for wheat production are reallocated for cereals under conservation agriculture, no additional budget requirements are needed.

Assumptions for CA

- The added value of agriculture residues in conventional agriculture (cereals) is:
  - Counterbalanced by the saved water and fertilizers used wherever deficit irrigation is applied (5,000ha).
  - Covered by subsidies in rainfed areas (10,000ha)
- Total area under CA (scope):
  - Baseline 1,500ha of cereals (wheat, barley, corn) and legumes (vetch, alfalfa, lentils, chickpea) with 30% annual increment, due to the presence of incentives.
  - Baseline 500ha of olive trees and other rain feed fruit trees (almond, cherry) with annual increment of 25%.
  - Baseline 100ha of irrigated fruit trees (apple, apricot, cherry, peach, plum, etc.) with annual increment of 20%.
- Yield in CA is stable if not increased in a 10 year period, for all crops in general. Oppositely in conventional agriculture annual variability is high. In this report we assume that:
  - Yields are similar for both conventional agriculture and CA for irrigated fruit trees.
  - Yield annually decreases by 1% for cereals under conventional agriculture.
  - Yield is constant for olive starting the 3[th] year after conversion to CA, while under conventional growth, biennial fluctuation in yields reaches 50%.
  - The price of the seeder (grain crops) is counterbalanced by the price of machinery normally used in conventional agriculture.
  - In CA the use of herbicides for weed control is high in the first 3 years, with an additional cost to maintain a green cover. The cost of these operations is about USD 100/ha the first year, USD 40/ha the second and the third year. Oppositely, no-till enables savings of USD 350/ha (machinery, energy and labor cost for plowing) for cereals, legumes and irrigated fruit trees, and USD 650/ha for olive tree (2 plowings/year).
  - Additional costs on the farmers are directly deducted from the savings in cost of production.

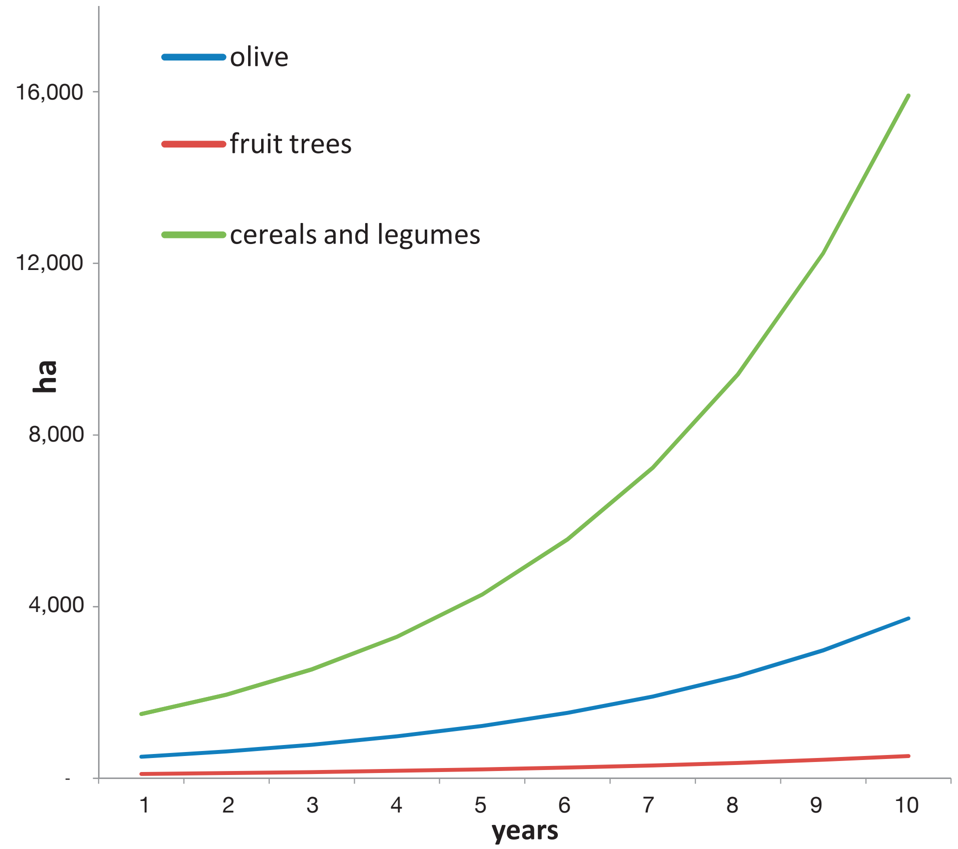


Fig. 53 - The projected expansion of areas under CA for a 10-year period

Source: Author's own design

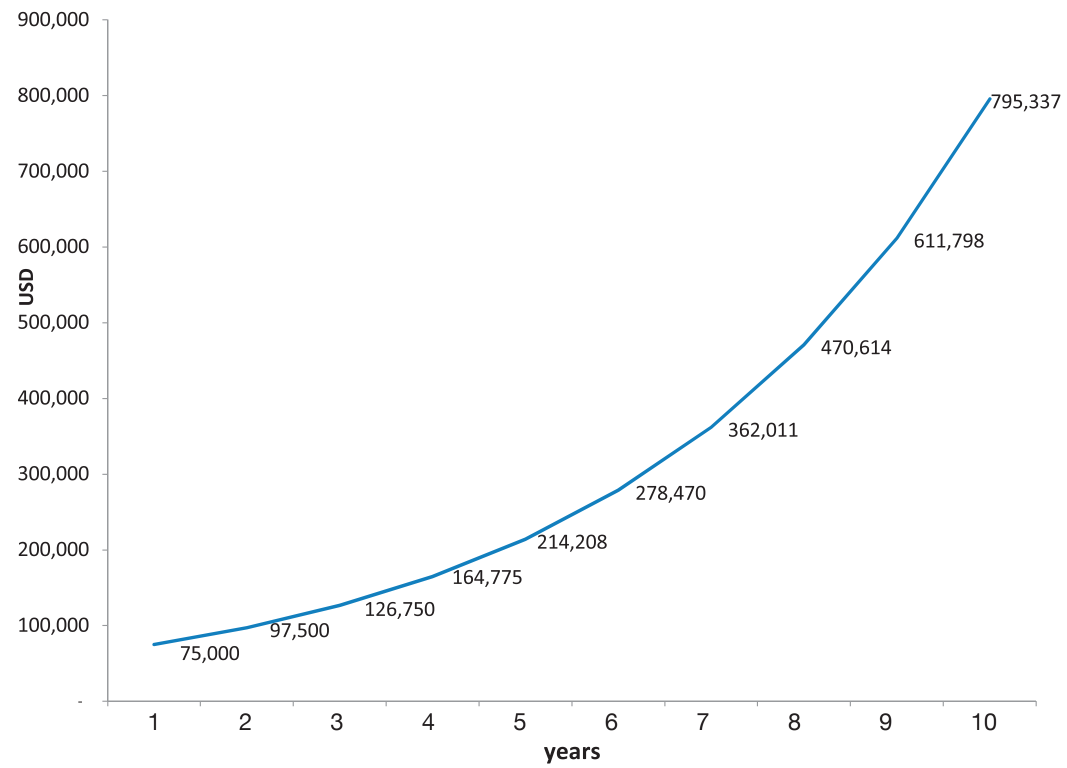


Fig. 54 -The estimated annual subsidies in USD for cereals and legumes according to their annual surface increase

Source: Author's own design

The expected benefits at farm level after a 10-year period will be mainly from reduced cost caused by minimizing land preparation cost (energy, labor) and consequently increased farmers' revenues by:

- USD 760/ha/year for cereals/legumes.

- USD 490/ha/first year, then USD 620/ha starting 2nd year for rainfed trees.

- USD 250/ha/first year then USD 310/ha starting 2nd year as reduced cost from no-till for irrigated fruit trees.

Figure 55 illustrates different NPV according to crop type in Conservation agriculture. Benefits at farmer's level with or without the deployment of CA are shown for olive tree in Table 64. Olive tree was taken as an example for analysis since its values as considered in the mid-range as shown in Fig. 56.

In conclusion, adopting and diffusing conservation agriculture for cereals, olive and fruit trees on up to 16,000ha in 10 years will enable: i) achieving a total Net Present Value over a 10 year period estimated at USD 36.9 million (Annex VI), ii) improving soil and water conservation through minimal soil disturbance and maintaining a green cover or agriculture residues on the soil surface, iii) reducing CO_2 emissions through minimal soil disturbance and iv) preserving food security, since yields are stable (availability of food), with lower inter-annual variation.

The mobilized resources to realize these benefits are less than USD 3.5 million. Therefore, and since the benefits exceed by far the cost of the technology, the transfer and diffusion of CA is a favorable and encouraged practice in Lebanon.

Table 64 – Cost Benefit Analysis (in USD): an example for olive production at farmer's scale (1ha).

	Revenues under conventional agricultural practices	Revenues under CA	Additional revenue under CA	Additional costs from applying CA	Net benefits from applying CA	Discounted net adaptation benefits (6%)
	A	B	C=B-A	D	E=C-D	$F=E/(1+0.06)^{yr}$
Year	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha
1	380	1,000	620	0	620	585
2	340	800	460	0	460	409
3	380	1,000	620	0	620	521
4	340	1,000	660	0	660	523
5	380	1,000	620	0	620	463
6	340	1,000	660	0	660	465
7	380	1,000	620	0	620	412
8	340	1,000	660	0	660	414
9	380	1,000	620	0	620	367
10	340	1,000	660	0	660	369
NPV						4,528

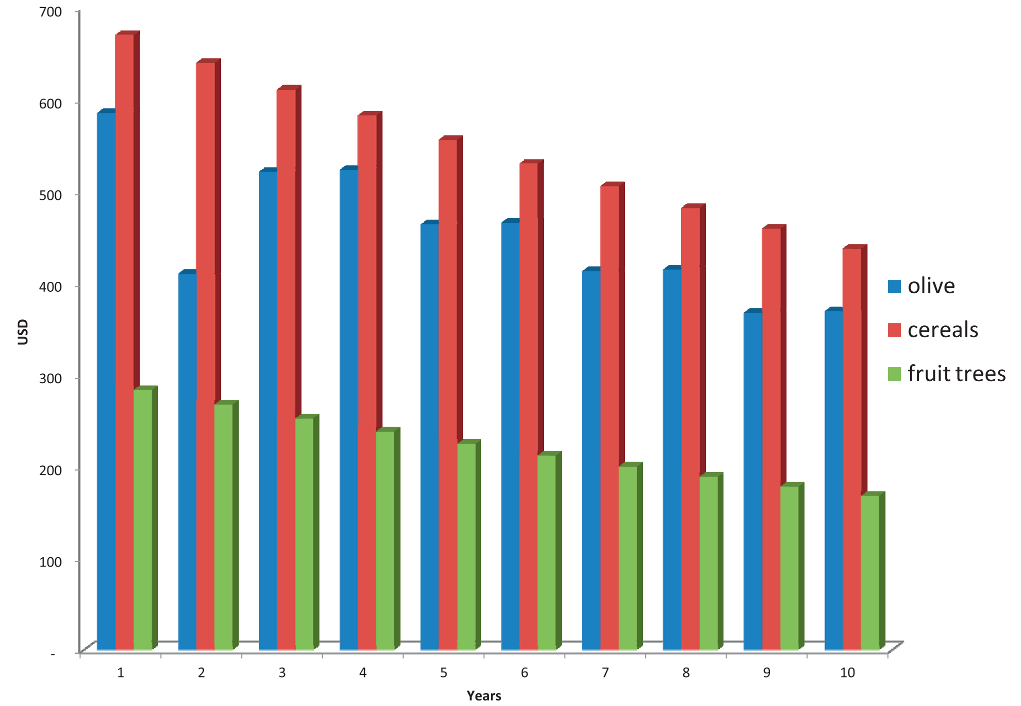


Fig. 55 - Comparison of annual NPV per ha over a 10-year period for 3 types of crops under CA at farmer's level

Source: Author's own design

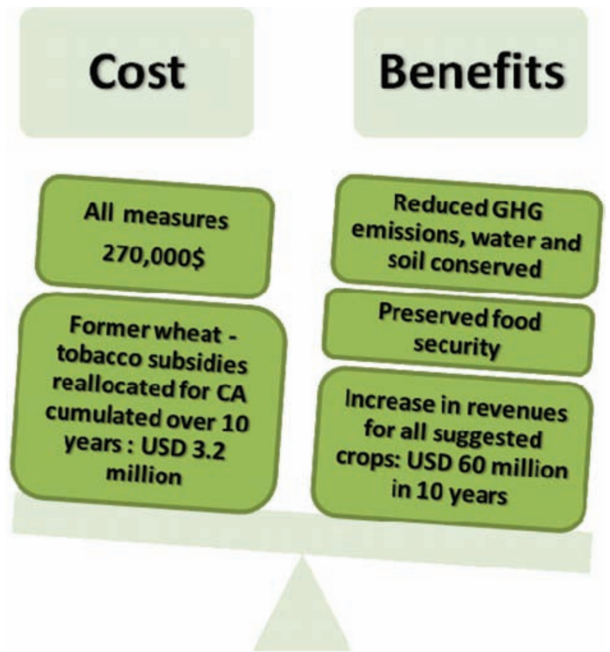


Fig. 56 - Costs and benefits of Conservation Agriculture over a 10-year period

Source: Author's own design

6.4.5 Technology Action Plan for Conservation Agriculture

Target for technology transfer and diffusion

The target for the action plan proposed is a large scale and long term project between 2015 and 2025 aiming at shifting more than 4,000ha of fruit trees and 15,000ha of cereals and legumes to Conservation Agriculture. The required budget is 3.47 million USD.

The Technology Action plan for the deployment and diffusion of conservation agriculture is presented in Table 65.

Table 65 - Technology Action plan for Conservation Agriculture

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Donors
Conducting training sessions and filed work	1	To increase the experience of technicians in CA	National and international experts (ICARDA, ACSAD, LARI, GIZ, etc.)	MoA, NGOs	Short term	Number of training sessions, Percent active technicians in disseminating CA	5, 000 For 50 technicians	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Conducting experimental studies in fields of research institutes and on farm level	1	To better understand the effect of CA on different crops under different agro-climatic conditions	LAR, Academic institutions	MoA, NGOs, farmers	Medium term	Publications of research results Number of experiment plots % of budget dedicated to R&D	240,000 for experiments in 6 LARI stations and 20 on-farm plot covering 10 crops	
Conducting field days and visits to demonstration plots, seminars and TV programme	1	To change farmers behavior concerning no-till and show the comparative advantages of CA	MoA, LARI, NGOs	farmers	Medium term	Number of farmers converted to CA, surface producing in CA	9,000 for 450 farmers participating in seminars and field days; 6,000 for TV program	
Lobbying to get ministerial proposal to shift from crop-oriented to practice-oriented	2	To avoid additional public debt, and promote CA	National consultant-MOET, MoF, MoA, Parliament	farmers	Long term	Parliament and government decisions and law amendment	10,000 For National consultant study	
Allocating the necessary budget for subsidies	2	To give incentives to farmers to keep their crop residues in field and enhance R&D	MoF, MoET, MoA	farmers	Long term	Amount of subsidies per annum given to cereal-legume growers	3,200,000 for subsidies as estimated in assumptions	

6.5 Analysis of Technology: Selection of Adapted Varieties and Rootstocks (SAVR)

6.5.1 General description of SAVR

This technology embeds the replacement of actual seeds and seedlings produced locally or imported, by appropriate adapted varieties and rootstocks to future climate.

SAVR is a consumer good involving public and private sectors as well as different actors within the market chain, mainly seed and seedling importers, which are usually agriculture companies. Most of the import is demand driven, where farmers make their requests. Imported plant material is in many cases patented, and royalties legitimate to plant breeders as Intellectual Property Right (IPR), are added to the price which makes the SAVR of a higher cost. In the case of many horticultural crops, seeds are germinated and grafted locally then sold to farmers such as fruit tree and grapevine seedlings, however in most cases, the plant material origin, property right and quality are not guaranteed since plants are not inspected or certified by a third party.

Regulations for seed and seedlings import are minimal. A prior permit of import is currently being required, however registration of varieties is not yet done. Certificates of origin and phytosanitary certificate are required by both MoA and Custom Service, yet plant material authenticity, traceability and property right are not guaranteed. Lebanon which is not a member of the International Union for the Protection of New Varieties of Plants (UPOV) is trying to overcome this obstacle through bilateral agreements with foreign nurseries in order to import and pay the necessary royalties, hence enable SAVR multiplication locally. Standards and norms of multiplied plant material are limited to the seedlings delivered by "Machatel Loubnan" nurseries association which authenticity and sanitary inspection are guaranteed through a certification programme conducted by LARI-MoA. Yet a limited number of seedlings of varieties of pome stone and citrus fruits are produced.

The Ministry of Agriculture is trying to develop a seed/seedling policy to monitor and control this market. In collaboration with LARI, it has initiated the multiplication and certification of some non-patented varieties in accredited nurseries. However sanitation, conservation and multiplication of local SAVR are still far from being reached in the short term. Further diffusion of plants by local nurseries without paying the mentioned royalties will not be a solution on the long run; exports of products resulting from patented varieties to countries under UPOV is restricted. Making the necessary institutional arrangements for IPR will not only stimulate foreign trade, but also create the necessary enabling environment for the development of biotechnologies and SAVR in Lebanon.

Table 66 presents the legislation related to seed and seedlings varieties.

Table 66 - List of laws, decrees and decisions related to seed and seedlings

Type	Number	Title	Date issue	Remarks
Control in Import				
Law	778	Plant Quarantine	28/11/2006	
Decision	781/1	Conditions to import seeds other than potato seed	26/8/2011	Import permit/Quality control
Decision	783/1	Conditions to import propagating plants for fruit trees	26/8/2011	Import permit/Quality control
Decision	782/1	Conditions to import banana plants	26/8/2011	Import permit/Quality control
Decision	780/1	Conditions to import strawberry plants	26/8/2011	Import permit/Quality control
Decision	1/1038	Amendment of the decision 781	23/11/2011	Some exceptions
Decision	877/1	Conditions to import potato seeds for the season 2011-2012	26/9/2011	Quality control, yearly issued
Decision	900/1	Conditions to import potato seeds for trial	11/10/2011	
Decision	1/496	Sampling for inspection	21/9/2010	Including Seeds and seedlings
Organizing the Seedlings sector				
Decision	41/1	Establishment of a committee at MoA to organize the private nurseries	27/1/2010	Participants from public and private sector
Decision	526/1	Registration and control of private nurseries	4/6/2011	Compulsory Registration and control of private nurseries
Certification Programme for Seedlings				
Decision	493/1	Establishment of a scientific certification committee at MoA	20/9/2010	Its mission: To promote and supervise the certification program
Decision	528/1	Voluntary Certification of seedlings of Fruit trees produced in private nurseries	4/6/2011	Implementation of the seedlings certification
Decision	457/1	Establishment of the Certification Committee for seedlings of Fruit trees produced in private nurseries	19/5/2012	Its mission to implement the decisions 526 and 528
Decision	876/1	Amendment of the first article of the decision 751	26/9/2011	Add a member to the certification committee

Type	Number	Title	Date issue	Remarks
Production of Seeds and Seedlings				
Law	240	Patent	7/8/2000	Including PVP
Decision	346/1	Production of Potato seeds	23/10/1973	Not actually implemented
Ratification of related agreements				
Law	360	Ratification of CBD	1/8/1999	MoE focal point
Law	31	Ratification of Cartagena Protocol	16/10/2008	Only draft law prepared at MoE
Law		Ratification of the ITPGRFA	4/6/2004	LARI focal point Draft law prepared

Source: Siblini, 2012

6.5.2 Identification of Barriers for SAVR

The use of adapted varieties and rootstocks requires not only investments, equipments but also changes in behavior and practices of the different market components, from the producer to the consumer level. Key barriers for the transfer and diffusion of SAVR are listed below:

- Difficulties in changing food and agriculture habits to the new adapted varieties: the society in Lebanon and the export market is used to some old varieties of fruits and vegetables (i.e. Spunta potato, Red Delicious Apple, Pink Tomato, etc.) and changing their consumption habits is a main challenge for the market expansion.
- Market failure: growers are reluctant to use SAVR as they have difficulties in marketing new products.
- Limited know-how and information about SAVR: farmers and nurserymen are not aware of the yield and quality benefits of SAVR, and lack experience in field operations of new varieties.
- High cost of imported patented plant material: additional royalties and shipment fees are added to cost.
- Limited availability of healthy/certified plant material (for non-patented varieties and rootstocks): the existing plant material is often carrying viruses or diseases since it is not multiplied from healthy mother plants.
- Limited qualified nurseries: few nurseries are collaborating with MoA and LARI for the certification programme due to lack of infrastructure.
- Import restrictions on some patented varieties: some providers do not allow the import of specific varieties to Lebanon, since the country is not a member of UPOV.
- Export difficulties: since products do not meet international standards and pirated patented varieties cannot be exported to countries under UPOV, Lebanese growers are facing difficulties in exporting products.
- Lack of financial facilities (subsidies, access to long term credits) for SAVR: fruit trees need a long period to start producing, and agriculture credits adapted to such conditions are lacking.
- Limited research and development programmes: the implementation of SAVR requires a long research program, where SAVR can be tested and conserved before dissemination.
- Scarcity in human skills in research and academic institutes: the number of technicians specialized in the field is very limited.
- Deficit in necessary infrastructure: to multiply and sanitize SAVR, and study the performance of SAVR under different site conditions, and use them as demonstration plots for farmers. Local varieties need to be conserved in special sites, sanitized and further multiplied by nurseries and monitored for certification.

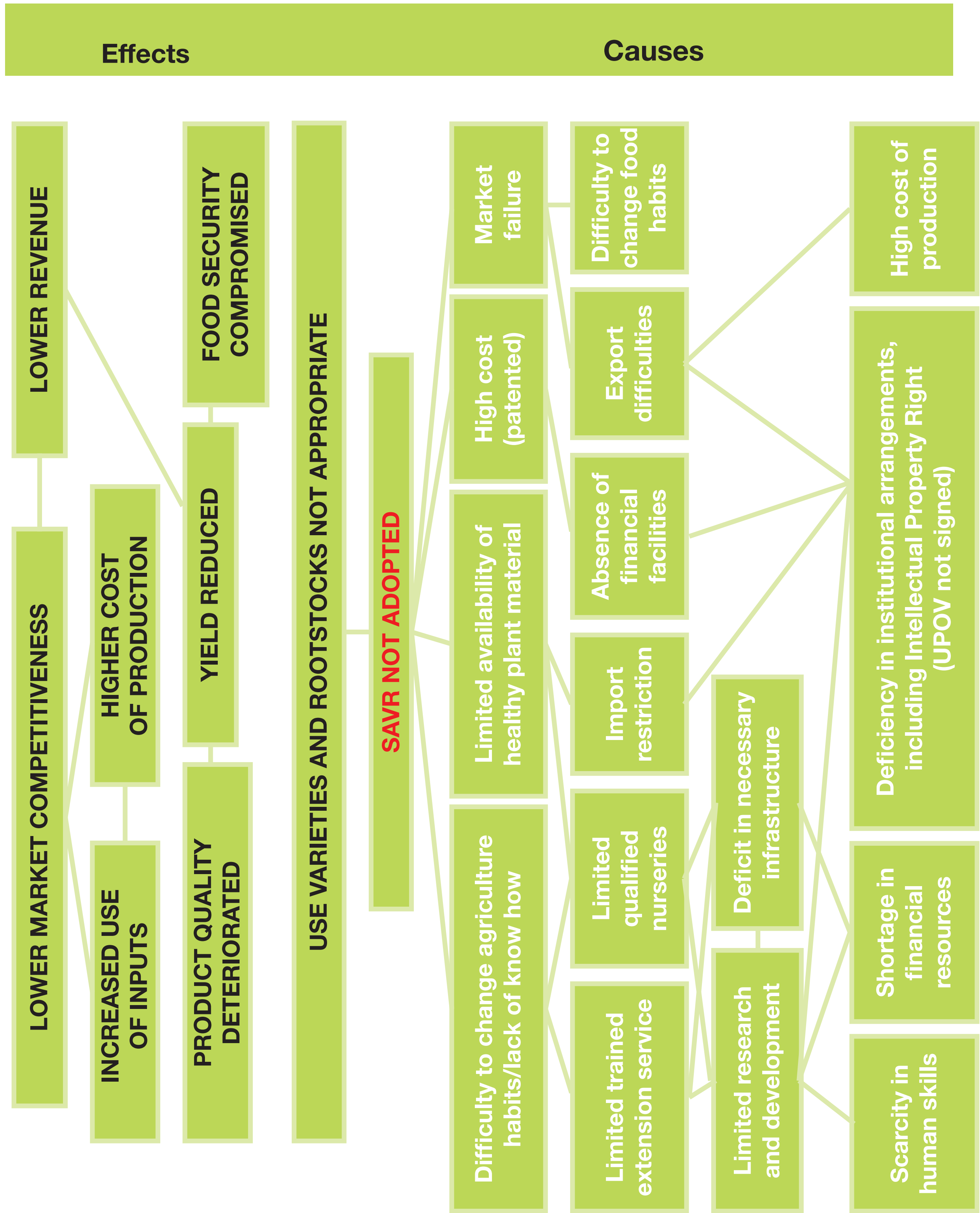


Fig. 57 - Problem tree of Selection of Adapted Varieties and Rootstocks

Source: Author's own design

- Shortage in financial resources: essentially in R&D, capacity building, awareness campaign and for allocating subsidies.
- Deficiency in institutional arrangements: for crediting system, subsidies and Intellectual Property Right in Lebanon.
- High cost of production: this is due to low yields and excessive use of inputs leading to a diminished competitiveness of Lebanese products especially for the export markets (not directly linked to SAVR).

The root problem of the selection and use of adapted varieties and rootstocks is the absence of institutional arrangements for protecting Intellectual Property Right since Lebanon is not a member country of the International Union for the Protection of New Varieties of Plants. This has a direct effect on the limited research and development and the deficiency of biotechnologies in the country, as the royalties for breeders are not guaranteed. The most affected varieties and rootstocks are fruit trees and grapevine which require a larger time span for plant breeding with higher investments.

Other main causes hindering the use of adapted varieties and rootstocks are the difficulties in changing food habits in Lebanon and exporting destination countries and the high cost of production. All are barriers directly causing market failure of SAVR and consequently the abstinence from using them. This is the case of many crops, including potato, apple, and some horticulture crops like watermelon. As for cereals and legumes, LARI has already created multiplication plots to supply farmers with new adapted varieties selected by ICARDA of wheat, barley, chick-pea, lentils and fava bean.

Figure 57 illustrates the key barriers, and their complex inter-linkage due to the wide market chain of SAVR. Nevertheless, the effects of non-adoption of SAVR are similar to any other technology in the agricultural sector, with direct impact on food security and farmer's revenue, as yields are reduced.

6.5.3 Identification of Measures for SAVR

The barriers of adoption of SAVR are, with the respective measures to overcome them are presented in Table 67.

Table 67 - List of barriers for SAVR and respective measures to overcome them

Category	Barriers	Measures	Stakeholders
Human skills	- Scarcity of human skills in research and academic institutes. - Limited trained extension service.	Training of trainers for extension service, LARI staff, private sector and NGO technicians.	MoA, LARI, service providers, NGOs
Information and awareness	Lack of know-how and information about SAVR.	- Capacity building of Extension service through training and demonstration plots at farmers, nurserymen and seed importers level. - Awareness campaign about the importance of SAVR.	MoA, nurserymen, NGOs, seed importers, farmers
Social, cultural and behavioral	Difficulties in changing food and agriculture habits.	Marketing campaign, tasting, awareness about SAVR products.	Media, public
Market failure	- Market failure for SAVR products, difficulty to export SAVR. - Import restrictions. - Limited availability of healthy/certified plant material (for non-patented varieties and rootstocks).	- Marketing campaign. - Adhesion to UPOV. - Respect of Intellectual Property Right. - Product traceability establishment. - Promotion of the multiplication of local certified plant material.	Media, MoA, MoET
Institutional and organizational capacity	Limited research and development programmes.	Increasing R&D programmes on SAVR into different research stations (LARI) and on farm level, on different varieties and rootstocks under diverse climatic and soil conditions, accounting market potential.	MoA, LARI, AUB, key farmers
Technical	- Limited qualified nurseries; - Limited availability of healthy/certified plant material (for non-patented varieties and rootstocks). - Deficit in necessary infrastructure for plant conservation, sanitization and demonstration plots.	- Establishing the necessary infrastructure within research institutes to enable conservation, sanitization and multiplication of certified plant material. - Creating demonstration plots for extension purpose.	MoA, LARI, AUB
Policy, legal and regulatory	Deficiency in institutional arrangements for crediting system, subsidies and Intellectual Property Right in Lebanon.	- Undertaking the necessary decisions and laws allowing subsidies for SAVR. - Conducting a participatory process to reach the respect of Intellectual Property Right. - Ratifying international agreements to resolve import restrictions on patented plant material.	MoEc, MoF, MoA, parliament
Economic and financial	- High cost of imported patented plant material; - Absence of crediting system, subsidies for farmers and funds for R&D.	Allocating the necessary budget for research and development as well as for the necessary funds for demonstration plots and extension and infrastructure for plant material multiplication and certification.	MoA, MoF, LARI, AUB, donors

6.5.4 Cost benefit analysis for SAVR

The Cost Benefit Analysis focuses on: i) crops vulnerable to climate change, ii) crops where SAVR is recommended as a measure to increase resilience, iii) crops of a high importance in terms of economy and food security. These include tomato (in greenhouses and open field), potato and fruit trees.

After bilateral meetings with representatives from major stakeholders (MoA department of Horticulture, service providers, and the nurseries association: Machatel Loubnan) , costs related to public investments are estimated as follow:

- Infrastructure for multiplication, conservation, demonstration: USD 2,000,000.
- R&D (including sanitization and certification): USD 2,000,000.
- Training of trainers: USD 100,000.
- Marketing studies, campaigns to promote SAVR, tasting, etc.: USD 100,000.
- Awareness campaign on intellectual property right: USD 20,000.
- Product traceability system establishment: USD 50,000.
- Respect of IPR - adherence to UPOV process: USD 20,000.
- Institutional and financial arrangements to subsidize SAVR- financial mechanism to sustain R&D: USD 25,000.
- Subsidies covering price difference between conventional plant material and SAVR: around USD 23 million in 10 years, for fruit trees, potato and tomato. This figure could reach more than USD 25 million if all horticulture crops are accounted. Free distribution of seedlings as currently applied by MOA, will be hence replaced by a more efficient mechanism, that guarantees plant material quality, its traceability and its diffusion to the concerned beneficiaries.

Hence, the total cost for deploying SAVR will not exceed USD 30 million. It should be noted that costs of SAVR at farmer's level are minimal and do not exceed 4% of the total cost of production of horticulture crops in general. The main expense will have to be borne by the government to create the enabling environment for the diffusion of this practice.

Assumptions about market demand for SAVR

- Fruit trees seedlings demand from SAVR is accounted as follow:
  - Locally produced: 250,000 seedling/baseline year, with an increment rate of 50,000 seedlings/year
  - Imported: 250,000 seedling/baseline year, with a decreasing rate of 25,000 seedlings/year to reach a constant value of 150,000 seedlings/year
- Adapted potato seeds demand is accounted as follow:
  - Imported: 100t/baseline year, with annual increment of 100t to reach a constant rate of 600t/year.
- Tomato seedlings demand for greenhouses is accounted as follow:
  - A baseline production of 600,000 seedlings/year with an annual increase of 20% the first year, then 25% the 3 following years, as Methyl-Bromide will be totally banned from the market. Further, the increment rate will decrease to 20%, then 10% to reach a constant production.
- Tomato seeds demand for field cultivation will be assumed to remain start at 1 million seeds, with an annual increase of 1 million seeds/ year to reach a threshold of 9 million seeds/ year.

Assumptions for yields and sale prices for SAVR

- Yields without SAVR are expected to decrease by 1% as an annual trend for all crops as a result of impact of climate change. As for fruit trees, the trend is 5% as tree productivity decreases due to ageing.
- Tomato conventional production yields 30 tonnes in open field and 100 tonnes in greenhouses, while the use of SAVR enables producing 40 tonnes in open field and 150 tonnes in greenhouses. Sale prices for SAVR are the same open field, and USD 70/tonnes higher for greenhouse production.
- Potato adapted varieties have the same yield of the current ones. Sale prices for adapted varieties are USD 50/ tonnes higher (USD 450/tonnes instead of USD 400/tonnes)
- Fruit trees production is averaging 20 tonnes/ha, however the use of SAVR will gradually increase from null to reach 30 tonnes/ha, the 9th year after plantation. Sale prices for fruits resulting fro SAVR are USD 300/ tonnes higher (USD 1,000/tonnes instead of USD 700/tonnes).

In this scenario, after 10 years, 1,485ha of tomato under greenhouses will be produced with SAVR, and 3,600ha in field, 1,500ha of potato will be converted to adapted varieties in vulnerable areas, and 7,525ha of fruit trees will be using SAVR, as illustrated in Fig. 58

Consequently, with this rate of annual increment of SAVR, the cost of subsidies covering the difference between the cost of conventional varieties and rootstocks and SAVR will be as follow:

- The budget mobilized for subsidies during a period of 10 years, according to the rates mentioned above will be around USD 23 million according to figure 59.
- The NPV per ha over a period of 10 years according to the mentioned assumptions for fruit trees, potato, tomato in greenhouses and in open field are mentioned in figure 60.

Locally produced fruit tree seedlings	Imported patented fruit tree seedlings	Locally produced horticulture crops seedlings	Imported horticulture crops seeds (i.e. tomato)	Potato seeds
USD 1.5/seedling	USD 6/seedling	USD 0.25/seedling	USD 5/100 seeds bag	USD 50/ tonnes of seeds

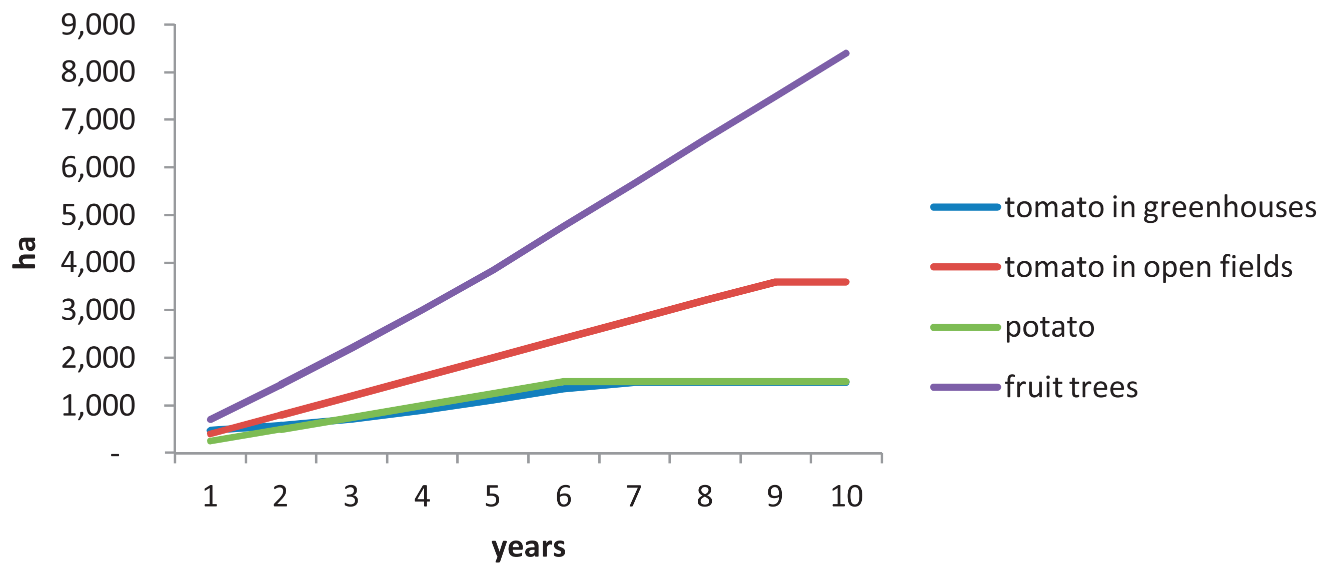


Fig. 58 - Evolution of cultivated areas with SAVR over 10 years

Source: Author's own design

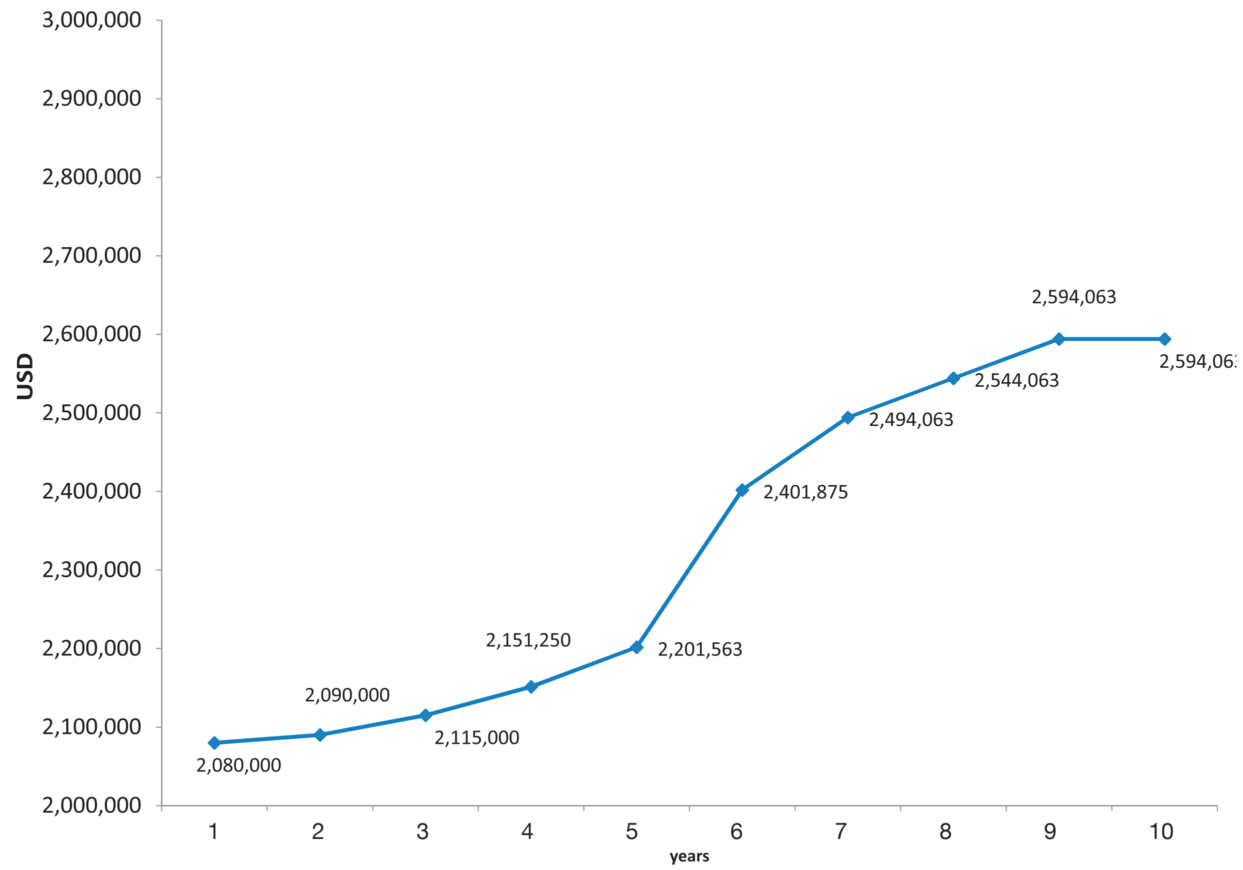


Fig. 59 - The evolution of the estimated annual budget allocated for subsidies for the diffusion of SAVR

Source: Author's own design

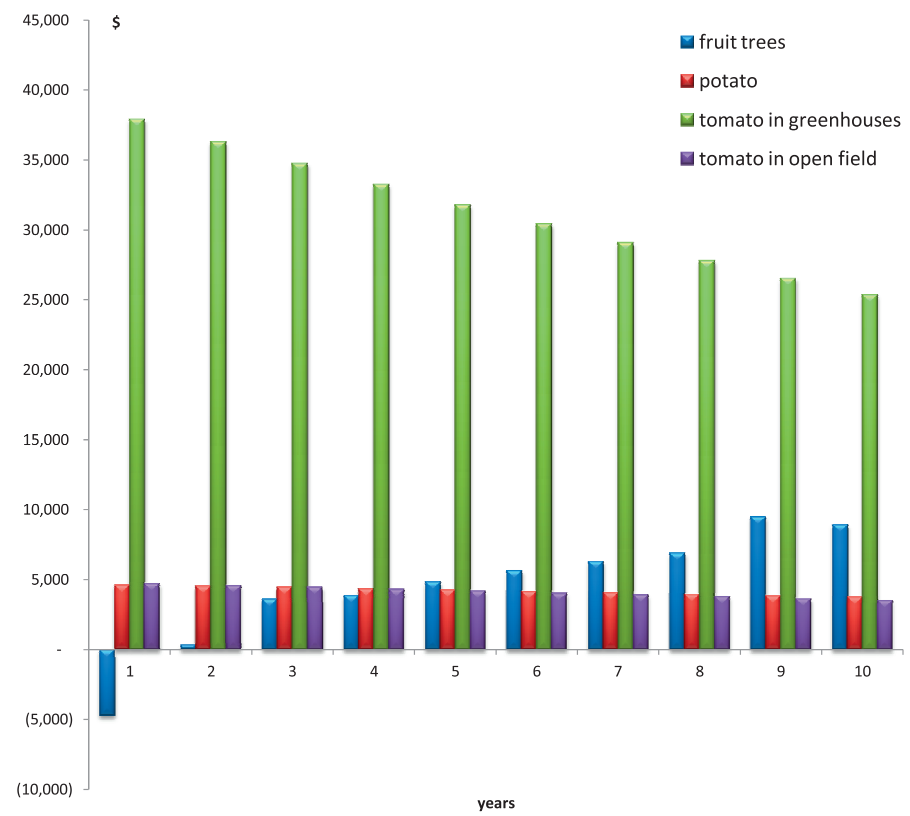


Fig. 60 - NPV over a 10 years period for 1ha of fruit trees, potato, tomato in greenhouses or open field.

Benefits at farmer's level have been studied for fruit trees, which has the longest period for investment return using imported SAVR as shown in the Table 68.

Following the rate of expansion of the use of SAVR mentioned in Fig. 59, with the assumed subsidy rates per type of crop, and benefits estimates per type of crop over a 10 years period, the total NPV would reach more than USD 892 million with a total cost for diffusion not exceeding USD 30 million. Yield will be sustained, while about 10% losses will be expected under conventional agriculture. Food security will be preserved. Products will be more marketable, and more likely to be exported. Nurseries and seed importers will benefit from the technology deployment. Pesticide, chemical and water use will be reduced when compared to conventional varieties and rootstocks, with a positive impact on the environment, and on the quality of the product. Therefore and since the benefits of using SAVR exceeds the cost of adopting the technology, it is cost-efficient to transfer and diffuse the SAVR technology in Lebanon.

Table 68 – Cost Benefit Analysis (in USD) of SAVR per 1ha of fruit orchard for the first 10 years after plantation

	Revenues under conventional agricultural practices .	Revenues under SAVR.	Additional revenue under SAVR.	Additional costs from using SAVR.	Net benefits from using SAVR.	Discounted net adaptation benefits (6%).
	A	B	C=B-A	D	E=C-D	F=E/(1+0.06)^{yr}
Year	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha
1	0	0	0	5,000	-5,000	-4,717
2	140	500	360	0	360	320
3	700	5,000	4,300	0	4,300	3,610
4	2,100	7,000	4,900	0	4,900	3,881
5	3,500	10,000	6,500	0	6,500	4,857
6	7,000	15,000	8,000	0	8,000	5,640
7	10,500	20,000	9,500	0	9,500	6,318
8	14,000	25,000	11,000	0	11,000	6,902
9	14,000	30,000	16,000	0	16,000	9,470
10	14,000	30,000	16,000	0	16,000	8,934
NPV						45,216

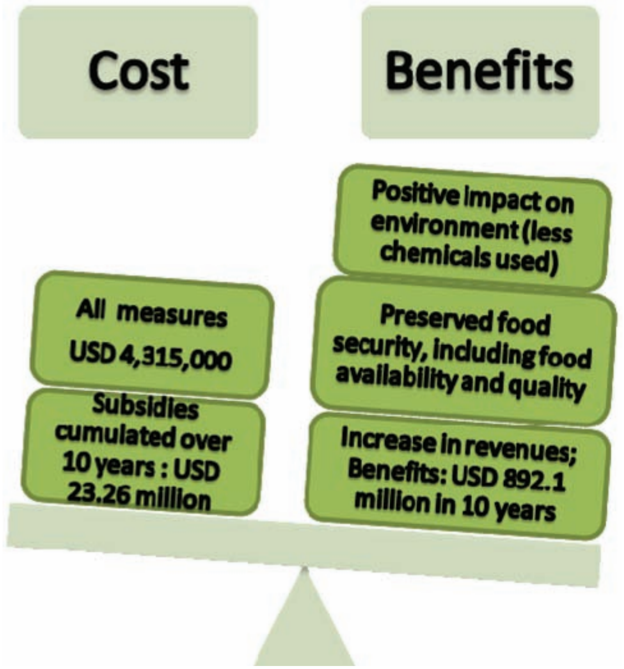


Fig. 61 - Cost and benefits of SAVR diffusion and transfer

Source: Author's own design

6.5.5 Technology Action Plan for Selection of Adapted Varieties and Rootstocks

Target for technology transfer and diffusion

The transfer and diffusion of this technology is a very long term project and of a large scale. The target of this action plan is to achieve the adoption of SAVR on 15,000ha of various horticulture crops, in a period of 10 years, at a cost of around USD 4.3 million. Including subsidies in the cost calculation could increase the budget to USD 23 million. In order to achieve this target in the near future, a technology action plan is hereby proposed.

In the light of the seed policy and certification of plant material efforts that are implemented by MoA, the project suggests measures leading to overcome barriers related to the respect of Intellectual Property Right, the import and export of patented plant material and their products. The installation of the necessary infrastructure enabling all the activities enhancing the transfer and diffusion of SAVR is coupled with research and development programmes, marketing campaign to promote SAVR products, extension and capacity building. Social acceptance and changing farmer's behavior could be corrected through incentives or subsidies covering the difference in price between common plant material and seeds and SAVR. Hence stakeholders list is very wide ranging from decision makers, to researchers, extension technicians, nurserymen, seed and plant material importers, exporters, farmers and consumers. The action plan for SAVR is presented in Table 69.

Table 69 - Technology Action plan for the Selection of Adapted Varieties and Rootstocks

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Donors
Conducting training of trainers through seminars, training workshops, field visits	1	Improving human skills for the diffusion of SAVR, and for the installation of a national register of varieties.	International and national experts.	MoA extension service, LARI staff, private sector and NGO technicians, media staff	Short term	number of training sessions, percent active technicians in disseminating SAVR.	75,000 to train 100 technicians and researcher on biotechnology techniques, multiplication, sanitation, certification, plant disease monitoring, distinguish-uniformity-stability (DUS) and value of commerce and use (VCU), etc.	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation.
Conducting training of farmers through field visits to demonstration plots	2	Improving farmers' behavior and perception to SAVR.	MoA extension service, NGOs.	Nurserymen; Seed importers; farmers	Medium to long term	Changes in varieties and rootstocks produced or imported and in plantations.	25,000 to train 1000 key farmers, 20 seed importer, 50 nurserymen.	
Promoting New varieties through tasting in agriculture fairs and awareness campaigns	3	Reducing market failure risk, enhancing exports and stimulating local market demand.	Media.	Farmers; public	Long term	Changes in demand on SAVR in major supermarkets Changes of export quantities of SAVR.	100,000 for participation in 5 national and regional agriculture fairs, tasting, TV and other media publicity.	
Acquiring the necessary land and procurement of material within research institutes	1	Enabling conservation, sanitization and multiplication of certified plant material. Creating demonstration plots and mother plant plots.	MoA with international assistance.	LARI, research institute	Medium term	Number of mother plots established Number of certified seedlings produced per variety and rootstock per nursery.	2,000,000 for mother plots for 50 varieties and rootstocks,, equipments for multiplication, sanitation and certification in 4 stations.	
Conducting experimental studies in research stations and farmer exploitation nationwide	2	Understanding the performance of different varieties and rootstocks under diverse climatic and soil conditions, accounting market potential.	Research centers (LARI) and academic institutions.	MoA extension service, nurseries, seed importers, key farmers	Long term	Number of publications on SAVR Performance of SAVR in terms of yield compared to traditional plant material in different regions % of budget dedicated to R&D.	2,000,000 for 10 years of multiplication trials in different regions, and sanitization and certification at nursery level to produce the amount of seeds and seedlings as estimated in the assumptions.	
Providing subsidies for SAVR, enforcing Intellectual Property Right	1	To increase the import of patented SAVR for all crops and their multiplication in Lebanon. To create within the national seed policy the enabling environment for the diffusion of SAVR.	MoET, MoF, MoA, parliament assisted by international and national experts.	seed importers, nurseries, exporters, farmers, research institutes	Medium term	laws, decrees or decisions elaborated in relation to intellectual property right national seed policy amendments.	50,000 for experts assisting MoET and MoA, 3 workshops, law amendments, and creation of a legislative framework for SAVR.	
Allocating the necessary budget for subsidies	3	To give incentives to farmers to use SAVR.	MoF, MoET, MoA.	Farmers	Long term	Amount of subsidies per annum.	25,000,000 in 10 years as estimated in assumptions.	
Creating a seed law and a national registrar for traceability of produced or imported plant material	2	to achieve the seed law and guarantee plant material quality control and authenticity and enable Intellectual property right respect.	MoET, MoA assisted by international and national experts.	seed importers, nurseries, research institutes	Medium to long term	seed law created and number of SAVR registered in a national register system.	50,000 for experts and establishment of the system.	
Signing International agreements to resolve import restrictions on patented plant material. Or adhesion to UPOV-respect of Intellectual Property Right	2	To overcome future expected restrictions on imports and exports of patented products and enhance biotechnology in Lebanon, through ensuring funds from royalties generated by the release of new varieties.	Media, MoA, MoET assisted by international and national experts.	seed importers, nurseries, exporters, farmers, research institutes	Long term	Law on adherence to UPOV value of exports number of local varieties registered in the national or international registers for new patented varieties.	20,000 for expert charges and 3 national workshops, at decision makers level to reach a consensus about adhesion to UPOV.	

6.6 Analysis of Technology: Risk-Coping Production system - Good Agriculture Practices (GAP)

6.6.1 General description of GAP

Good Agriculture Practices (GAP) is a risk–coping production system which includes field operations related to plantation scheme management, fertilization management, pest management and harvesting.

In this section, GAP for grapevine is taken as an example for the Cost Benefit Analysis as it embeds several additional adaptation practices requiring investments in plantation scheme (adapting trellis and pergola systems) and in field operations (pruning vines, leaves and grapes, etc.).

Regulations for Good Agriculture Practices (GAP) are inexistent, with a first shy initiative of implementing a farmers "Terms of Reference" on grapevine to ensure better control on the quality of the product, and reduce pesticide residues. LIBNOR has implemented a series of non-mandatory norms and standards for the end product of several crops. MoA has set regulations for the import, packaging, and trade of pesticides (Decree 13528, 1998; Decision 392/1, 2003) and material related to plant protection (Decision 29/1, 1962 and its amendments starting 2003) and fertilizers (Decree 15659, 1970). These include a list of prohibited molecules, and regulations for import, bottling and labeling. Instructions on the safe use of pesticides are shown on the product label.

6.6.2 Identification of Barriers for GAP

The list of barriers for GAP transfer and diffusion for the different agriculture market chains is as follow:

- Difficulty to change farmer's behavior: This is most valid for pruning methods and pest management.
- Limited information: farmers are not aware of the concept and benefits of GAP.
- Inappropriate land tenure system: By law, the use of agricultural lands is limited to a short renting period, namely for annual crops which hinder the adoption of GAP as farmers tend to intensify the use of land with the minimal investment possible.
- Deficiency in necessary equipments: some traps, pheromones, pesticide molecules, equipments, etc. are not abundantly found on the local market.
- Scarcity in budget: farmers do not have enough budgets to invest in new plantation schemes in vineyards and orchards.
- Absence of quality control: inspection on farms to control the use of chemical inputs is absent.
- Limited extension service: the human resources to diffuse GAP concept are lacking.
- Inefficient dissemination: although the information is available, the tools for communicating GAP to farmers are not always adapted to the local context (many are unable to read booklets, or unable to attend the demonstration plots or training sessions).
- Limited R&D programmes: GAP tools and recommendations are not studied for most crops yet.
- Import difficulties: import of traps, pheromones, natural predators and other non-chemical products are facing administrative constraints and service providers are not encouraged to import these items which reduce their sales of pesticides.
- Inappropriate crediting system: access to agriculture credits in Lebanon is very limited.
- Weak institutional/financial arrangements: to facilitate import of non-chemical products, enhance agriculture crediting systems and to mobilize resources for technology transfer and diffusion.

The complex inter-linkage between these barriers is mentioned in Fig. 62

6.6.3 Identification of Measures for GAP

Good Agriculture Practices have numerous barriers to overcome, including limited human resources, financial resources and institutional and financial arrangements. The identified measures to overcome the barriers are listed in Table 70.

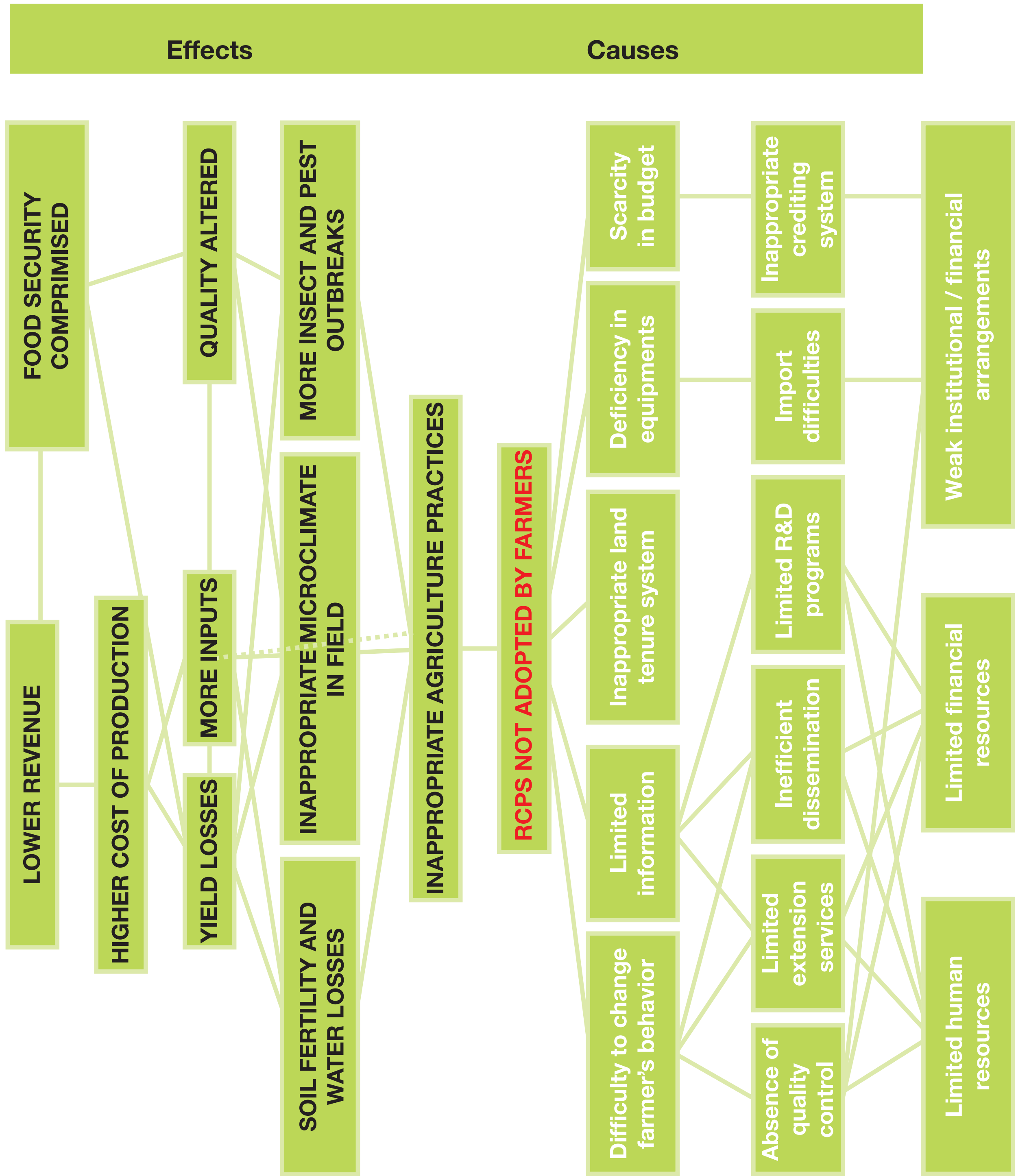


Fig. 62 - Problem tree of Risk-Coping Production System: Good Agriculture Practices

Source: Author's own design

Table 70 - List of barriers for GAP and respective measures to overcome them

Category	Barriers	Measures	Stakeholders
Human skills	Limited human resources for implementing extension and research.	Recruitment of competent technicians, researchers.	MoA, LARI, Civil Servant Council
Institutional and organizational capacity	- Limited extension service capacity - Inefficient dissemination Limited R&D programmes on GAP for most crops.	- Increasing field research and development programmes on GAP on main crops in different agro-climatic zones; - Planning and implementing an information dissemination strategy to farmers and relevant stakeholders. - Training of trainers.	MoA, LARI, NGOs
Policy, legal and regulatory	- Inadequate land tenure system. - Import difficulties for equipments. - absence of quality control and institutional and financial arrangements to guarantee the quality of GAP products. - Inappropriate crediting system from banks.	- Providing incentives for the import of equipments and material, - Elaborating norms of production (specifications). - Providing legislative arrangements for the recruitment of skilled technicians, - Establishing of quality control system and facilitating the agriculture crediting system.	MoA, Custom Service, MoF, Banking sector
Information and awareness	Narrow information on GAP at farmers level.	Organizing awareness campaigns and field visits to demonstration plots, seminars, and trainings .	MoA, NGOs
Economic and financial	Scarcity of funds for R&D and for recruitment.	Allocating the necessary governmental budget for R&D and information dissemination.	MoF, MoA, LARI
Social, cultural and behavioral	Inherited behavior affecting farmer's agriculture practices and acceptance for GAP.	Organizing field visits to demonstration plots and conducting seminars for farmers to learn and train them about the advantages GAP.	MoA
Technical	Deficiency in suitable equipments.	Facilitating equipment import by service providers.	Service Providers, Custom Service, MoA

6.6.4 Cost benefit analysis for GAP

The estimated public expenditure to overcome barriers related to GAP makes a total of USD 325,000, detailed as follow (Agrical, 2012; MoA, FAO, IC, 2011):

- Research and development: USD 250,000.
- Training of trainers: USD 20,000.
- Information dissemination strategy: USD 5,000.
- Awareness campaign (media, field visits, etc.): USD 50,000.

If the recruitment of additional technicians in public institutions is not foreseen on the short term, the mainstreaming of NGOs efforts for training their existing technicians onto GAP could be a solution for information diffusion. These efforts should be backed up by audio-visual packages to be diffused by media.

Since Good Agriculture Practices are diverse and different from one crop to another, in this particular exercise table grapevine is selected for the cost-benefit analysis exercise. This crop is not only vulnerable to climate change, but is also of national importance. The additional cost and benefits for shifting to GAP at table grapevine grower's level is estimated as follow:

- Adapting plantation scheme infrastructure (first year): USD 3,000/ha.
- Adapting training and pruning methods (first 3 years): USD 50/ha.
- Soil fertility management: USD 400/ha saved annually.
- Integrated Pest management: USD 250/ha (starting the 4th year) saved
- Insect-proof nets(4th year): USD 5,000/ha.
- Additional labor (grape pruning, hormone application and so, starting the 4th year): USD 200/ha.

In the case of table grapevine growers, after a 10-year period, 2,000ha will have adopted GAP. The total cost spent by the grapevine growers is expected to reach USD 8.66 million for the mentioned area and period. Costs and benefits at farmer's level are illustrated in Table 71.

Costs and benefits of the transfer and diffusion of GAP, with an emphasis on Table grape production are illustrated in Fig. 63.

Assumptions for table grapevine under GAP

- Baseline area under GAP: 200ha
- Annual increment rate: 200ha
- The expenses of farmers will not be subject to subsidies.
- Yield in GAP is higher than in conventional agriculture: 30t/ha instead of 20t/ha
- Yield is subject to an annual decrease of 1% in for grapevine under conventional agriculture, while it remains stable under GAP.
- Since Baseline year, Table grapes under conventional have 10% less marketable production.
- Grapes under GAP have a better quality; we consider that there 50% higher price for products under GAP: USD 0.75/kg for grapevine under GAP instead of USD 0.5/kg for conventional production.

Table 71 –Cost Benefit Analysis (in USD) of 1ha of vineyard under GAP for a 10-year period

	Revenue under conventional agriculture without adaptation	Total revenues under GAP	Additional revenue under GAP	Additional costs from applying GAP	Net benefits from applying GAP	Discounted net adaptation benefits (6%)
	A	B	C=B-A	D	E=C-D	$F=E/(1+0.06)^{yr}$
Year	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha
1	9,000	22,500	10,850	2,650	8,200	7,885
2	8,910	22,500	13,940	-350	14,290	13,740
3	8,821	22,500	14,029	-350	14,379	13,826
4	8,733	22,500	9,217	4,550	4,667	4488
5	8,645	22,500	14,305	-450	14,755	14,187
6	8,559	22,500	14,391	-450	14,841	14,270
7	8,473	22,500	14,477	-450	14,927	14,353
8	8,389	22,500	14,561	-450	15,011	14,434
9	8,305	22,500	14,645	-450	15,095	14,515
10	8,222	22,500	14,728	-450	15,178	14,595
NPV						126,292

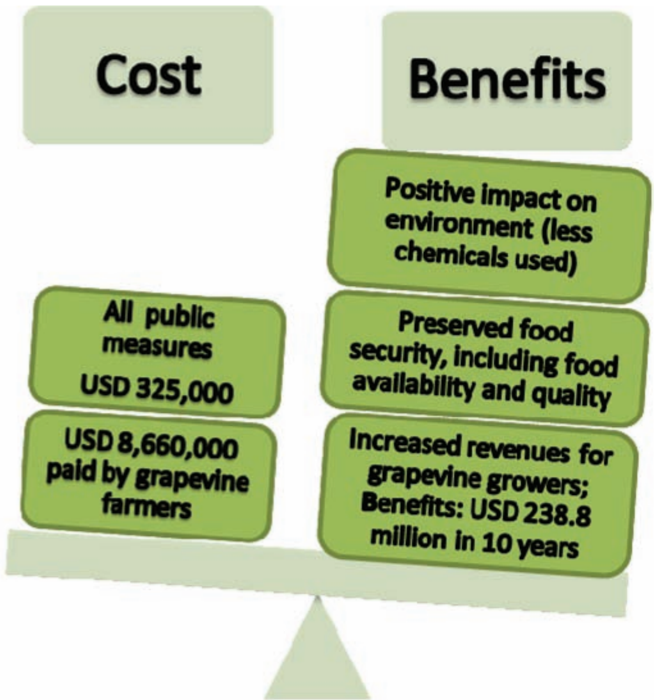


Fig. 63 - CBA for the transfer and diffusion of GAP for table grapevine.

Source: The author's own design

Benefits related to the transfer and diffusion of GAP include: i) less inputs in terms of chemicals, with a positive impact on the environment (water and soil) and food quality, ii) food security preserved due to food availability (yield stability), increase in revenues (access to food) and preserved food quality and, iii) benefits exceeding USD 238 million in 10 years following the assumptions related to yield, surface applying GAP and NPV per 1ha in a 10-year period, as mentioned in Figure 63.

Costs from public expenditure are USD 325,000 while the expenses paid by table grapevine growers are USD 8.66 million, making a total of USD 9 million approximately. Based on a revenue of USD 238.8 million for 10 years, and compared to the costs incurred for the deployment of the GAP, results show that the adoption of good agricultural practices are cost-efficient and feasible in Lebanon.

6.6.5 Technology Action Plan for a Risk Coping Production System: Good Agriculture Practices

Target for technology transfer and diffusion

If GAP is to be applied at a national scale, and for different crops, a nationwide awareness and training campaign is to be initiated, especially that Good Agricultural Practices can be easily coupled to other technologies or practices for optimal efficiency and adaptation at farmer's level. The appropriate technology action plan is presented Table 72.

Table 72 - Technology Action plan for Good Agriculture Practices

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation Indicators	Estimated cost	Donors
Initiating civil servants recruitment procedure	2	To overcome the lack of human resources for R&D.	Civil Servant Council	MoA, LARI	Short term	Number of recruited personnel.	0	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Conducting experiments in different research stations and on farm in all agro-climatic zones	1	To better understand the response of crops to different RCPS, including GAP and adapt practices according to crops and agro-climatic zones.	LARI, NGOs	MoA, NGOs, farmers	Medium to long term	Number of experiments conducted Number of publications related to GAP.	250,000 for experiments in at least 5 stations, and at 50 farmers on 8 major crops.	
Elaborating communication tools	2	To ensure an efficient diffusion to farmers of information, including research results.	MoA assisted with external experts	MoA, Custom Service, MoF, Banking sector	Short term	Strategy report.	5,000 fees for the expert.	
Conducting annual seminars to show research results, field visits	1	To increase the skills of technicians.	MoA, NGOs external experts	MoA, NGOs staff	Medium term	Number of technicians Guidelines on gap for different crops.	20,000 to train 50 technicians by experts.	
Providing import facilities for equipments and material	2	To facilitate the deployment of GAP and overcome constraints related to material import, quality control and lack of agriculture credits.	MoA, Custom Service, MOF, Banking sector	Service providers, exporters, consumers and farmers	Medium to long term	Number of decisions and decrees taken; % of custom rates; Elaborated standards for GAP; % of loans for agriculture investments.	0	
Elaboration of standards of production Allowing agriculture crediting system								
Conducting field visits to demonstration plots, seminars, training	3	To sensitize the farmers about GAP and change their behavior in agriculture practices.	MoA	Farmers	Medium term	Cost of production Yield variation Quality control reports.	20,000 cost of 3 seminars and field visits per farmer, for a target of 1000 farmers.	

6.7 Linkages of identified barriers

The three selected technologies are characterized by common barriers that are interlinked. These focus mainly on the absence or deficiency of specific institutional or financial arrangements and to awareness and information dissemination as well as research and development. For instance, financial resources are needed not only to conduct research programmes on topics related to the three technologies, but also for ensuring subsidies, which require governmental decisions to shift subsidizing mechanism from crop oriented (for wheat and tobacco) to practice oriented (for the use of SAVR or adopting CA, etc.). Meanwhile indirect subsidies or services provided by some institutions (i.e. distribution of seedlings to farmers; extension activities) should be embedded in the process of transfer and diffusion of SAVR, CA and GAP.

Although these might be of different nature, the major actors involved are public institutions, namely: i) the Ministry of Agriculture, ii) the Ministry of Finance and iii) the Ministry of Economy and Trade. Other public institutions, such as i) the Ministry of Environment, ii) the Green Plan, iii) the Lebanese Agriculture Research Institute, iv) the General Directorate of Customs, v) the General Directorate of Urban Planning, and vi) The Council for Development and Reconstruction could also be involved. A holistic approach for overcoming these barriers could be overseen with the mentioned stakeholders. Other important actors are private or international research institutions active in Lebanon (AUB, USJ, LU, USEK, CNRS, ICARDA, and ACSAD) or active NGOs in the diffusion of technologies (Arc-en-Ciel, Frem Foundation, Hariri Foundation, Moawad Foundation, Safadi Foundation, YMCA, etc.).

Mainstreaming of measures for overcoming these common barriers is hence required. Such effort would optimize the efficiency of transfer and diffusion of the technologies.

6.8 Enabling Framework for overcoming the barriers in agriculture

The use of a Selection Adapted Varieties and Rootstocks, Conservation Agriculture and Good Agriculture Practices concern mostly farmers' behavior and their readiness to change their agriculture production system and field operations. Therefore, the enabling framework is limited to the capacity of public institutions to transfer these technologies on the grass root level. Few arrangements to facilitate the requirement of necessary equipments are to be done (like seed drillers for some crops under CA or plant material under SAVR). Nevertheless, most of the work concern extension service capacity to diffuse the technologies, and research programmes prior to this diffusion.

A major concern is the capacity of absorption of additional projects or programmes within the public institutions which chronically suffer from the limited human resources and infrastructure enabling the proper implementation of such programmes. Therefore, the proposed technology action plans require international assistance with the participation of local NGOs, research institutions and international organizations that have a long expertise in transfer and diffusion of these technologies. The ownership of these technologies by the MoA is crucial for further development of projects aiming at overcoming barriers related to the transfer and diffusion of these technologies. So far, all the selected technologies fall under the framework of the Agriculture Strategy 2010-2014. The Ministry of Agriculture is being active in encouraging conservation agriculture, elaborating communication tools for GAP and developing a seed policy, which would be a perfect ground for enhancing SAVR and resolving constraints related to Intellectual Property Rights.

The Water sector

Water sector

7.1. Sector Overview

Lebanon's Second National Communication to the UNFCCC has projected a decrease in precipitation and water losses due to evapotranspiration increase in the near future. With a temperature rise of 2°C, water resources are estimated to decrease by 450 Mm³ per year (MoE/UNDP/GEF, 2011). The effect of climate change on snow, which is vital for water resources in Lebanon, is considerable. River flows would increase between December and February, however as snow melt decreases from April to June, river flows will dramatically decrease during periods of high demand for irrigation water.

Lebanon's water resources are considered to be under stress since the Ministry of Energy and Water puts the total renewable resources (drinking, industrial and irrigation) per capita per year at 926 m³ which is slightly lower than the international benchmark of 1,000 m³/capita/year. This situation will be exacerbated since the total renewable resources are projected to reach 839 m³ by 2015 (MoEW, 2010b).

Lebanon has 16 perennial rivers and 23 seasonal rivers and total annual river flow is about 3,900 Mm³, of which an estimated 700 Mm³ flow into neighboring countries. 75% of the flows occur between January and May, 16% between June and July and 9% between August and October (Comair, 2010).

Most of the surface water used to secure supply comes from captured spring sources. Lebanon has some 2,000 springs. Their total yearly yield exceeds 1,200 Mm³; however, less than 200 Mm³ is available during the summer period. The total annual exploited volume is 637 million m³ (MoEW, 2010b).

Lebanon has two dams, the Qaroun dam on the Litani River, and Chabrouh dam which captures runoff from rain and the Laban Spring. Their respective static storage capacity is 220 Mm³ and 8 Mm³ respectively. Currently, only 30 Mm³ is being utilized from the Qaroun Dam for water supply and irrigation and the rest is used to generate electricity.

Current demand estimates vary with the source and assumptions. According to the national water sector strategy developed by the Ministry of Energy and Water in 2010, water withdrawal was estimated at 1,310 Mm³, of which almost 60% was for agricultural purposes, 29% for municipal use and 11% for industry. Groundwater and surface water account for 53.4% and 30.2% of total water withdrawal respectively. Recycled irrigation drainage accounts for 12.6%, and reused treated wastewater for 0.2%. The share of water withdrawal for agriculture is likely to decrease over the coming years as more water will have to be diverted for municipal and industrial purposes.

Irrigation is a necessity for agricultural productivity in most parts of Lebanon, given its prevailing drought during the summer growing season. Irrigated surfaces reached over 104,000ha (MoA, 2008). Irrigation is the major factor enabling production intensification in agriculture. However, unsustainable water management practices, water governance shortcomings, and environmental risks including climate change are among the main obstacles facing the sector.

Over 50% of irrigation water comes from underground wells and boreholes while 80% of potable water comes from groundwater sources. In addition, private wells have increased greatly in the last few years, due to population growth, economic development and urban expansion (MoEW 2010b). Aquifers are being overexploited and wells are drying up or increasing in salinity.

Rivers, springs, and groundwater continue to be adversely impacted by raw sewage and other wastes, both domestic and industrial, being discharged without any regulation or control from establishments. While all the water resources are being impacted by bacteriological contamination, in the agricultural areas, the runoff and infiltration of residues from fertilizers and pesticides is exposing them to further environmental degradation. Furthermore, runoff from urban areas may contain heavy metals and hydrocarbons which could impact the quality of receiving waters. Generally, coastal wells are subject to severe salt water intrusion, and many are being put out of operation (Shaaban, 2009).

7.1.1 Actions at sectoral level

In order to increase water availability and optimize water efficient use, the MoEW developed a 10-Year plan to build dams and lakes that would add approximately 650 Mm³ per year to the stock of available renewable freshwater resources mainly for drinking purposes. Similar plans have been conducted by the MoA and Green Plan to increase water harvesting from surface run-off in water efficient use through the promotion of drip irrigation. In addition, the recently established Lebanese Center for Water Management and Conservation is currently promoting urban/communal water harvesting and domestic efficient use.

Faced with mounting water-related challenges, Lebanon has invested in expanding existing water supply networks, providing wastewater collection and treatment systems, developing additional water resources, building the capacity of institutions to manage infrastructures, and improving service delivery. Overall progress however has been predictably slow.

Key emerging issues include options for augmenting water resources, and new approaches for water management including integrated water resource management (i.e. the elaboration of Irrigation or Water Act), water demand management, protection of water recharge zones and protection from flood plains. Some relevant Laws related to the water sector are listed in Table 73

Table 73 - List of relevant laws, decrees and decisions related to water sector

Type	Number	Title	Date issue	Remarks
Creation and organization of Water syndicates and their role				
Law	221	Organization of the water sector.	2000	Amended by Law 241, 2000 and law 377, 2001.
Decree	8122	Application of some clauses of Law 221.	2002	Fusion of water committees into regional water services.
Decree	65	Creation of a water syndicate for the water use of Nahr el Jawz River.	1943	
Decision	320	Conservation and use of public water .	1926	Amended by the decree 680, 1990. Includes clauses for the creation of water syndicates.
Creation and organization of water infrastructures				
Decision	3	Water policy for the creation of dams and hill lakes.	2003	10 year strategy; under Law 221, 2000.
Decree	13785	Creation of green Plan.	1963	Installation of hill lakes, water reservoirs, irrigation system on farm level.
Decree	20022	Creation of Qasmiyeh irrigation scheme.	1958	Irrigation scheme for farmers using water of Qassmiyeh (Litani) River.
Ottoman law		Rights for irrigation and use of distribution network and rivers and their maintenance.	1918	
Ottoman law		Irrigation law.	1913	
Water Use				
Law	3339	Property law	1930	
Ottoman law		Ottoman Journal for judicial provisions: Regulation of water use.	1876	

Source: Karam, 2012

7.1.2 Scope of work

In this project, technologies serving the overall target to increase water availability and optimize water efficient use are proposed and can be deployed at farm or exploitation level with minimal investments, and improve substantially farmers and crop resilience to climate change. The following technologies have been retained:

Increasing water availability: rain water harvesting from hill lakes or earth lakes, rainwater harvesting from ground surfaces or roads, and rainwater harvesting from greenhouse tops.

Optimizing efficient water use: efficient water use in irrigation systems, water users association and soilless culture.

Snow monitoring and the use of treated waste water are suggested technologies that would embark on both categories.

7.2 Possible adaptation technology options in the Water sector and their adaptation benefits

The proposed technologies in most cases are a combination of hard technologies (i.e. equipments), soft technologies (i.e. monitoring demand and supply then management) and organizational technologies (organization of users into associations).

7.2.1 Rainwater harvesting from hill lakes or earth lakes (RWHH)

Managing micro-catchments for water harvesting in earth lakes or hill lakes is a common technology for water harvesting used in the world. The technology consists of storing rainwater in excavated lakes where surface runoff is driven to increase storage capacity. Stored water can be allocated for both agriculture and domestic use; however a distribution system is required in order to transport water to the crops or settlements. In the case where the hill lake is collective, a water user association is needed to share maintenance costs and agree on distribution patterns. Suitable topography, geological conditions and the amount of rainfall are the key prerequisites for the construction of hill lakes. If the hill lake is excavated into a permeable soil, a layer of clay or impermeable membranes should be installed in order to retain the stored water. The mountainous topography of Lebanon increases the geographical extension where this technology can be deployed. Rainwater harvesting from hill lakes enables increasing water availability under current and future climate, to meet the increasing demand. Consequently this technology enables the reduction of vulnerability of crops and populations in mountainous areas. The use of surface runoff will also reduce the use of underground water, making water resources more available to the users in the lower parts of the watershed.

In Lebanon, this technology is witnessing some development. Since the initiation of the Green Plan in 1964, hundreds of hill lakes all over the country have been constructed with an excavated area of 60,000ha. In 2008, the Green Plan constructed several hill lakes (mostly in North Lebanon and Northern Bekaa), with a total capacity of 98,139 m^3 (Green Plan, 2009). However many barriers are hindering this practice to be widely used to optimize water availability in all areas in Lebanon.

7.2.2 Rainwater harvesting from ground or roads (RWHR)

Rainwater harvesting could be achieved from ground surface (roads) that constitutes the catchment area where the rainfall or water runoff is initially captured. Surface water flowing along the ground during rain is usually diverted toward a reservoir below the surface.

Rainwater harvesting represents an adaptation strategy to climate change for people living with high rainfall variability, both for domestic supply and to enhance crop, livestock and other forms of agriculture (UNEP RISOE Center, 2011a). This technology requires 1) designing new roads to be executed or rehabilitating existing roads in a manner enabling water drainage through canals to a lower point, 2) the construction of a pond for decantation and collecting sediments, and 3) a reservoir from earth or concrete material for storage. This technology is not applied so far in Lebanon and could be a potential for any area with a minimal slope allowing water runoff towards the collection point. A project has already been initiated in Bchaaleh in Batroun highlands, with a fund by the Environmental Fund for Lebanon (EFL). Stored water is an additional resource enabling to cover the increasing demand under future climate, for both domestic and agriculture uses.

7.2.3 Rainwater harvesting from greenhouse tops (RWHG)

Like any other roof top, greenhouses could be a potential ground to harvest rainwater. The collected water is stored in an underground concrete or plastic tank or even an earth reservoir. The technology is simple and quick to deploy. Water can be allocated for domestic use or for irrigation, especially when coupled with an efficient irrigation system. This technology although targeting a small proportion of land mainly on the coastal areas and mountains where precipitations are significant, it is important to increase water harvesting and reduce the pressure on pumping from the underground water which is prone to sea intrusion (Shaaban, 2009). Moreover, rain harvesting from greenhouse tops will increase water availability during the critical months of late summer and early autumn. Reducing the risk of salinity in both soil and water will increase the resilience of crops to prolonged drought and to some fungal outbreaks (Shaaban, 2009; Hanafi, 2008) and avoid increased crop vulnerability to climate change.

7.2.4 Efficient water use irrigation system (EWUIS)

Efficient water use irrigation systems are a combination of several hard technologies using different equipments (drip, micro-sprinkler) and soft technologies (models for water needs according to the relation between the soil, climate demand and crop characteristics). Efficient irrigation systems like drip-irrigation reduce water evaporation and percolation as the water is directly applied to the root zone of the plants. However, using an efficient irrigation system like drip along with monitoring water demand by the plants can allow reaching up to 90% efficiency (UNEP RISOE Center, 2011a). Supplying the plants with their water requirement on time will avoid water stress and provide higher yields when compared to crops under conventional irrigation methods. Moreover, water monitoring will optimize supplementary irrigation namely for cereals, legumes and forage crops (ICTSD, 2010). Hence, EWUIS increases the resilience to climate change and provides benefits for farmers in the form of minimized labor for irrigation, minimized cost for weed control as well as increasing yield (UNEP RISOE Center, 2011a). Revenues can increase by a minimum of 15% due to increased yield and reduced cost of production. Indirect benefits include the saved energy for pumping, plowing and the minimized chemical spraying. EWUIS is suitable for all crops grown in Lebanon, however, institutional and organizational arrangements for monitoring water demand and for scheduling water distribution into a network within an irrigation scheme are essential.

7.2.5 Water users' association (WUA)

A WUA is a unit of individuals that are formally and voluntarily associated to each other for the purposes of cooperatively sharing, managing and conserving a common water resource. The core activity of a WUA is to operate the waterworks under its responsibility and to monitor the allocation of water among its members. All farmers benefiting from a common water source can establish a WUA. It is a prerequisite to monitor irrigation networks and for irrigation systems requiring on-farm water supply on a daily basis (i.e. drip systems).

This organizational "technology" has been successfully applied in different countries, and is highly recommended to increase the resilience of water users to climate change (UNEP RISOE Center, 2011b). In Lebanon, the establishment of WUAs is absent since it requires several institutional arrangements (such as a Water Act or Irrigation Act). However several water committees and informal users' groups exist. Benefits of WUA are indirect, but enable the optimal use of irrigation systems, and hence optimal yields are obtained. The modernization of water distribution systems is a key prerequisite of WUA. Enabling monitoring water supply according to the climate demand can reduce crops vulnerability to climate variability by saving water by more than 40%, enabling further efficiecy in water use.

7.2.6 Soilless agriculture (SA)

This technology is cross-cutting between the agriculture and water sectors. However, since the major advantage of soilless agriculture is related to water efficient use and water quality, this technology is listed within the water sector. Soilless agriculture relies on the use of water culture using a liquid film technique or natural inert material substrate culture. Despite beeing characterised as intensive agriculture that increases the adaptation to climate through controlling the climate environment of the greenhouse, soilless agriculture resolves the problem of uncertainty of water and nutrient status of the soil. It enables protecting crops from water salinity, water shortage, soil-borne diseases (Hanafi, 2008), while offering good yields and quality of products. Soilless agriculture is feasible for crops grown greenhouses and it is still at its early stage in Lebanon due to the high technical requirements and high investment costs. Soilless agriculture can be harnessed by other technologies related to greenhouses like water harvesting from roof tops and Integrated Production and Protection.

7.2.7 Use of treated wastewater in irrigation (UTWWI)

The proposed technology presents a model or protocol for reusing treated wastewater in irrigation for recommended crops. The objective is to make efficient use of treated wastewater, ensure water for plants, without having any negative impact on human health or the environment. UTWWI will replace the rarified water resources and increase water availability for irrigation under current and future climate scenarios (UNEP RISOE CENTER, 2011; Choukrallah, 2011) and hence avoiding the pollution of aquifers. The components of UTWWI are a combination of crop selection, irrigation methods, and adoption of appropriate management practices (Steinel and Margane, 2011a). This soft technology consists of i) elaboration of regulations that permit the use of appropriately treated wastewater for irrigation of specific crops, while minimizing health risk, ii) monitoring effluent supply and its quality, and iii) training farmers on the preparation of an appropriate on-farm management strategy. To be able to implement UTWWI, wastewater treatment is a prerequisite. UTWWI does not require sophisticated expensive treatment plants, and can be functional with constructed wetlands (i.e. treatment through reed plantation) that are cost-effective and non energy intensive. In Lebanon, several treatment plants have been planned to serve major cities of which several are under construction. In parallel several municipalities and communities have made their own arrangements to improve wastewater collection and disposal. However, institutional and organizational challenges are numerous, such as the absence of laws specific to the use of treated wastewater, the absence of a financial mechanism to sustain the treatment plants, and the acceptance of the society including farmers to the UTWWI (Steinel and Margane, 2011b). The direct benefits of UTWWI are the reduced vulnerability of crops due to increased water supply and the reduction of water and soil pollution.

7.2.8 Early warning system for water supply management (river flow) through snowpack monitoring (EWS-SPM)

Lebanon depends mostly on its snow cover to feed river basins and the groundwater. Large variations in snow cover between years has direct impacts on water supply to rivers, especially that changes in flows can have adverse effects on multipurpose water resources supply (Shaaban, 2009). Methods for monitoring and predicting stream flow help increasing the readiness to climate uncertainty by predicting water supply and developing water safety plans (UNEP RISOE CENTER, 2011). This hard technology aims at providing an early warning system for water supply management, by developing a model that predicts stream flow variation based on snow cover in the river basin. Such models rely on snow cover spatial and temporal variations data derived from remote sensing. The system includes: 1) on-ground snow stations that record real time snow depth in different locations, 2) gauging stations on the river that records stream flow data and, 3) satellite images for snow cover monitoring. The Litani River Authority has the necessary institutional arrangement and expertise for undertaking such work. Beneficiaries range from water authorities to water users. Benefits from EWS-SPM are indirect, and related to the optimal use of available water resources for all sectors. Planning agriculture design according to the available water resources will minimize the risk of plant water stress and hence, preserve yields.

7.2.9 Criteria and process of technology prioritization

Process of technology prioritization

The technology prioritization process was elaborated based on the Multi-Criteria Analysis approach, where different technologies are ranked based on specific weighed selection criteria. The final weighed score is calculated according to the below formula:

$$\frac{\text{Tech.score-min.score}}{\text{Max.score-min.score}} \times \frac{\text{Weight of criterion}}{\text{Total weights}}$$

Technologies were identified and analyzed based on literature review, field experience and results of individual meetings conducted with different experts working in the field. 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.

Based on this extensive dissemination process, an expert consultation meeting was held where a pool of experts validated the choice of technologies, the selection criteria and the proposed weights. A ranking was then conducted by attributing scores based on general consensus.

Selection criteria

Specific selected criteria allowed stakeholders to answer simple questions related to economical viability, environmental reliability and social acceptability of technologies and to compare between the technologies in order to prioritize the most appropriate for Lebanon.

The following criteria were retained for the prioritization exercise: capital and operational cost, extent of use, capacity to increase water supply , capacity to increase water efficient use, need for human resources and knowledge, need for infrastructure, social acceptance and negative environmental impact. Each criterion answers more than one question. For instance, the extent of use depends on the number of beneficiaries, the targeted agriculture-subsector, the covered regions, etc.

Absolute scale with misleading figures and numbers were avoided by ranking on relative basis over a top score of 5 -1 and weights of 1.5 were attributed to the criteria that were more significant in technology deployment.

The list of criteria with their scale and respective weight is presented in Table 74.

Results of the technology prioritization

After reviewing and fine tuning the criteria and their relative weights, a ranking was performed using weighed scores of MCA. The final results are reported in Table 75.

As appeared in Table 76, the top ranked technologies were: Rainwater harvesting from greenhouses, Rainwater harvesting from roads, and Water User Associations. Due to the importance of efficient water use, it has been agreed to tackle efficient water use as common base and overarching concept for the three selected technologies.

Table 74 - Brief description of the criteria of selection, their scale and respective weight

Criterion	Description	Scale	Weight
Capital and operational cost	This includes initial cost to establish the technology as well as the annual maintenance and operational costs. Some figures per surface or volume units are provided for some technologies. It highlights the easiness of access of farmers to the technology.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	High (1.5)
Extent of use	It assesses the extent to which the technology is applicable within the different geographical contexts, agro-ecological zones, and the number of targeted beneficiaries.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Capacity to increase water efficient use	The technology's ability on improving water efficient use. The higher the values the more water is used efficiently.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	High (1.5)
Capacity to increase water supply	The technology's ability on improving water supply. The higher the values the better supply of water.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Need for human resources and knowledge	The technology's human requirements and qualification. If the requirements in human resources and in training are high, the score is lowest.	Very low (5) Low (4) Medium (3) High (2) Very High (1)	Standard (1)
Need for infrastructure	It reflects the availability of the infrastructure needed to deploy the technology. If the infrastructure is absent, the score is lowest. If the infrastructure is simple, and available, the score is highest. It highlights the time requirement to establish and disseminate the technology.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Social acceptance	It reflects the social acceptance at all levels: water users, farmers and decision-makers.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)
Negative Environmental Impact	If there is a negative impact of the technology on the environment, the score is low.	Very low (1) Low (2) Medium (3) High (4) Very High (5)	Standard (1)

Table 75 – MCA exercise results for the water sector

Criteria	Weight	Rainwater harvesting from ground /roads		Rainwater harvesting from hill/ earth lakes		Rainwater harvesting from greenhouse tops		Efficient Water Use Irrigation System		Use of treated wastewater in irrigation		Soilless Agriculture		Water Users' Association		Early warning system for water supply management through snow pack monitoring	
		Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score	Score	Weighed score
Capital and Operational Cost	1.5	2	0.05	1	0.00	3	0.11	2	0.05	2	0.05	1	0.00	4	0.06	2	0.05
Extent of use	1.5	5	0.06	3	0.00	3	0.00	4	0.08	3	0.00	3	0.00	5	0.16	3	0.00
Capacity to increase water efficient use	1.5	4	0.08	3	0.00	5	0.16	5	0.16	3	0.00	5	0.16	3	0.00	4	0.08
Capacity to increase water supply	1	4	0.08	5	0.11	3	0.05	1	0.00	4	0.08	1	0.00	1	0.00	2	0.03
Need for knowledge and human resources	1	4	0.08	2	0.03	5	0.11	2	0.03	3	0.05	1	0.00	2	0.03	1	0.00
Need for infrastructure	1	3	0.05	2	0.03	5	0.11	2	0.03	2	0.03	1	0.00	5	0.11	3	0.05
Social Acceptance	1	5	0.11	4	0.07	5	0.11	5	0.11	3	0.04	2	0.00	3	0.04	5	0.11
Negative environmental impact	1	1	0.00	4	0.11	1	0.00	2	0.04	2	0.04	2	0.04	1	0.00	1	0.00
Total		28	0.61	24	0.33	30	0.63	23	0.48	22	0.28	16	0.19	24	0.49	21	0.32

Table 76 - Multi-Criteria Analysis results for the technologies of the water sector.

Rank	Technology	MCA score
1	Rainwater harvesting from greenhouses	0.63
2	Rainwater harvesting form roads	0.61
3	Water users' association	0.49
4	Efficient water use irrigation systems	0.48
5	Rainwater harvesting from hill lakes	0.33
6	Early warning system for water supply management through snow pack monitoring	0.32
7	Use of treated wastewater in irrigation	0.28
8	Soilless agriculture	0.19

7.3 Barrier Analysis and Enabling Framework

7.3.1 Classification of technologies

The proposed technologies are divided to 4 categories: i) consumer goods, ii) public goods, iii) capital goods, and iv) non-market goods. Rainwater Harvesting from greenhouse tops is to be a technology that can be applied deployed at the exploitation level, whereas Rainwater Harvesting from Roads is a technology targeting collective users. The former embeds equipments for water drainage, storage and pumping to be purchased by the farmers from service providers. The latter technology requires more collective or public investments on capital goods like roads, drainage system, decantation lake and storage lake. Should harvested water be exclusively from public roads, and distributed for users by a public entity, it would be classified as a public good. In this case, roads are private to a group of farmers that will directly share the stored water among themselves therefore, the rainwater harvesting from roads has been classified as capital good. Water User Association, which is an organizational technology providing a service to user is considered as a non-market technology.

Fig. 64 - Technology classification according to type of goods for the water sector

Source: The author's own design

7.3.2 Methodology of identification of barriers and action plans

The barrier analysis of the proposed technologies was conducted based on literature review as well as group and individual consultations with key experts in the field, including the public institutions, research institutes, NGOs, service providers and direct beneficiaries (communities, farmers). The beneficiaries' feedback and participation was retrieved from direct meetings with pioneer farmers adopting one of the technologies, technicians of the Green Plan, the Litani River Authority and NGOs active in the sector. Questionnaires for beneficiaries involved in at least one of the technologies to analyze social acceptance and farmer's ownership were conducted along with this process.

A Cost Benefit Analysis (CBA) for the transfer and diffusion of the selected water technologies was also conducted. Since water pricing and monitoring are inexistent in Lebanon, the CBA was based on estimations and assumptions related to the potential revenues based on the crops related to the increased availability of water, or the incurred savings from using alternative water source. Water availability under a future climatic scenario with 20% reduction in water availability (MoE, UNDP, GEF, 2011) with or without adaptation is an additional pertinent method to show out the benefits of the technologies. A more in-depth CBA will be required to better estimate the real cost and benefit of adaptation of the water sector.

Finally, action plans specific to each technology were proposed to reach the targets of increasing water resources and optimizing water efficient use. These Technology Action Plans (TAP) were designed in a matrix that answers basic questions on the measures or activities to be conducted, their priority and their importance and responsibilities, The matrix included as well the time frame of these activities, the indicators for their monitoring and evaluation, estimated budget and finally the potential donors.

Note that many aspects are common to all technology action plans. In many cases, the same activities are to be conducted by the same actors for different beneficiaries under different technology action plans. Result-based indicators for monitoring and evaluation are proposed in most cases. Donors are common to all action plans as well. For this purpose, mainstreaming of efforts and coordination are highly required to achieve a maximum efficiency and effectiveness of the proposed action plans.

Fig. 65 - The different steps of the barrier analysis for transfer and diffusion of technologies of the water sector.

Source: The author's own design

7.4 Analysis of Technology: Rainwater Harvesting from Greenhouse tops (RWHG)

7.4.1 Description of technology

This technology is designed to collect rainwater from greenhouse tops, store it in earth concrete reservoirs, and use it for irrigating greenhouse crops. The technology is targeted for crops cultivated under greenhouses, and consequently has a defined limited market. RWHG increases the resilience of the crops as it ensures an autonomous reliable water resource of good quality, in periods of extended drought and increased salinity in ground and surface water. RWHG will sustain cropping in greenhouses, in areas where water availability and quality are becoming compromised by climate change in areas with significant precipitations (>600mm/year).

7.4.2. Identification of Barriers for Rainwater Harvesting from Greenhouse tops

The identified causes of the non diffusion of RWHG are diverse, with one killer barrier being the reduced cost-effectiveness of the technology when it is highly affected by limited rainfall or oppositely, the availability of surface water for irrigation at a much lower cost. Other key barriers include:

- Availability of surface water: in many irrigation schemes where water is available for free (mainly from surface water), farmers are not encouraged to invest RWHG (killer barrier).
- Limited rainfall: in areas where precipitations are below 600mm/year (killer barrier).
- Limited awareness: since RWHG is a new technology, both farmers and service providers are not necessarily aware of it.
- Absence of dissemination of the technology: since the few initiatives found are not yet transferred to farmers or promoted by any service provider.
- Limited quantity of harvested water: the farmer is not optimizing the use of limited quantity of water to make the system cost-effective through for example improper irrigation practices and cropping systems.
- Limited research and development: Plant water demand according to the climate variability especially for greenhouse crops and the offer illustrated by rainwater harvesting are not monitored.
- Limited spread of technology in market (service providers): as it is implemented individually by few farmers, service providers are not interested in such technologies.
- Limited available land for water storage: in small holdings in coastal areas where the available land is totally used for exploitation .
- Inappropriate land tenure system: as landowners do not rent land on a long term, farmers are less expected to invest in RWHG.
- High cost of land rental due to absence of land use zoning: farmers are driven to aim at maximum profit due to high cost of land, leaving less available surface on their exploitation for water storage. This is mainly caused to the improper land use zoning that does not valuate lands according to their end-use.

Linkages of barriers and their effects are shown in figure 66.

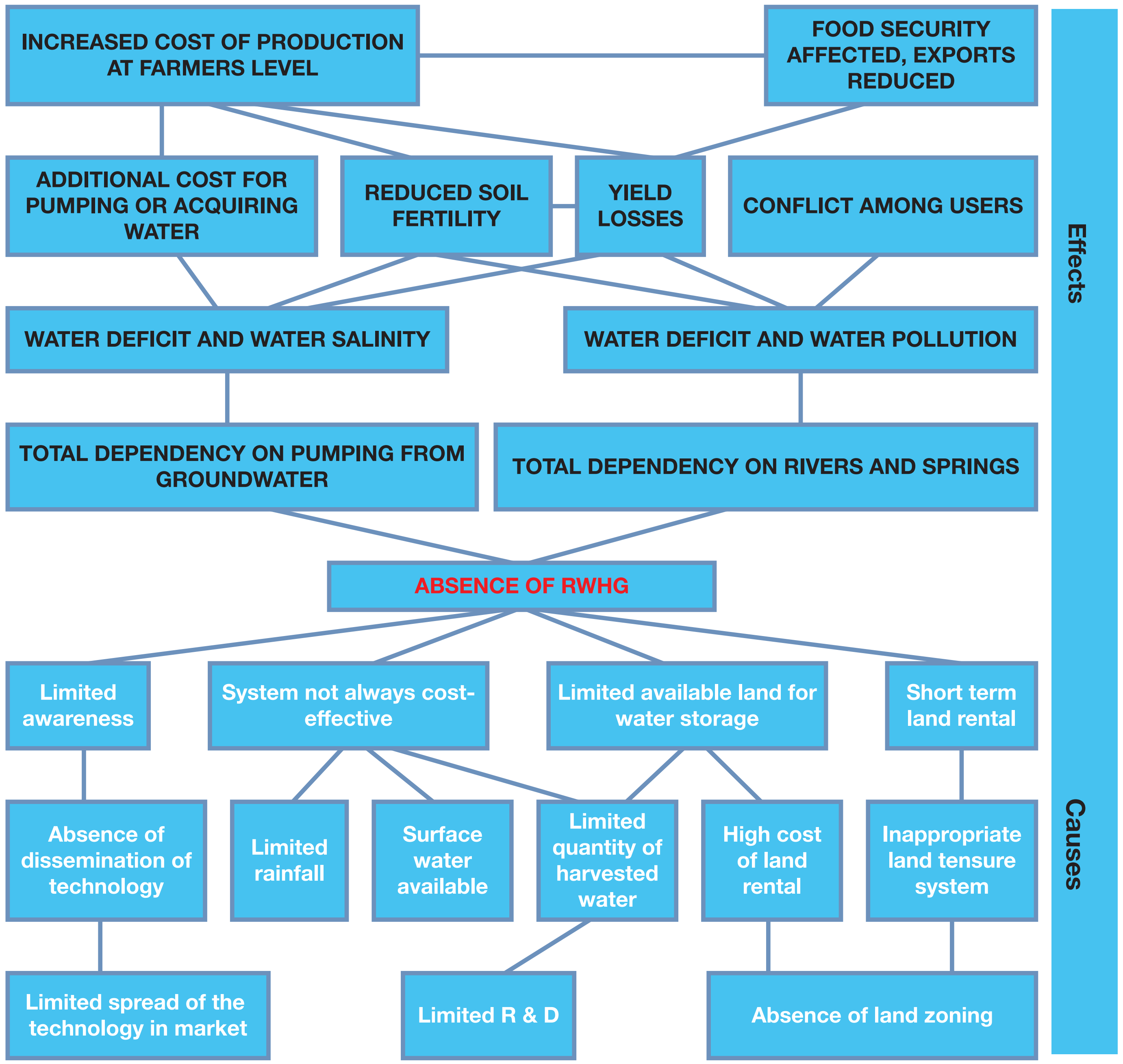


Fig. 66 - Problem tree for RWHG.

Source: Author's own design

7.4.3 Identification of measures for Rainwater Harvesting from Greenhouse tops

Measures to overcome barriers and to enhance the deployment of RWHG are to be conducted on two main axes: i) increase the awareness of farmers and ii) ensure a sustainable agriculture land management. Barriers related to short land rental constitute a more general and historical problem in Lebanon, while barriers related to system cost-effectiveness cannot be changed.

For the first axis, efforts on different levels should be implemented, including service providers' sensitization, and research and development programmes improvement. This will overcome the absence of the technology on the market and ensure scientifically proven information diffusion to farmers.

For the second axis, the initiation of a land use planning zoning to preserve agriculture land will enable overcoming barriers related to land tenure, land availability and short-term rental.

The key barriers and their respective solutions are mentioned in Table 77.

7.4.4 Cost Benefit Analysis for Rainwater Harvesting from Greenhouse tops

The estimated costs mentioned below are extracted from the AgriCAL project (Agrical, 2012) document and meetings with farmers (Sakr, 2012). Costs and assumptions are detailed as follow:

- Awareness raising - information transfer: USD 5,000.
- System Installation could be partially covered by Green Plan and be considered as public expenditure however these are site-specific and demand driven and cannot be accounted for at this stage.

Different scenarios are shown in Fig. 67 and Fig. 68:

- 100% pumping from ground water, in both high crop demand/low precipitation and low crop demand/high precipitation scenarios.
- 75% of Surface irrigation complemented by pumping in high crop demand/low precipitation scenario.
- 43% of Rainwater Harvesting from Greenhouse tops complemented either by surface water or pumping in high crop demand/low precipitation scenario.
- 100% of Rainwater Harvesting from Greenhouse tops in low crop demand/high precipitation scenario.

The deduced benefits are calculated by deducing only the cost of water from the revenue (USD 3,200/ year/greenhouse).

Table 77 – List of barriers and measures to overcome them for RWHG

Category	Barriers	Measures	Stakeholders
Information and awareness	- Limited awareness. - Absence of dissemination.	Awareness campaign.	MoA, Green Plan, farmers, media
Institutional and organizational capacity	-Limited Research and development. - System ineffectiveness. - Limited quantity of harvested water.	Conducting research and development programmes on RWH on farm level, on different storage variances for: i) better cost effectiveness, ii) optimizing stored water use according to climate demand and iii) selecting crops according to storage capacity.	LARI Academic institutions
Market failure	Limited spread of Technology in market.	Integrating RWHG system within greenhouse infrastructures deployed by the service providers.	Service providers
Policy, legal and regulatory	Short term land rental due to inappropriate land tenure system; - Limited available land. - High cost of land rental. - Absence of land use zoning.	Initiating land use zoning process, namely to protect the remaining agriculture areas on the coastal zone, where most greenhouses are located.	MoPWT (DGUP), CDR, Municipalities

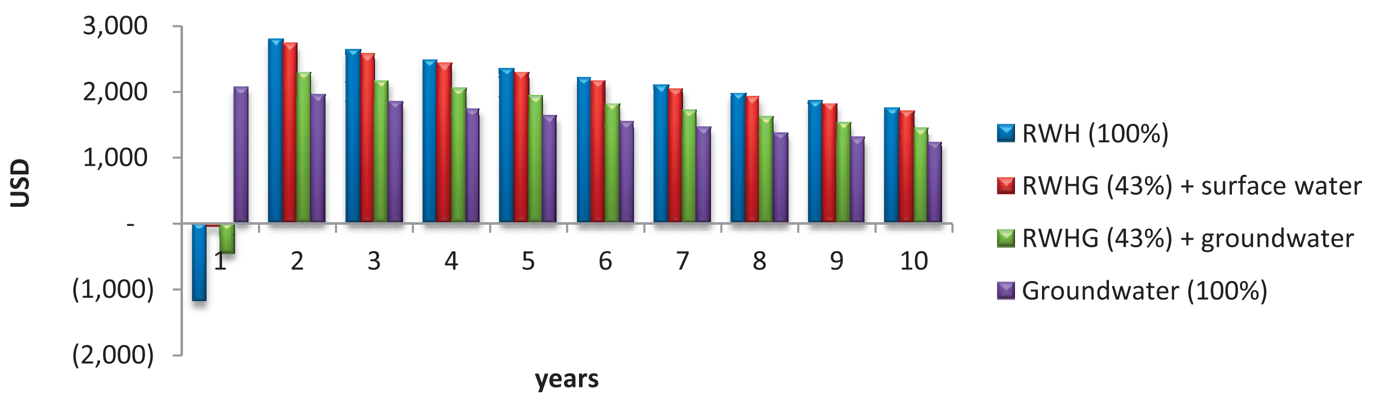


Fig. 67 - Discounted benefits over a period of 10 years for different water source scenarios

Source: Author's own design

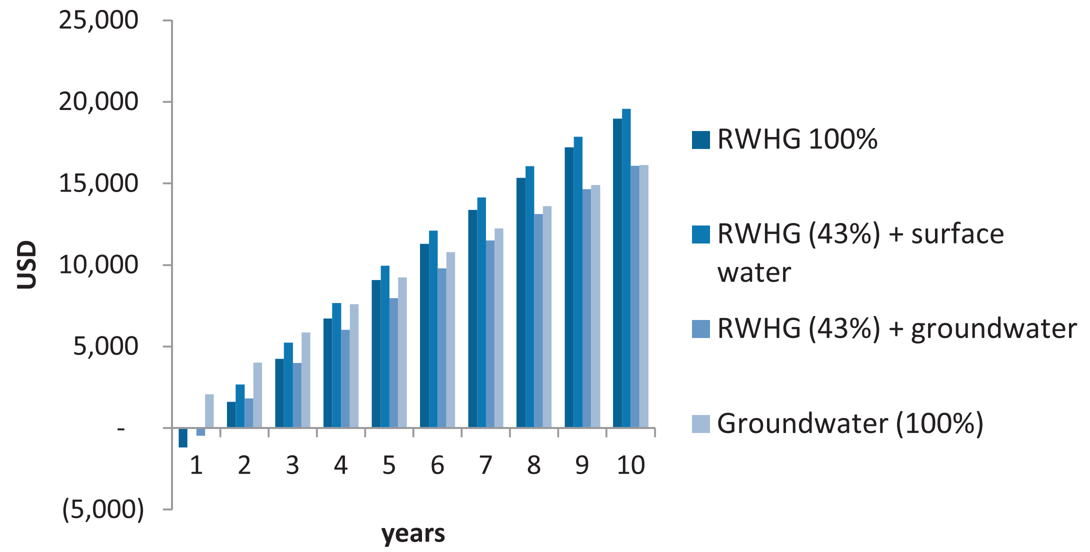


Fig. 68 - Cumulated discounted benefits over a period of 10 years from different water source scenarios

Source: Author's own design

Under all scenarios, RWHG is cost efficient to farmers, except if the farmer has a sustainable source of surface water of a standard quality all year round. Even if RWHG does not cover all the water demand, 43% of the water demand will keep the system cost-effective.

Beside the reduced costs from pumping, GHG emission is significantly diminished and the risk of water pollution and soil degradation is minimized if compared to other water sources. In addition, the farmer is more autonomous in terms of water supply and relies less on other fluctuating resources, which increases his resilience and reduces conflict risks among users. The farmer will preserve his water resources under future climate, which enables him to keep producing, and consequently sustain his revenue and food security.

Costs and benefits of RWHG are drawn in the figure below. From what is mentioned above, RWHG is feasible whenever it ensures a minimum of 50% of plant water requirements. RWHG is not cost-effective in areas where surface water is available for free.

7.4.5 Technology action plan for Rainwater Harvesting from Greenhouses

Target for technology transfer and diffusion

The target of the action plan is to be able to collect rainwater form 25,000 greenhouses (standard single span), between 2015 and 2025 considering that 50% of the total cost is subsidized.

The technology action plan for the diffusion of the Rainwater Harvesting from Greenhouses technology is presented in Table 78.

Assumptions for Rainwater Harvesting from Greenhouse tops

- An annual average rainfall of 600mm are necessary to cover from RWHG, water demand for the crops inside a greenhouse.
- A storage unit can be used for irrigation before being totally filled, which supposes that a storage unit could be filled twice a year.
- The annual demand of a standard greenhouse of 400m^2 is between 360 and 550m^3 depending on the crop type and microclimatic conditions.
- The collected water from a standard greenhouse is 240m^3 for an area with average precipitations of 600mm/year, up to 400m^3 in areas having 1,000mm/year of rainfall.
- The storage unit of a greenhouse should have a minimal capacity of 125m^3 (half of the annual water demand) in exploitations with limited land available.
- Cost of storage unit is USD 16/m^3 in earth reservoirs. The economy of scale is not accounted.
- Cost of drainage system (USD 30/m) or USD 1,200/greenhouse. This can be reduced by half in "Chappelle" system. To add USD 180/greenhouse for service providers' technical assistance.
- Current maximal cost of land rental (value of area dedicated for earth reservoir): USD 1/m^2/year. The economy of scale is not accounted.
- Pumping cost is USD 1.833/m^3 at 500m altitude, on a deep water Table.
- In this exercise we consider that the price is the same even next to sea level where water Table is shallow, in order to value the poor quality of water (salinity).
- Surface water annual fees in a common irrigation scheme are USD 100/year. We assume that this water is rarely available all year round due to several reasons (water shortage, leakage problems, water pollution, etc.).
- A greenhouse produces 4 tonnes of crops, sold at USD 800/tonnes, generating a revenue of USD 3,200/ha/year.

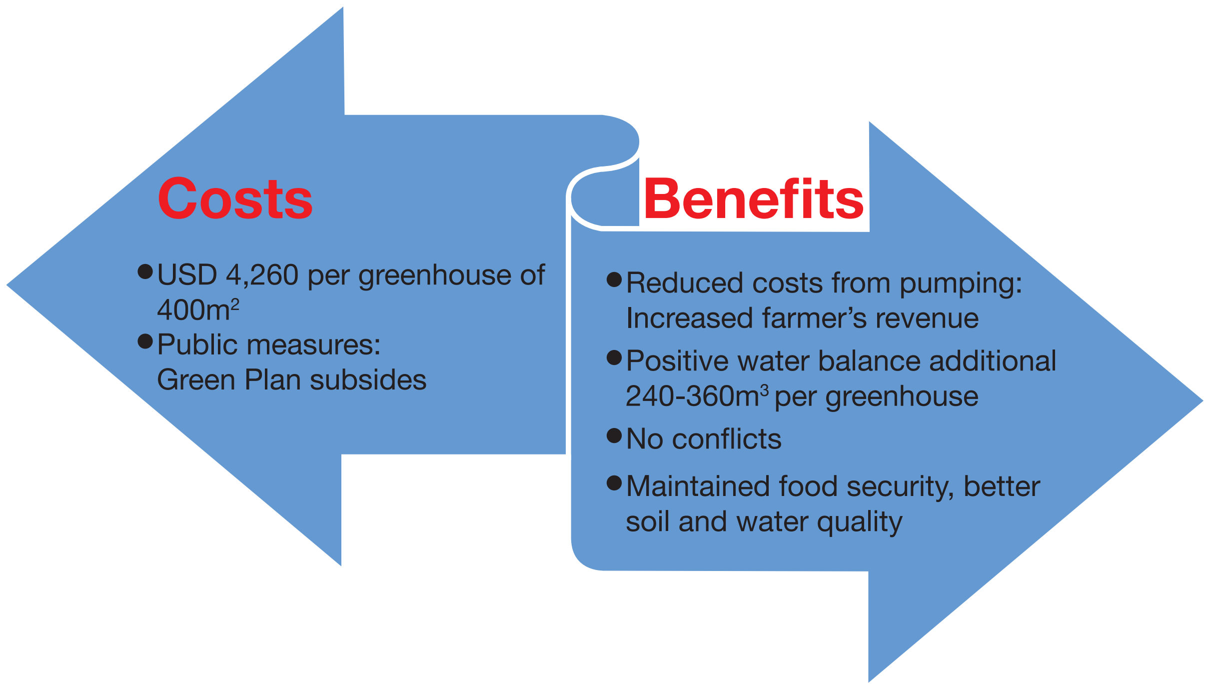


Fig. 69 - Cost and Benefits of RWHG

Source: Author's own design

Table 78 - Technology Action plan for Rainwater Harvesting from Greenhouses

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring and Evaluation indicators	Estimated cost (USD)	Donors
Organizing awareness campaign through seminars, field visits and TV programmes	1	To disseminate the information and promote RWHG to farmers.	National experts, MoA extension service, media, Green plan	Service providers technicians, farmers	Medium term	Number of farmers demands at Green Plan for installing RWHG system.	5,000 for 3 seminars, 3 field visits and a TV program.	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation.
Conducting experiments on farm level, on different storage variances	2	To increase information about the optimal use of RWHG for better resilience to climate, better water efficiency and optimal cost effectiveness.	Research centers and academic institutions	Farmers	Medium term	Number of experiments conducted and number of publications; Increase in the number of greenhouses adopting RWHG according to the crop; calculation of water efficiency for different crops in greenhouses adopting RWHG.	15,000 to conduct research at farm level: a one-year full study for 3 type of crops in two climatic zones (two researchers plus inter students).	
Integrating drainage system in the design of greenhouse	2	To avoid market failure and reduce the cost of the infrastructure.	Service providers	Farmers	Short term	Number of greenhouses produced with drainage system by service providers.	0	
Initiating land use zoning process	1	To protect the remaining agriculture areas on the coastal zone, where most greenhouses are located.	DGUP	Farmers, municipalities	Long term	Number of municipalities having land use zoning agriculture surface preserved on coastal areas.	0	
Increasing Green Plan budget for implementing water reservoirs for RWHG	2	To avoid budget constraints at farmers level to implement RWHG.	Government, Green Plan	Green Plan, farmers	Medium term	Funds allocated for water reservoirs for RWHG; number and their capacity of achieved reservoirs.	2,000,000 annually covering 50% of the cost of reservoirs with a capacity of 500,000 m^3.	

7.5 Analysis of Technology: Rainwater Harvesting from Roads (RWHR)

7.5.1 Description of technology

Rainwater harvesting from all type of roads, in agriculture area, enables collecting water from surface runoff on the roads, and the upstream. Water is carried through the drainage system to a decantation earth lake then stored in another lake. Water is further pumped and distributed to the farmers/fields surrounding the road. Targeted roads are both asphalted or agriculture roads, which consequently involves a larger number of stakeholders. These include different public institutions, including the Ministry of Public Works (with its main directorates for public works and urban planning), the Ministry of Agriculture, the Ministry of Interior and Municipalities, the Ministry of Finance, the CDR and the Green Plan. Landowners of contingent lots to the road as well as farmers are also concerned.

This technology is usually being promoted to increase the resilience of the local agriculture communities to climate change. The harvested water could be allocated for either agriculture or domestic use, as well as for recharging the aquifers. In this chapter, water is only considered for agriculture use. This technology has a potential to increase crop adaptation to climate change by ensuring additional water resource for irrigation, in areas with significant precipitations or surface run-off.

7.5.2 Identification of Barriers for Rainwater Harvesting from Roads

Several barriers hinder the deployment of RWHR, however they all have a major root cause related to the absence of institutional and financial arrangements to ensure the necessary budget, to inform the local authorities about the importance of RWHR, improve public works quality, undertake adequate urban planning and road design and ensure the necessary land for water storage. The list of key barriers identified for RWHR is as follow:

- Limited awareness: farmers and technicians are not aware of the potential benefits of RWHR.
- Inappropriate road design: roads are not designed to enable water catchment through drainage system.
- Additional cost for infrastructure: collecting, converging and storing water requires additional cost.
- Drainage not accounted in public works: most roads have no drainage system.
- Topography constraints: many roads are designed and constructed in areas where water harvesting is limited due to the topography of the terrain.
- High cost of land acquisition: acquiring land for water storage in urban and peri-urban areas is almost impossible due to the high cost of land.
- Presence of roads in private lands: most agriculture roads or urban roads are totally private which requires the permitting of the owners to undertake the necessary works.
- Limited information on drainage impacts at authorities' level: most municipalities are not aware of the cost of floods and transport deficiency due to the absence of rainwater drainage system.
- Restricted professional Contractors: most contractors for minor scale public works are not backed up by professional engineers to follow works onsite.
- Inappropriate urban planning or land use management: most roads do not have water catchment or enough space to implement RWHR.
- Scarcity of funds: funds for adapting road design to RWHR are not allocated.
- Insufficiency in financial and institutional arrangements: RWHR is not accounted in the tender dossiers and budget allocated for road construction.

Linkages between barriers are illustrated in the figure below:

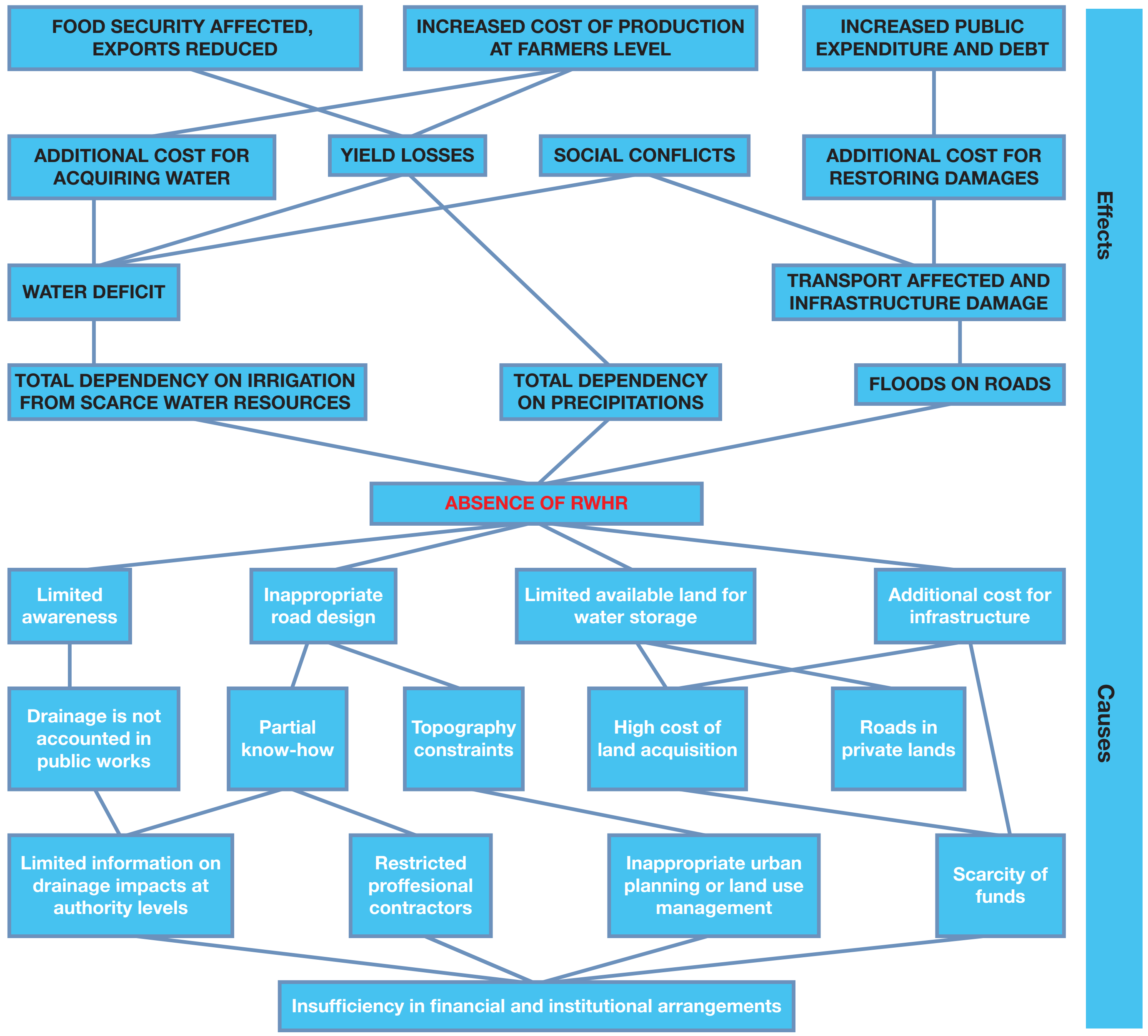


Fig. 70 - Problem tree of RWHR.

Source: Author's own design

7.5.3 Identification of measures for Rainwater Harvesting from Roads

A first initiative for rainwater harvesting from roads is currently being undertaken by EFL with the municipality of Bchaaleh in North Lebanon to install a drainage system and decantation and storage units in the area and to sell water to the community at a competitive price. This initiative has served in this analysis for the collection of concrete information on barriers and cost analysis.

On a communal scale, barriers are minimal when rainwater is harvested from municipal and public roads, the topography usually enables optimizing water harvesting and installing the system, and land is available for digging and establishing the decantation and storage units. Water distribution, system maintenance and economical sustainability are usually covered by the municipality.

If the selected road is private, and shared with many owners, barriers to overcome are related mostly to land availability and the willingness of the owners and users to participate. Funds are lacking and difficult to access. Therefore, institutional arrangements for the entities responsible on the execution of such works (i.e. MoPWT, CDR, Green

Plan) enabling designing roads for RWHR and allocating the necessary funds is a major step to overcome barriers to transfer and diffusion. An example of creating an enabling environment is the Green Plan which creates agriculture roads on a demand-driven basis. This approach overcomes barriers related to land availability and land use, as well as conflicts among land owners.

The list of barriers and their respective measures are listed in Table 79.

7.5.4 Cost benefit analysis for Rainwater Harvesting from Roads

The expected public expenditure mentioned below is extracted from the AgriCAL project document (Agrical, 2012) and based on bilateral meetings with Green Plan technicians and EFL (EFL, 2012; Greenplan, 2012):

- Institutional arrangements: USD 5,000.
- Implementing regulations for road design and norms: USD 10,000.
- Installation of financial mechanism: USD 5,000.

Table 79 – List of barriers and measures to overcome them for RWHR

Category	Barriers	Measures	Stakeholders
Human skills	Partial know-how; Restricted professional contractors.	Training of technicians of concerned actors; Enhancement of a sound control of works.	Green Plan, MoPWT, Municipalities
Information and awareness	Limited awareness; Limited information on drainage impacts at authorities' level.	Awareness campaign at Municipalities level about RWHR, and land use and urban planning.	Municipalities, DGUP
Institutional and organizational capacity	Drainage is not accounted in public works.	Road designs elaborated by concerned Ministries, Green Plan and Municipalities taking drainage system into account.	Green Plan, MoPWT, MoIM
Technical	Topographic constraints.	Elaborating proper urban planning and road designs.	Municipalities, DGUP, MoPWT
Economic and financial	Additional cost for infrastructure; High cost of land acquisition (private land); Scarcity of funds.	Budget allocated for Green Plan, MoPWT and Municipalities to implement RWHR.	Municipalities, Green Plan, CDR, MoIM, MoF, MoPWT
Policy, legal and regulatory	Inappropriate road design; Limited available land for water storage Inappropriate urban planning or land use management; Insufficient financial and institutional arrangements.	Conduct the necessary arrangements for budget allocation and the elaboration of regulations and norms for roads and RWHR; Implement a process of land use planning in concerned areas.	MoF, MoIM, Green Plan, DGUP, MoPWT

Based on these assumptions, RWHR is viable within a period of 14 years as illustrated in Table 80. Benefits are expressed in terms of horticulture crops sold in the additional irrigated area from RWHR. An increase in higher surface run-off or higher precipitation will increase the cost-effectiveness of RWHR.

Assumptions for RWHR

- Road slope > 5%
- Road length: 1,000m
- Road width: 6m
- Rainfall: 0.8m/year
- Additional water coming from upstream >50%
- Losses in infiltration : 20%
- Losses in evaporation during storage: 15%
- Water available for irrigation: 4,900m^3
- The expected costs per road are:
  - Road design for RWH (drainage system): USD 1,025/m
  - Decantation unit including sieves, filters and pumtps: USD 2,500
  - Digging earth for storage: USD 8/m^3
  - Vehicle for water distribution: USD 40,000
  - Annual maintenance of system: USD 250
  - Annual cost for water distribution: USD 150
- The stored amount will produce 20t of agriculture products, with an average value of USD 800/t

Table 80 - Cost benefit analysis for RWHR over a period of 14 years for a 1km road serving

	Revenues without RWHR	Revenues under RWHR	Additional revenue under RWHR	Additional costs from RWHR	Net benefits from RWHR	Discounted net adaptation benefits (6%)
	A	B	C=B-A	D	E=C-D	F=E/(1+0.06)^{yr}
Year	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha	USD/ha
1	0	16,000	16,000	-137,480	-121,480	- 114,604
2	0	16,000	16,000	400	15,600	13,884
3	0	16,000	16,000	400	15,600	13,098
4	0	16,000	16,000	400	15,600	12,357
5	0	16,000	16,000	400	15,600	11,657
6	0	16,000	16,000	400	15,600	10,997
7	0	16,000	16,000	400	15,600	10,375
8	0	16,000	16,000	400	15,600	9,788
9	0	16,000	16,000	400	15,600	9,234
10	0	16,000	16,000	400	15,600	8,711
11	0	16,000	16,000	400	15,600	8,218
12	0	16,000	16,000	400	15,600	7,753
13	0	16,000	16,000	400	15,600	7,314
14	0	16,000	16,000	400	15,600	6,900
Benefits					81,320	
NPV						15,681

7.5.5 Technology Action Plan for Rainwater Harvesting from Roads

Target for technology transfer and diffusion

Since the establishment of agriculture roads and water harvesting equipments are demand driven under the Green Plan's policy, the target for the below action plan (Table 81) is to achieve RWHR over 50km of roads between 2015 and 2025. Beneficiaries will be farmers having their exploitations along these roads. The estimated cost is USD 70,000 per 1Km of roads, or 3.5 million USD to achieve a target of 50km over a 10-year period.

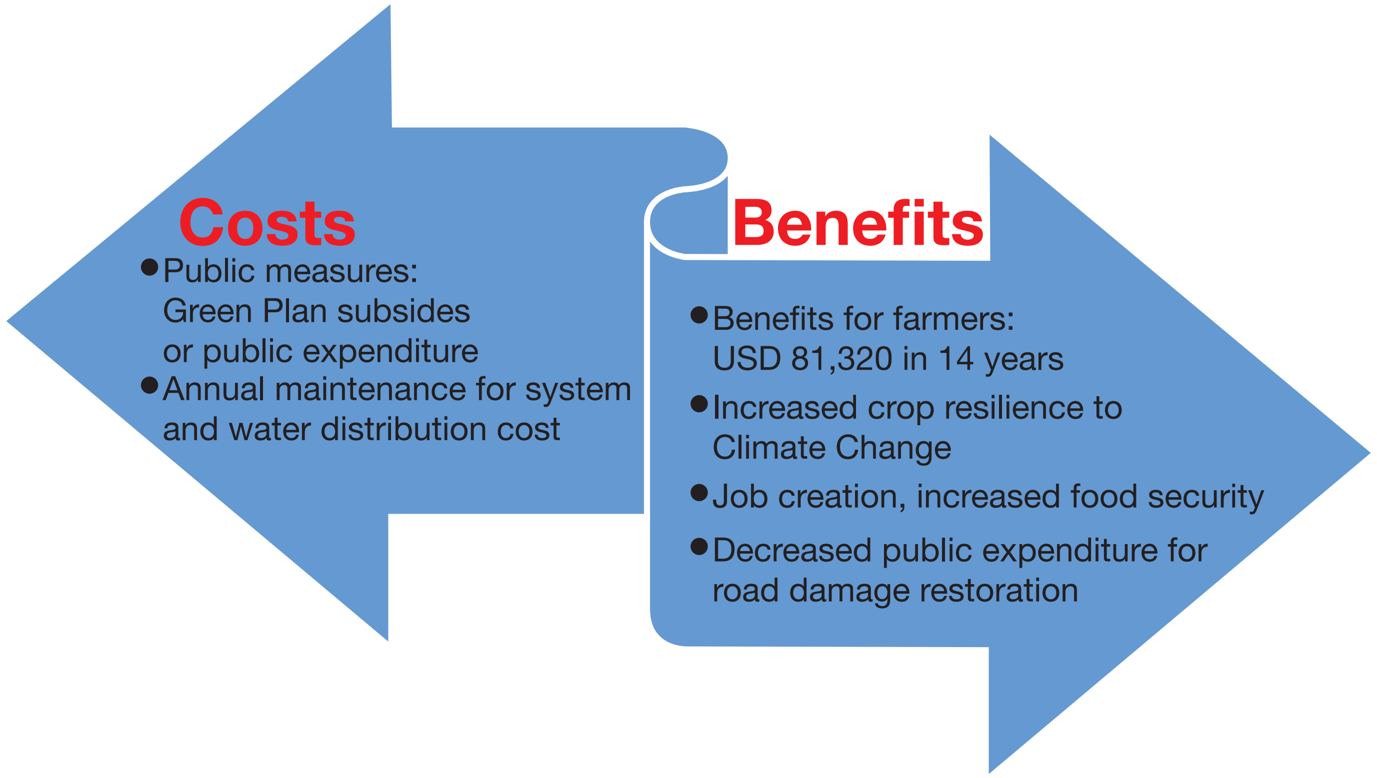


Fig. 71 - Cost and benefits of transfer and diffusion of RWHR

Source: Author's own design

Table 81 - Technology Action plan for Rainwater Harvesting from Roads

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Training of technicians at the order of engineers	1	To be able to adapt road design for RWHR.	National experts	Green Plan; CDR; MoPWT; DGUP; Orders of engineers	Short term	Number of trained technicians able to create new road designs.	2,000 to train 10 technicians	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Elaboration of adapted tender documents control construction works	3	To be able to control public works according to set standards and design.	CDR, MoPWT, Green Plan, Municipalities	Public, farmers, municipalities, Government	Medium term	Number of roads according to preset design.	0	
Awareness raising through Seminars, bi-lateral meetings, TV program	1	To better understand the impact of rainwater and flood risk, drainage, and the importance of RWHR and to avoid market failure and enhance RWHR from existing and planned roads.	Trained technicians, media	CDR; Municipalities; MoPWT; DGUP; public work contractors	Long term	Number of demands for roads with infrastructure for RWH and drainage in municipalities, and demands for urban planning and zoning.	3,000 for 3 seminars and a TV program	

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Elaborating terms of references with technical specifications for new road designs.	2	To set standards for road design, in order to enable RWHR and reduce floods in urban areas.	CDR; MoPWT; Green Plan and Municipalities	Public, farmers, municipalities, Government	Medium term	Tender dossier and technical specifications elaborated.	0	
Conducting arrangements for budget allocation and creation of a financial mechanism	2	To ensure the extra funds for achieving the required infrastructure and land acquisition for water storage and to maintain the system.	Government, MoF, MoIM, CDR; national financial expert	MoPWT, Municipalities, Green Plan	Long term	Budget allocation for RWHR within the annual budget of the beneficiaries.	5,000 for the charges of the financial expert	
Re-considering urban planning and land zoning upon request of municipalities	3	To overcome the limited availability of land for water storage and ensure the sustainability of agriculture land benefiting from RWHR.	DGUP	Municipalities, farmers	Long term	Number of municipalities having land use zoning and urban plans.	0	

7.6 Analysis of Technology: Water Users Association (WUA)

7.6.1 Brief description of the technology

A Water User Association is an organization for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material, and human resources for operation and maintenance of a local water system, such as a river or water basin. The association plays a key role in integrated approaches to water management that seek to establish a decentralized, participatory, multi-sectorial and multi-disciplinary governance structure.

The objectives of a WUA commonly include: i) Conservation of water catchments, ii) Sustainable water resource management, iii) Increase availability of water resources and, iv) Increase the usage of the water for economic and social improvements. Its core activity is to operate the waterworks under its responsibility and to monitor the allocation of water among its members. WUA is hence different from the traditional "water committee" that used to manage spontaneously without any institutional or scientific support water distribution in common water sources in villages, and that was prohibited recently by law.

7.6.2 Identification of Barriers for Water Users Association

The key barriers, as illustrated in the problem tree illustrated in Fig. 72, are as follow:

- Difficulties in managing a common water resource: Farmers individualism and the difficult distribution of roles, costs and water amount among users are the main barriers which is behind the failure of the resolved local water committees in some watersheds in Lebanon.
- Limited social acceptance for water pricing: legal pricing is difficult to adopt due to religious tradition imposing water as a free resource for all. The current symbolic water usage fees are not enough for water monitoring, covering the fees of maintenance of the distribution system and monitoring of water flow amongst users.
- Insufficiency in water laws: such as "Water Act" setting the basis of modern WUA, knowing that Law 221 merged all local water committees under regional committees. One law in 1943 enabled the creation of a "water syndicate" however this law became obsolete with time.
- Limited awareness at social (water users) and decision maker's level: the social perception is incrusted into the old "water committees" and stakeholders are not aware of WUA existence.
- Inherited sharing rights: the "water turn" and share is based on inherited number of hours per week or month, which does not enable irrigation on a daily basis or based on climatic demand.
- Scarce human skills to manage WUA: where the required skilled human resources are limited
- Unsuitable university curricula: the lack of knowledgeable engineers capable of running a WUA is due to the absence of appropriate university curricula for water management
- Absence of institutional support: No clearly defined institutional body organizes WUAs and supervises their work.
- Limited institutional and financial arrangements: for funding irrigation distribution schemes and for implementing a university curriculum on WUA, as well as making the necessary law amendments enabling the creation of WUA.
- Limited enabling structure for water monitoring: water distribution system, pressurized with counters is essential for water flow and distribution monitoring.
- Deficit funds: to establish water distribution networks and monitoring system.
- Low revenues: farmers with their modest income are not able to fund the installation of water distribution networks or to cover upgrade and maintain the existing network.

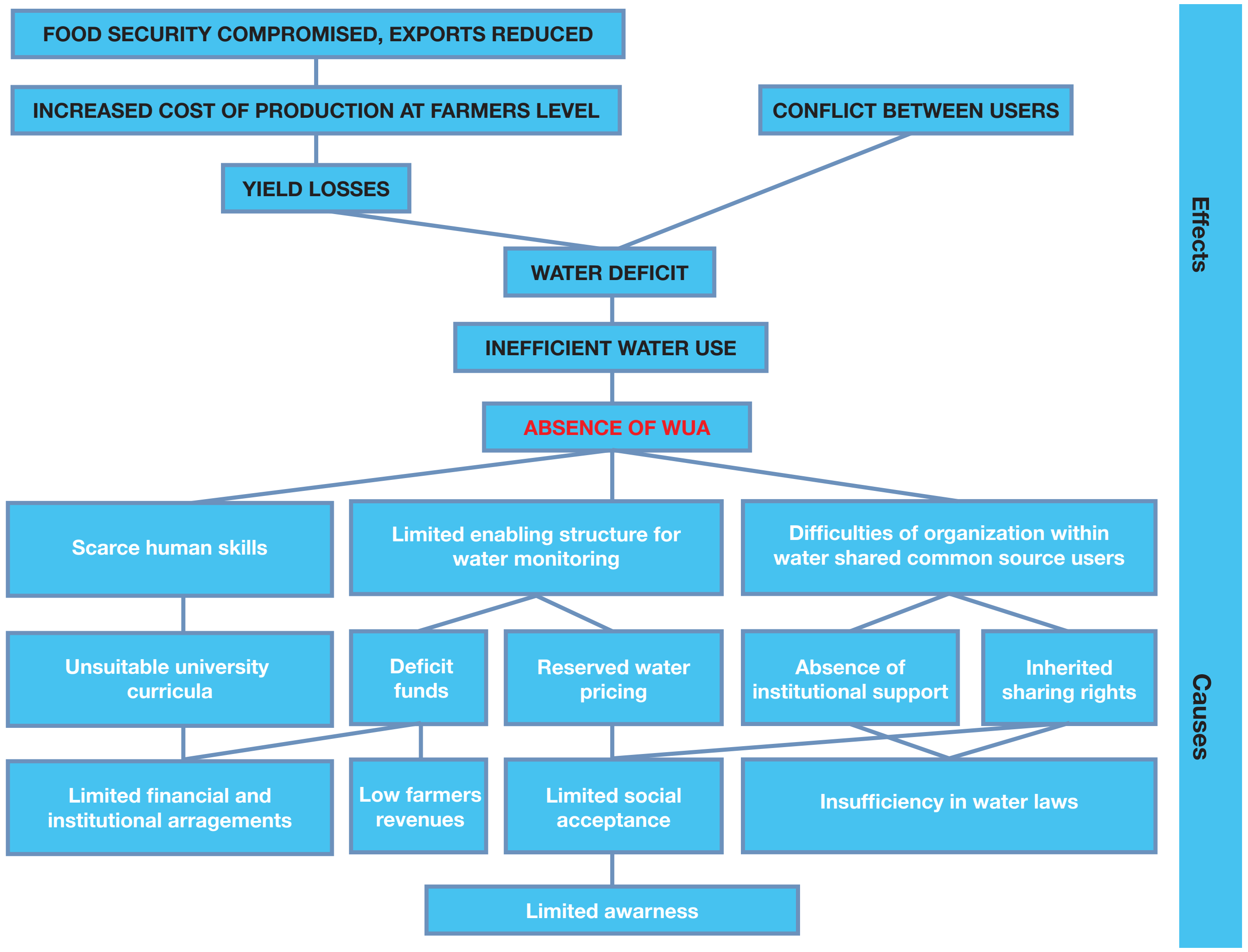


Fig. 72 – Problem tree of WUA

Source: Author's own design

7.6.3 Identification of measures for Water Users Associations

As Water User Association has several barriers, the measures to overcome these barriers should be performed through a mainstreaming process to boost the transfer and diffusion of WUA.

These measures include activities on the social and behavior aspects of the local communities, in regard to enhancing communal thinking, understand the impact of climate change and the positive aspects of WUA, improve social acceptance towards water pricing and institutional and organizational arrangements related to inherited share rights in collective water springs. For this purpose, Media, LRA, MoEW, MoA and NGOs are all involved and should synchronize their activities for better efficiency.

A particular attention should be given to capacity building of technicians and human skills, starting from an adequate curriculum at university level to specialize engineers in water and WUA management.

Finally, all efforts should be backed up by a legislative framework capable of initiating an institutional support for WUA, a water law and the necessary institutional and financial arrangements for WUA creation and establishment of the infrastructure for water distribution.

These barriers and the measures to overcome them are illustrated in Table 82.

Table 82 – List of barriers and measures to overcome them for WUA

Category	Barriers	Measures	Stakeholders
Human skills	Scarce human skills to run WUA.	Introducing the WUA management skills and concept within the curricula of agriculture/natural resources management faculties.	Academic institutions
Information and awareness	Limited awareness at social (water users) and decision maker's level.	Awareness campaign about the importance of WUA in relation to water management as an alternative to water committees.	Media, MoEW, LRA, MoA, Municipalities
Social, cultural and behavioral	Limited social acceptance for water pricing or to change inherited sharing rights, absence of communal thinking; lack of trust among users.	Awareness raising at social level, to show the importance of WUA, and the positive impact of changes related to water pricing and inherited sharing rights.	Media, water share owners and users
Institutional and organizational capacity	Lack of organization among users sharing a common water resource.	- Promoting communication among actors. - Capacity building/lobbying at all levels to boost arrangements enabling the installation of WUA, and enabling good governance for water resources.	Media, MoEW, LRA, MoA, Municipalities, farmers (water users)
Policy, legal and regulatory	Insufficiency in water laws; Absence of institutional support; Unsuitable university curricula.	Reviewing actual laws, do the necessary amendments, and elaborate the legislative framework for WUA. - Assigning a legal body to enable institutional support. - Introducing WUA concept in university curricula.	MoJ, MoEW, LRA
Economic and financial	- Reserved water pricing. - Limited financial arrangements for infrastructure and university curricula. - Low revenues of users. - Deficit funds.	Elaborating a cost-effective financial mean that could be an alternative to water pricing for implementing the necessary water distribution infrastructure.	MoF, MoEW, LRA

Assumptions for WUA

- Target area to reach in irrigation schemes under WUA: 5000ha
- There is no change in the cost of production assuming that the contribution fees of the farmer are covered by the spared cost of labor for irrigation, weed control…
- Farmers will use efficient irrigation systems on farm, that they will install on their own
- Estimated yield improvement: 4.5t/ha for irrigated horticulture crops and fruit orchards
- Estimated crop price: USD 800/t
- Water used for surface irrigation without WUA: 8,000m^3/ha, while under WUA, there are at least 2,000m^3/ha of saved water.
- Water sources are expected to be 10% less by 2040 and plant needs higher by 5%
- Plant water demand (6,000m^3/ha) is estimated to increase by 5% by 2040

7.6.4 Cost benefit analysis for Water Users Association

Meeting with relevant stakeholders (CDR, 2012; MoA, 2012; and LRA, 2012) enabled the estimation the costs of these measures as follow:

- Awareness at community level: USD 50,000.
- Lobbying, information diffusion at decision makers' level: USD 20,000.
- Review of laws, law amendments and elaboration of "water act": USD 50,000.
- Introducing the WUA and water management concept within university curricula: USD 10,000.
- Elaborating a study for alternative funding mechanism: USD 10,000.

Establishing the water distribution infrastructure (outside farm gate): USD 180/ha for a target area of 5,000ha of irrigated schemes: USD 900,000

Hence the total cost for deploying WUA is USD 1,040,000.

Following the assumptions mentioned above, water availability under the current conditions and by 2040, with or without WUA is expressed in Table 83.

The benefits will be:

- Reduced water losses from 50% to less than 10% with water savings and additional resources available even by 2040 (currently 1 million m^3 and 450,000 m^3 by 2040).
- Improved yields by 15% from water monitoring according to climate demand.
- Enabled use of efficient irrigation system (drip): water efficient use up to 90% on farm level, labor reduced, less energy and labor for weed control, etc. (This will not be accounted in CBA, as we assume the farmer will invest in drip system, and get the benefits of it, independently from the measures).
- Increased revenues by USD 4,000,000/year for 5,000ha with WUA.

Table 83 – Water balance in m^3 with or without WUA under current and future scenario

		Available water (m^3)	Water used for irrigation (m^3)	Plant need (m^3)	Water losses (m^3)	Water balance (m^3)
2012	Without WUA	40,000,000	40,000,000	30,000,000	-10,000,000	0
	With WUA	40,000,000	30,000,000	30,000,000	0	10,000,000
2040	Without WUA	36,000,000	36,000,000	31,500,000	-4,500,000	0
	With WUA	36,000,000	31,500,000	31,500,000	0	4,500,000

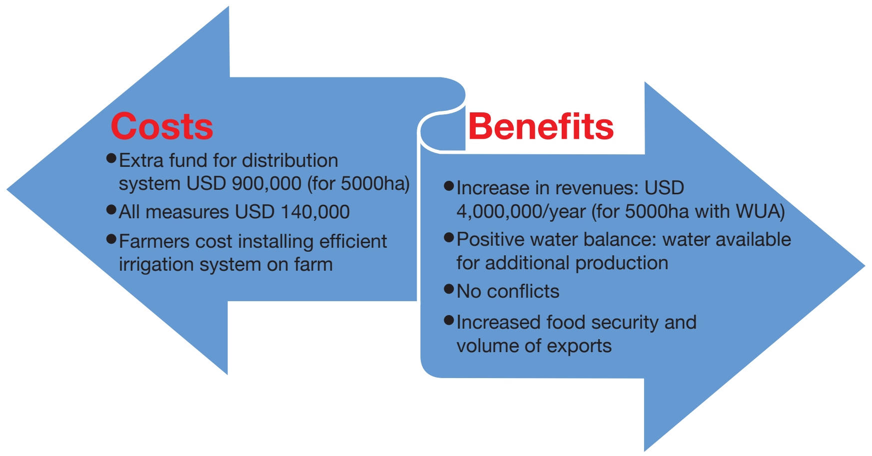


Fig. 73 – Costs and benefits of WUA

Source: Author's own design

7.6.5 Technology Action Plan for Water Users' Association

Target for technology transfer and diffusion

The overall target is to apply the concept of WUA in irrigation schemes totaling 5,000ha between 2015 and 2025. The estimated budget for the deployment of WUA and its diffusion is USD 1.04 million, out of which USD 900,000 are for water distribution and monitoring infrastructure. The technology Action plan for water users association is presented in Table 84.

7.7 Linkages of identified barriers

The lack of awareness at different levels of the ladder of responsibilities is the most common barrier for the three technologies, along with the abscence of land use planning and zoning and the high cost of land, as land rental for a long term period is difficult under the current land tenure system. Budgetary requirements for the necessary infrastructure for water storage or distribution are also a common aspect between RWHR and WUA. This offers the opportunity of tackling barriers like water pricing and water laws deficiency. The major actors concerned in overcoming these barriers are: the Ministry of Energy and Water, the Ministry of Agriculture, the Ministry of Justice, the Ministry of Public Works and Transport (namely the Directorate of Urban Planning), the Ministry of Finance, the CDR, the Green Plan and the Litani River Authority.

7.8 Enabling Framework for overcoming the barriers in the water sector

The prioritized water technologies have different aspects. RWHR which is a public good requires the ownership of the relevant responsible implementing bodies. In the scope of this report, RWHR is addressed with the Green Plan. This institution which implements agriculture roads based on farmers' demand is fully supportive to adopt the technology, and ensure partial funding for RWHG (for water storage units). Nevertheless, Green Plan capacity to absorb additional projects is limited due to its limited capacity to conduct large projects. Internationally assisted projects as well as the capacity building of the institution are necessary.

RWHG which has a simple market chain reduced to the farmers and service providers could be enhanced by the promotion of the technology as a whole package with the installation of greenhouse and irrigation infrastructures.

WUA is an organizational technology involving different public institutions including MoEP, LRA, CDR and MoA that are acting at different levels (water collection and distribution, water monitoring and water use). A principle milestone is related to the definitions of roles and responsibilities of all actors, through appropriate legislative framework, enabling the creation of WUAs. Further, a participatory top-down approach to ensure social acceptance is a must in order to resolve difficulties related to users organization, water pricing and inherited water sharing rights.

Table 84 - The technology Action plan for Water users Associations

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Introducing the WUA concept within university curricula after approval by Ministry of Education	2	To ensure qualified technicians in WUA and related fields.	International expert MoEducation	Agriculture and natural resources management faculties (LU, AUB, USJ, USEK); students	Long term	Number of students attending courses related to WUA, water management and related fields	10,000 for the charges of the expert	World Bank Adaptation Fund GEF IFAD FAO Islamic Bank EU USAID Kuwaiti Fund Italian, Spanish Cooperation
Awareness campaign through the organization of workshops and TV programmes	1	To increase awareness and information about WUA as an alternative to water committees; to show the importance of WUA and the positive impact of changes related to water pricing and inherited sharing rights and gain social acceptance.	National and international experts, LRA, FAO, NGOs	MoEW, MoJ, MoA, CDR, MoIM, municipalities, farmers (water share owners and users)	Medium to long term	Number of meetings and attendance of concerned parties to workshops; Number of demands for the creation of WUA by water users	50,000 for the charges of experts, 3 workshops for technicians and decision makers, 10 seminars for water users	
Capacity building of farmers and and lobbying at all levels	3	To establish a coordination mechanism leading to the installation of WUA and familiarize all stakeholders with team work and communication.	National and international experts, LRA, FAO, UNDP	MoEW, MoJ, MoA, CDR, MoIM, municipalities, farmers (water share owners and users)	Short to medium term	Number of meetings and attendance of concerned parties; Project law proposal enabling the creation of WUA; Number of effective WUA	20,000 for the charges of experts, 3 workshops and 5 bilateral meetings	

Measures	Priority	Objective	Responsible parties	Beneficiaries	Time scale	Monitoring & Evaluation indicators	Estimated cost (USD)	Donors
Proposing a law for WUA and lobbying for adoption by council of ministers	2	To enable institutional support.	National and international experts MoJ, MoEW, MoA, LRA Parliament	Farmers (water share owners and users)	Medium to long term	Law amendments enabling the creation of WUA: Executive decrees and terms of references the responsible organism for institutional support; regulation of shares of common water sources	50,000 for the charges of the experts and the cost of workshops	
Preparation of feasibility study and financial mechanism for WUA	3	To find an alternative to water pricing for implementing (and maintain) the necessary water distribution infrastructure.	National and international experts, LRA, FAO, UNDP, MoF	Created WUA (water users), MoEW, CDR	Long term	Feasibility study report; budget allocated for the creation of water distribution infrastructure; annual financial report of WUAs	10,000 for the charges of the experts	
Establishing the water distribution infrastructure	2	To enable water distribution, monitoring and water efficient use (outside farm gate).	MoF, CDR, MoEW, LRA	Created WUA (water users)	Long term	Length and capacity of created water distribution infrastructure; area covered under effective WUA	900,000 for a target area of 5,000 ha	

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Annexes

Annex I - List of stakeholders

Name	Affiliation	Consultation Approach
Alaa Moussa	Schneider	Workshops
Amal Deghaili	Greenplan	Workshops
Amid Sahyoun	BUTEC	Workshops
Angela Akl	GIZ/EFL	Workshops
Boghos Ghougassian	MECTAT	Workshops and interviews
Chafic Abi Said	Energy Expert	Meeting
Chafic Estephan	LARI	Workshops
Charbel Rizk	MoA	Workshops and interview
Charbel Zeidan	EFL-CDR	Workshops
Dietmar Ueberbacher	Italian Cooperation	Workshops
Dr. Carla Khater	CNRS	Workshops
Dr. Charbel Afif	USJ-FS	Workshops
Dr. Elia Choueiri	LARI	Workshops and interviews
Dr. Hassan Harajli	CEDRO	Workshops and interviews
Dr. Hassan Jaber	ALMEE	Workshops and meeting
Dr. Hassan Machlab	ICARDA	Workshops
Dr. Ihab Jomaa	LARI	Workshops and interviews
Dr. Imad Suleiman	ESCWA	Workshops
Dr. Issam bashour	AUB	Workshops and meeting
Dr. Leila Dagher	AUB	Interview
Dr. Michel Afram	LARI	Workshops and interviews
Dr. Nadim Farjallah	AUB	Workshops
Dr. Raymond Ghajjar	LAU/MoEW	Workshops and interviews
Dr. Riad Chedid	AUB/MoEW	Workshops and interviews
Dr. Salah Kandil	ESCWA/SDPD	Workshops and interviews
Dr. Talal Darwich	CNRS	Workshops

Name	Affiliation	Consultation Approach
Dr. Tamam Nakkash	Team international	Workshops and interviews
Dr. Bothayna Rashed	ESCWA	Workshops
Farah Charafeddine	Energy Expert	Interview
Farah Choucair	MoF	Workshops
Faten Adada	CDR	Workshops and interviews
George Abboud	Green Party	Workshops
Georges Akl	MoE	Workshops
Habib Maalouf	Al-Safir newspaper /Leb. Environment Party	Workshops and interview
Hassan Jaafar	MoEW	Workshops
Hicham Kotob	EDL	Workshops
Hisham Malaeb	MoPWT	Workshops and interviews
Hussam Hawwa	IRG	Workshops and interviews
Jad Abou Arrage	ARC-EN-CIEL	Workshops and interviews
Jawdat abou jaoude	CDR	Workshops
Jean Paul Sfeir	Solarnet	Workshops
Jeanine Kounjian	IFP	Workshops
Kassem Jouni	GIZ	Workshops and interviews
Katia Fakhry	UNDP	Workshops
Krekor Baboyan	MoF	Workshops
Lea hakim	MoF	Workshops and interviews
Lutfallah El Hage	GETI/Order of Engineers	Workshops and interview
Mabelle Chedid	ARC-EN-CIEL	Workshops
Manar Dagher	MoA	Workshops and interviews
Marie-Therese Kfoury	LARI	Workshops and interviews
Maya Abboud	UNDP	Workshops
Maya Mhanna	MoA	Workshops and interviews
Mona Fakih	MoEW	Workshops
Mufid Duhayni	MoEW	Workshops

Name	Affiliation	Consultation Approach
Nabil Amacha	LRA	Workshops and interviews
Nader Hajj Chehade	LCEC	Workshops and interviews
Naji Tannous	Energy expert	Workshops
Nancy Awad	CDR	Workshops
Nour Oueidat	ESIB	Workshops
Philip Al Hajj	Fransabank	Interview
Pierre Khoury	MoEW/LCEC	Workshops and interviews
Rana el Hajj	AUB IFI	Workshops
Randa Massad	LARI	Workshops and interviews
Rani Al Achkar	LCEC	Workshops
Raymond Khoury	Green Plan	Workshops and interviews
Ricardo Khoury	ELARD	Workshops
Roger Francis	CNRS-RS	Workshops
Ronald Diab	NEC/EEG	Workshops
Samir Sarkis	Green Party	Workshops
Siham Daher	MoET	Workshops and interviews
Tarek Yehia	NEEDS	Workshops
Wajdi Khater	ARC-EN-CIEL	Workshops and interviews
Wassef Kodeih	CEDRO project	Workshops
Ziad Al Zein	MoEW/LCEC	Workshops and interviews
Ziad Khayat	MoEW	Workshops and interviews

Annex II - Multi- Criteria Analysis Calculations for the Power Sector

Selection criteria	Absolute weight	Relative Weight	CCGT			RE		
			Value	Standard score	Weighed score	Value	Standard score	Weighed score
GHG reduction (Tons)	0.30	0.30	1,711,106.00	1.00	0.30	270,588.00	0.16	0.05
Fuel cost (USD/MWh)	0.30	0.30	70.00	0.03	-0.01	209.00	0.10	-0.03
Capital cost (10^3USD/MW)	0.15	0.15	0.40	0.00	0.00	1.05	0.14	-0.02
O$M cost (USD/MW)	0.10	0.10	556,764.00	1.00	-0.10	358,328.00	0.63	-0.06
Option Sustainability	0.10	0.10	1.90	0.00	0.00	2.00	0.08	0.01
Societal benefits	0.05	0.05	2.00	0.10	0.00	1.81	0.00	0.00
Total					0.19			-0.06
Rank					1st			6th

Selection criteria	Wind			PV		
	Value	Standard score	Weighed score	Value	Standard score	Weighed score
GHG reduction (Tons)	14,212.00	0.01	0.00	1,258.00	0.00	0.00
Fuel cost (USD/MWh)	0.10	0.00	0.00	0.10	0.00	0.00
Capital cost (10^3USD/MW)	1.90	0.33	-0.05	4.00	0.78	-0.12
O$M cost (USD/MW)	19,000.00	0.00	0.00	40,000.00	0.04	0.00
Option Sustainability	2.90	0.77	0.08	2.90	0.77	0.08
Societal benefits	2.09	0.14	0.01	3.90	1.05	0.05
Total			0.04			0.01
Rank			2nd			3rd

Selection criteria	Hydro			Biomass		
	Value	Standard score	Weighed score	Value	Standard score	Weighed score
GHG reduction (Tons)	181,507.00	0.11	0.03	102,492.00	0.06	0.02
Fuel cost (USD/MWh)	0.10	0.00	0.00	50.00	0.02	-0.01
Capital cost (10^3USD/MW)	3.50	0.67	-0.10	5.00	1.00	-0.15
O$M cost (USD/MW)	35,000.00	0.03	0.00	284,700.00	0.49	-0.05
Option Sustainability	2.00	0.08	0.01	3.20	1.00	0.10
Societal benefits	3.81	1.00	0.05	3.40	0.80	0.04
Total			-0.01			-0.05
Rank			4th			5th

Annex III -Marginal Abatement Cost Calculations for Power Sector

		CCGT	Wind	Hydro	PV
Capital cost	USD	270,000,000	190,000,000	245,000,000	4,000,000
Annual benefit/cost	USD	377,485,920	1,900,000	2,450,000	40,000
Annual average CO2 savings	(tonnes/year)	1,711,104	142,613	181,507	1,257
Project life	(years)	25	25	25	25
NPV	USD	(3,437,885,499)	171,337,099	220,934,680	3,607,097
Cumulative savings for all projects	(thousand tonnes/year)	1,711.10	1,853.72	2,035.22	2,036.48
MAC (carbon not discounted)	(USD/tonnes)	(80.37)	48.06	48.69	114.78
Discounted life savings of carbon	(tonnes)	16,807,455	1,400,828	1,782,867	12,347
MAC (carbon discounted)	(USD/tonnes)	(204.55)	122.31	123.92	292.14

Annex IV. Market maps and problem trees for the transport sector

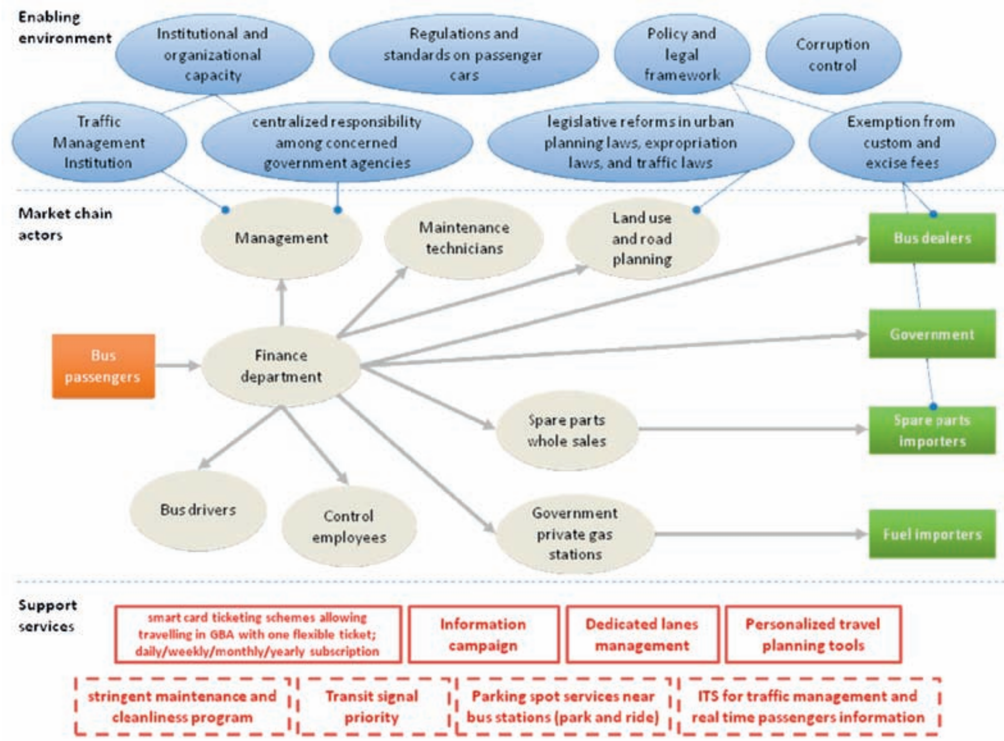

Figure 1. Market map for mass transit buses in GBA.

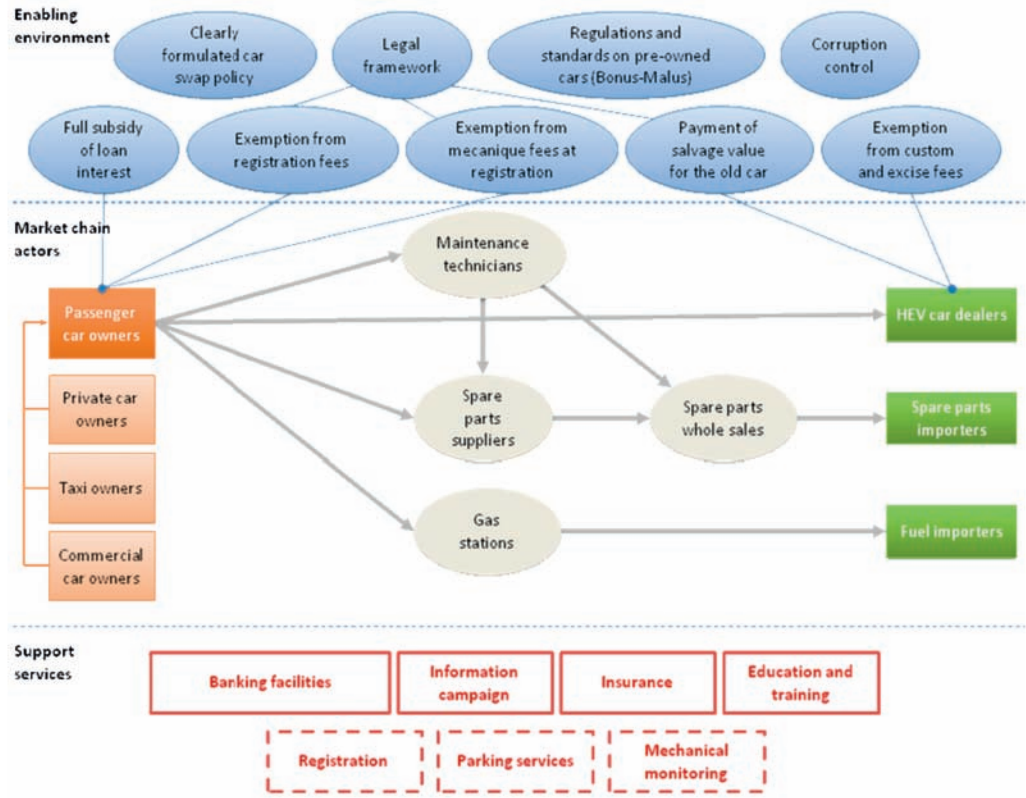

Figure 2. Market map for hybrid and fuel efficient vehicles.

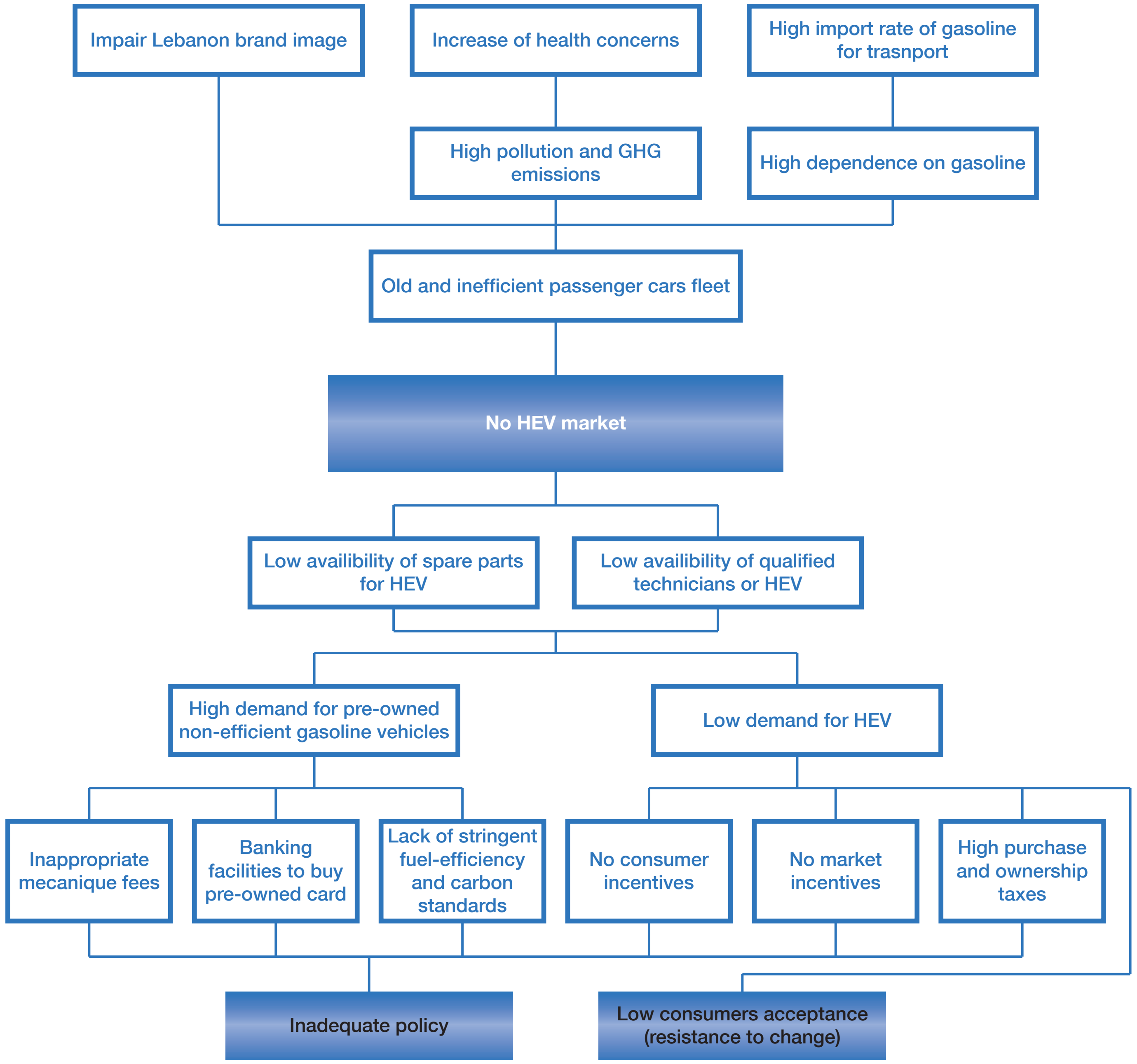

Figure 3. Logic problem tree: hybrid electric vehicles.

Annexes

Figure 4. Logic problem tree: mass transit bus system operated by the government on dedicated lanes in GBA.

Annex V. Assumptions in the transport sector

Table 1. Average consumption under GBA driving conditions (l/100km).

	Average passenger car	Non fuel-efficient car	Fuel efficient gasoline car	Full hybrid HEV	Diesel bus (diesel l/100km)
Urban peak	15.83	23.55	8.23	5.3	33.4
Urban off-peak	11.16	16.6	5.8	5.3	33.4
Rural	9.08	13.51	4.72	5.3	27.19

Table 2. Average speed under GBA driving conditions (Mansour, 2012).

	urban peak	urban off-peak	rural
Passenger cars (km/h)	17.6	39.1	51.3
Bus not operating on reserved lanes (km/h)	14.7	32.6	42.8
Bus operating on reserved lanes (km/h)	20	35	52

Annex VI Cost Benefit Analysis for the Technologies of the Agriculture Sector

Cost Benefit Analysis for CA

Table 1: Increase in area (A) adopting CA according to assumptions and respective subsidies

year	olive (ha), 25% annual increment	fruits (ha), 20% annual increment	cereals/legumes (ha), 30% annual increment	Subsidies rate (USD/ha) for cereals/legumes	total subsidies (USD)
	A_1	A_2	A_3		A_4
1	500	100	1,500	50	75,000
2	625	120	1,950		97,500
3	781	144	2,535		126,750
4	977	173	3,296		164,775
5	1,221	207	4,284		214,208
6	1,526	249	5,569		278,470
7	1,907	299	7,240		362,011
8	2,384	358	9,412		470,614
9	2,980	430	12,236		611,798
10	3,725	516	15,907		795,337
				Cumulated	3,196,462

Table 2: Costs for CA transfer and diffusion

CA measures	Public (USD)
R&D	240,000
Institutional arrangements	10,000
Training of trainers	5,000
Training for farmers	15,000
Total	270,000

Table 3: Additional revenues (benefits) related to CA

CA	OLIVE			FRUITS			CEREALS/LEGUMES			TOTAL CROPS
	Net revenue without CA (USD/ha)	Net revenue with CA (USD/ha)	Additional revenue from CA (USD)	Net revenue without CA	Net revenue with CA	Additional revenue from CA per surface	Net revenue without CA	Net revenue with CA	Additional revenue from CA per surface	Total additional revenue from CA (USD)
year	B_1	C_1	$D_1=(C_1-B_1)x(A_1)$	B_2	C_2	$D_2=(C_2-B_2)x(A_2)$	B_3	C_3	$D_3=(C_3-B_3)x(A_3)$	$D=D_1+D_2+D_3$
1	380	1,000	310,000	19,700	20,000	30,000	840	1,600	1,065,000	1,405,000
2	340	800	287,500	19,700	20,000	36,000	832	1,600	1,400,880	1,724,380
3	380	1,000	484,375	19,700	20,000	43,200	823	1,600	1,842,225	2,369,800
4	340	1,000	644,531	19,700	20,000	51,840	815	1,600	2,422,024	3,118,395
5	380	1,000	756,836	19,700	20,000	62,208	807	1,600	3,183,549	4,002,593
6	340	1,000	1,007,080	19,700	20,000	74,650	799	1,600	4,183,553	5,265,283
7	380	1,000	1,182,556	19,700	20,000	89,580	791	1,600	5,496,456	6,768,592
8	340	1,000	1,573,563	19,700	20,000	107,495	783	1,600	7,219,830	8,900,888
9	380	1,000	1,847,744	19,700	20,000	128,995	775	1,600	9,481,578	11,458,317
10	340	1,000	2,458,692	19,700	20,000	154,793	767	1,600	12,449,346	15,062,831
Total			10,552,877			778,760	8,032	16,000	48,744,441	60,076,079

Annexes

Table 5: Cost benefit analysis for all crops under CA

Year	Added revenue from all crops under CA(USD)	Total costs of CA (USD)	Discounted benefit for CA (USD)
n	D	$E= A_4$	$F= (D-E)/ (1+0.06)^n$
1	1,405,000	345,000	1,000,000
2	1,724,380	97,500	1,447,917
3	2,369,800	126,750	1,883,308
4	3,118,395	164,775	2,339,544
5	4,002,593	214,208	2,830,902
6	5,265,283	278,470	3,515,507
7	6,768,592	362,011	4,260,743
8	8,900,888	470,614	5,289,258
9	11,458,317	611,798	6,420,038
10	15,062,831	795,337	7,966,894
NPV			36,954,110

(*) Additional 270,000 USD are added the first year as cost for measures.

Cost Benefit Analysis for SAVR

Table 1: Increase in annual demand (A) on seeds and seedlings for SAVR according to assumptions

	Fruit trees					
yr	Produced seedlings	Cost (USD/ seedling)	Subsidy (USD/ seedling)	Imported seedlings	Cost (USD/ seedling)	Subsidy (USD/ seedling)
	A_1	B_1	C_1	A_2	B_2	C_2
1	250,000	3	2	250,000	9	6
2	300,000	3	2	225,000	9	6
3	350,000	3	2	200,000	9	6
4	400,000	3	2	175,000	9	6
5	450,000	3	2	150,000	9	6
6	500,000	3	2	150,000	9	6
7	500,000	3	2	150,000	9	6
8	500,000	3	2	150,000	9	6
9	500,000	3	2	150,000	9	6
10	500,000	3	2	150,000	9	6

	Tomato						Potato		
yr	Produced seedlings	Cost (USD/ seedling)	Subsidy (USD/ seedling)	Seed bags in field	Cost (USD/ bag)	Subsidy (USD/ bag)	Imported seeds (int)	Cost (USD/t)	Subsidy (USD/t)
	A_3	B_3	C_3	A_4	B_4	C_4	A_5	B_5	C_5
1	600,000	1	0	10,000	25	5	100	2,000	50
2	720,000	1	0	20,000	25	5	200	2,000	50
3	900,000	1	0	30,000	25	5	300	2,000	50
4	1,125,000	1	0	40,000	25	5	400	2,000	50
5	1,406,250	1	0	50,000	25	5	500	2,000	50
6	1,687,500	1	0	60,000	25	5	600	2,000	50
7	1,856,250	1	0	70,000	25	5	600	2,000	50
8	1,856,250	1	0	80,000	25	5	600	2,000	50
9	1,856,250	1	0	90,000	25	5	600	2,000	50
10	1,856,250	1	0	90,000	25	5	600	2,000	50

Table 2: Total cost for SAVR including subsidies according to the increase in annual demand on seeds and seedlings for SAVR

Year	Tomato field	Tomato greenhouse	Potato	Fruit trees	All crops	
	Surface (in ha)*				Total cost (USD)	Subsidies (USD)
n	S_1	S_2	S_3	S_4	$D = \sum(A \times B)$	$E = \sum(A \times C)$
1	400	480	250	700	3,750,000	2,080,000
2	800	576	500	1,435	4,185,000	2,090,000
3	1,200	720	750	2,205	4,650,000	2,115,000
4	1,600	900	1,000	3,010	5,137,500	2,151,250
5	2,000	1,125	1,250	3,850	5,653,125	2,201,563
6	2,400	1,350	1,500	4,760	6,393,750	2,401,875
7	2,800	1,485	1,500	5,670	6,728,125	2,494,063
8	3,200	1,485	1,500	6,580	6,978,125	2,544,063
9	3,600	1,485	1,500	7,490	7,228,125	2,594,063
10	3,600	1,485	1,500	8,400	7,228,125	2,594,063
Total					57,931,875	23,265,938

(*) Based on the number of seeds and seedlings annual demand; annual plantations of trees (local and imported) are cumulated

Table 3: Costs for the deployment of SAVR without subsidies (public expenditure)

SAVR measures	Public (USD)
Infrastructure for multiplication, conservation, demonstration	2,000,000
R&D (including sanitization and certification)	2,000,000
Training of trainers	100,000
Marketing studies, campaigns to promote SAVR, tasting…	100,000
Awareness campaign about intellectual property right	20,000
Product traceability establishment	50,000
Process for adherence to UPOV or respect IPR	20,000
Institutional and financial arrangements to subsidize SAVR/financial mechanism to sustain R&D	25,000
Total	4,315,000

Table 4: Additional revenues (benefits) from SAVR

	TOMATO OPEN FIELD			TOMATO GREENHOUSE		
Year	Net revenue without SAVR (USD/ha)	Net revenue with SAVR (USD/ha)	Additional revenue from SAVR per planted surface (USD)	Net revenue without SAVR	Additional revenue from SAVR	Additional revenue from SAVR per planted surface
	F_1	G_1	$H_1=(G_1 - F_1) \times S_1$	F_2	$H=H_1+H_2+H_3+H_4$	$H_2=(G_2 - F_2) \times S_2$
1	15,000	20,000	2,000,000	60,000	22,690,000	19,440,000
2	14,850	20,000	4,120,000	59,400	30,650,600	23,673,600
3	14,702	20,000	6,358,200	58,806	43,715,905	30,019,680
4	14,554	20,000	8,712,824	58,218	59,258,099	38,053,854
5	14,409	20,000	11,182,120	57,636	78,441,044	48,222,269
6	14,265	20,000	13,764,358	57,059	99,367,378	58,644,806
7	14,122	20,000	16,457,834	56,489	116,576,928	65,356,619
8	13,981	20,000	19,260,863	55,924	129,527,882	66,195,478
9	13,841	20,000	22,171,787	55,365	150,789,876	67,025,948
10	13,703	20,000	22,670,069	54,811	161,154,489	67,848,113
	143,427	200,000		573,708	892,172,200	

Annexes

Table 4: Additional revenues (benefits) from SAVR (Continued)

	POTATO			FRUIT TREES			Total crops
Year	Net revenue without SAVR	Net revenue with SAVR	Additional revenue from SAVR per planted surface	Net revenue without SAVR	Net revenue with SAVR	Additional revenue from SAVR per cumulated planted surface	Additional revenue from SAVR
	F_3	G_3	$H_1=(G_3 - F_3) \times S_3$	F_4	G_4	$H_4=\sum_n \{(G_4 - F_4) \times S_4\}_n + \{(G_4 - F_4) \times S_4\}_{n-1}$	$H=H_1+H_2+H_3+H_4$
1	21,000	26,000	1,250,000	-	-	-	22,690,000
2	20,790	26,000	2,605,000	140	500	252,000	30,650,600
3	20,582	26,000	4,063,425	700	5,000	3,274,600	43,715,905
4	20,376	26,000	5,623,721	2,100	7,000	6,867,700	59,258,099
5	20,173	26,000	7,284,355	3,500	10,000	11,752,300	78,441,044
6	19,971	26,000	9,043,813	7,000	15,000	17,914,400	99,367,378
7	19,771	26,000	9,343,375	10,500	20,000	25,419,100	116,576,928
8	19,573	26,000	9,639,942	14,000	25,000	34,431,600	129,527,882
9	19,378	26,000	9,933,542	14,000	30,000	51,658,600	150,789,876
10	19,184	26,000	10,224,207	14,000	30,000	60,412,100	161,154,489
	200,798	260,000		65,940	142,500		892,172,200

Table 5: Cost benefit analysis for all crops under SAVR

Year	Added revenue from all crops under SAVR (USD)	Total costs (USD)	Discounted benefit for SAVR (USD)
n	$H= H_1+H_2+H_3+H_4$	E	$I= (H-E)/(1+0.06)^n$
1	22,690,000	6,395,000*	15,372,642
2	30,650,600	2,090,000	25,418,832
3	43,715,905	2,115,000	34,928,922
4	59,258,099	2,151,250	45,233,973
5	78,441,044	2,201,563	56,970,575
6	99,367,378	2,401,875	68,356,853
7	116,576,928	2,494,063	75,871,621
8	129,527,882	2,544,063	79,671,220
9	150,789,876	2,594,063	87,716,875
10	161,154,489	2,594,063	88,539,314
NPV			578,080,827

(*) Additional USD 4,450,000 are added to the first year as cost for measures.

Cost Benefit Analysis for GAP

Table 1: Cumulated expansion of areas of grapevine production under GAP

Year	Farmer GAP cost (USD/ha) over 10 years	Grapevine area under GAP (ha) over 10 years	GAP cost per total area under GAP over 10 years
n	B	A	$C_n = A_n{*}B_n + \sum_n\{(A_n - A_{(n-1)}){*}B_{(n-1)} + A_{(n-1)}{*}B_n\}$
1	2,650	200	530,000
2	-350	400	460,000
3	600	600	460,000
4	4,550	800	1,300,000
5	-450	1,000	1,210,000
6	-450	1,200	1,120,000
7	-450	1,400	1,030,000
8	-450	1,600	940,000
9	-450	1,800	850,000
10	-450	2,000	760,000
NPV			8,660,000

Table 2: Public expenditures for the transfer and diffusion of GAP

GAP cost	Public expenditure (USD)
Research and development	250,000
Training of trainers	20,000
Information dissemination strategy	5,000
Awareness campaign	50,000
Total	325,000

Table 3: Additional revenues from GAP deployment on table grape production over a period of 10 years

Year	Revenue without GAP (USD/ha)	Revenue with GAP per farmer (USD/ha)	Additional revenue from GAP (USD/ha)	Additional revenue from GAP for total area under GAP (USD)	Additional net benefit per total area under GAP over 10 years (USD)
n	D	E	F =(E-D)	G=F*A	H=G-C
1	9,000	22,500	10,850	4,500,000	3,970,000
2	8,910	22,500	13,940	9,000,000	8,540,000
3	8,821	22,500	14,029	13,500,000	13,040,000
4	8,733	22,500	9,217	18,000,000	16,700,000
5	8,645	22,500	14,305	22,500,000	21,290,000
6	8,559	22,500	14,391	27,000,000	25,880,000
7	8,473	22,500	14,477	31,500,000	30,470,000
8	8,389	22,500	14,561	36,000,000	35,060,000
9	8,305	22,500	14,645	40,500,000	39,650,000
10	8,222	22,500	14,728	45,000,000	44,240,000
Total	86,056	225,000	135,144	247,500,000	238,840,000

Table 4: Cost benefit analysis for table grape production under GAP

Year	Additional revenue from GAP for total area under GAP (USD)	GAP cost per total area under GAP over 10 years (USD)	Discounted benefit for GAP (USD)
n	G	C	$I = (G-C)/(1+0.06)^n$
1	4,500,000	855,000*	3,245,283
2	9,000,000	460,000	7,600,570
3	13,500,000	460,000	10,948,635
4	18,000,000	1,300,000	13,227,964
5	22,500,000	1,210,000	15,909,127
6	27,000,000	1,120,000	18,244,379
7	31,500,000	1,030,000	20,264,290
8	36,000,000	940,000	21,997,078
9	40,500,000	850,000	23,468,774
10	45,000,000	760,000	24,703,385
NPV			159,802,881

(*) The cost of public expenditure (USD 325,000) is added to the costs of the first year.

Annex VII: Cost Benefit Analysis for the Technologies of the Water Sector

Cost Benefit Analysis for RWHR

Table 1: Calculation for water harvesting quantities per 1km of road with a minimal slope of 5%

Road length (m):	A	1,000
Width of road (m):	B	6
Precipitation (m):	C	0.80
Active rainfall (m):	D= C x 0.8	0.64
Total amount of water/1000m road (m^3)	E= D x A x B	3,840
Additional runoff (50%) from upper catchment to the road (m^3)	F= E x 1.5	5,760
Lost in evaporation in hill lake		15%
Total available water/1000m road (m^3)	G= F x 0.85	4,896

Table 2: Costs of the measures for the deployment of RWHR

Measure	USD/ Unit		Private/Public costs (USD)	Public costs (USD)
			K_1	K_2
Redesign roads and integrate drainage system for water collection (USD/m)	25	H= 10 x A	25,000	
Construction of earth/hill lakes (USD/m^3)	8	I= 8 x F	46,080	
Construction of decantation unit, sieves and filters installation (USD/unit)	2,500	J= 1,500	2,500	
Establishment of water distribution system (vehicle with a cistern)	40,000		40,000	
Regulations for road design, water quality				10,000
Institutional arrangements				5,000
Awareness raising and information transfer				5,000
Installation of a financial mechanism				5,000
Total			112,480	25,000

Table 3: Benefit from RWHR in terms of revenues from increased crop production according to the available water

Year	Annual crop produced (t)	crop price (USD/t)	Revenue (USD)
n	L = (G x 24.5)/6000*	M	O= L x M
1	20	800	16,000
2	20	800	16,000
3	20	800	16,000
4	20	800	16,000
5	20	800	16,000
6	20	800	16,000
7	20	800	16,000
8	20	800	16,000
9	20	800	16,000
10	20	800	16,000
Total			160,000

(*) We assume that 6000m3 /ha produce 24.5/ha of crops.

Table 4: Cost benefit analysis for RWHR

Year	Revenues (USD)	Costs	Discounted benefits
n	O	$K = K_1+K_2$	$P= (O-K)/(1+0.06)^n$
1	16,000	137,480	-114,604
2	16,000	400	13,884
3	16,000	400	13,098
4	16,000	400	12,357
5	16,000	400	11,657
6	16,000	400	10,997
7	16,000	400	10,375
8	16,000	400	9,788
9	16,000	400	9,234
10	16,000	400	8,711
11	16,000	400	8,218
12	16,000	400	7,753
13	16,000	400	7,314
14	16,000	400	6,900
NPV			15,681

Annexes

Cost Benefit Analysis for RWHG

Table 1: Calculation for water harvesting quantities per greenhouse, water demand per crop/altitude combination

		High demanding crop at sea level	Low demanding crop at 500m altitude
Greenhouse area (m^2)	A	400.00	400.00
Precipitation (m)	B	0.65	1.10
Active harvested rainfall (m)	C	0.6	1.0
Harvested rain/ greenhouse top	D= C x A	234.00	400.00
Crop water demand (GH/year/m^3)	E= (crop-climate demand/10000) x A x 2*	440.00	360.00
Irrigation requirement	F	550.00	400.00
Water to import (m^3)	G= F-D	316.00	0.00
% of water demand covered	D/F	43%	100%

(*) Crop-climate demand is estimated to 5500m^3/ha at sea level for a high demanding crop and 4500m^3/ha at 500m altitude for a low demanding crop. Since 2 cropping seasons are achieved, these figures are multiplied by 2.

Table 2: Costs for the deployment of RWHR

Measures	USD/Unit	
Cost of 1m^3 stored water in earth reservoir (USD)	16	H
Establishment of water drainage system and linkage to storage unit (USD)	1,200	I
Cost of pumping (USD/ 1000 m^3)	1,833	J
Surface water annual cost	100	K
Annual rental of the land occupied by earth reservoir (USD/m^2)	1	L

Table 3: Cost variation among different water source scenarios for one greenhouse

year	RWHG (100%) (USD)	RWHG (43%) + surface (USD)	RWHG (43%) + pumping (USD)	Groundwater (100%) (USD)
n	$M_1 = (D_1/2) \times H + I + L_1$	$M_2 = (D_2/2) \times H + I + L_2 + K$	$M_3 = (D_3/2) \times H + I + L_3 + (G \times J/1000)$	$M_4 = F \times J/1000$
1	4,460	3,260	3,639	1,008
2	60	140	619	1,008
3	60	140	619	1,008
4	60	140	619	1,008
5	60	140	619	1,008
6	60	140	619	1,008
7	60	140	619	1,008
8	60	140	619	1,008
9	60	140	619	1,008
10	60	140	619	1,008
Total	5,000	4,580	9,273	10,083

Table 4: Cost benefit analysis among different water source scenarios for one greenhouse

		RWHG (100%)		RWHG (43%) + surface		RWHG (43%) + pumping		100% pumping	
year	Benefits (USD)	Cost (USD)	Discounted benefits (USD)	Cost	Discounted benefits	Cost	Discounted benefits	Cost	Discounted benefits
n	O	M_1	$P_1 = (O - M_1)/(1+0.06)^n$	M_2	$P_2 = (O - M_2)/(1+0.06)^n$	M_3	$P_3 = (O - M_3)/(1+0.06)^n$	M_4	$P_4 = (O - M_4)/(1+0.06)^n$
1	3,200	4,460	-1,189	3,260	-57	3,639	-471	1,008	2,068
2	3,200	60	2,795	140	2,723	619	2,297	1,008	1,951
3	3,200	60	2,636	140	2,569	619	2,167	1,008	1,840
4	3,200	60	2,487	140	2,424	619	2,044	1,008	1,736
5	3,200	60	2,346	140	2,287	619	1,928	1,008	1,638
6	3,200	60	2,214	140	2,157	619	1,819	1,008	1,545
7	3,200	60	2,088	140	2,035	619	1,716	1,008	1,458
8	3,200	60	1,970	140	1,920	619	1,619	1,008	1,375
9	3,200	60	1,859	140	1,811	619	1,527	1,008	1,297
10	3,200	60	1,753	140	1,709	619	1,441	1,008	1,224
NPV			18,960		19,578		16,088		16,131

Annexes

Cost Benefit Analysis for WUA

Table 1: Costs for the measures for deployment of WUA

Measures	Cost (USD)
Awareness campaign at social level	50,000
Lobbying, capacity building, awareness at decision maker's level	20,000
Law revision, law amendments, creation of a water act	50,000
Introducing WUA in university curricula	10,000
Studies for alternative funding mechanism	10,000
Cost of infrastructure for 5000ha of irrigated areas (schemes)	900,000
Total	1,040,180

Table 2: Estimated additional annual revenue from the deployment of WUA

Yield improvement	Actual yield (t/ha)	Yield increase due to WUA (t/ha)	Crop value (USD/t)	Increased revenue due to WUA (USD/ha)	Increase revenue for 5000ha under WUA (USD)
A	B	C = A x B	D	E = C x D	F = 5000 x E
15%	30	4.5	800	3,600	4,000,000

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